Science in the Met Office : thirteenth report of session 2010-12 / House of Commons Science and Technology Committee.

House of Commons

Science and Technology Committee

Science in the Met Office

Thirteenth Report of Session 2010–12

HC 1538

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Report, together with formal minutes, oral and written evidence

Additional written evidence is contained in Volume II, available on the Committee website at www.parliament.uk/science

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All correspondence should be addressed to the Clerk of the Science and Technology Committee, Committee Office, 7 Millbank, London SW1P 3JA. The telephone number for general inquiries is: 020 7219 2793; the Committee's e-mail address is: scitechcom@parliament.uk.

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Summary

As the UK's national weather service, the Met Office aims to provide the UK and its citizens with the best weather and climate service in the world. The Met Office currently operates as a Trading Fund within the Department of Business, Innovation and Skills (BIS). The move, last year, from the Ministry of Defence to BIS is welcome, particularly given the potential for closer links with the research base and the opportunity for the Met Office to develop further its commercial activities. While we recommend that the Met Office continue to expand activities that generate commercial income, this must not put core services for the public sector or the Met Office's international reputation at risk. In addition to commercial revenue, the Met Office generates a significant proportion of its revenues from Government contracts and Customer Service Agreements. It is not unreasonable for the Met Office to expect clearly defined funding commitments from the Government over the period of the current spending review and we make recommendations seeking to address this problem. A clearly defined funding commitment would allow the Met Office to take a longer-term perspective on scientific and operational development.

There has been much speculation over recent years about whether it would be advantageous to privatise the Met Office. We are pleased that the Government has no plans to do so. Privatisation would put at risk the strong partnerships that the Met Office has built with international partners, particularly those with which it shares crucial meteorological data. We heard contrasting views on how easy it is to gain free access to Met Office data. We take some reassurance from the fact that the Met Office tries to address specific data concerns as and when they arise. Best practice about making data more freely available should be drawn on from other countries. We also welcome the Government's initiative under the Public Data Corporation to make more Met Office data available, but this should be done with as little bureaucracy as possible.

Met Office forecasts rely on observational data, high-quality computer models and powerful supercomputers. The Met Office collaborates well with a number of partners both in the UK and internationally to gain access to and share observational data and to test and develop models. Collaboration on supercomputing resources is looked at regularly by the Met Office and the international meteorological community but remote supercomputing options currently have limited use. Researchers have demonstrated that it would be possible to deliver more accurate forecasts if greater computer capacity were available. It is of great concern to us that these scientific advances in weather forecasting and the associated public benefits (particularly in regard to severe weather warnings) are ready and waiting but are being held back by insufficient supercomputing capacity. We consider that a step-change in supercomputing capacity is required in the UK and the Government should finalise the business case for further investment in supercomputing capacity soon.

The Met Office is consistently within the top three centres internationally in weather prediction. However, an accurate forecast is of little use if it is not communicated well and understood by the customer. The Met Office should work with broadcasters to improve communication. In particular, the inherent uncertainty in longer-term forecasts should be

clearly explained and we are keen to see broadcasters make greater use of probabilistic information in their weather forecasts. The Met Office is widely recognised as a world-leader in climate prediction, however, we note that the climate model did not accurately predict the extent of the flattening of the temperature curve during the last ten years.

We were pleased to find that science is very much at the heart of the services provided by the Met Office. Its science strategy, which proposed to better integrate weather and climate research, has been very well received across the meteorological community. Scrutiny of Met Office science is carried out by a number of bodies. We consider that the Met Office should attempt to streamline the scrutiny of science under one committee. It would also be timely to reassess the existing arrangements between the Met Office and the Government for ensuring there is a strong customer relationship with key government departments.

We welcome the way in which the Met Office is responding to the demands made of it and urge the Government to implement our recommendations in order to enable the Met Office to continue to improve the services it provides.

1 Introduction

Background

1. The Met Office is the UK's national weather service; it aims to "provide the UK and its citizens with the best weather and climate service in the world".[1] The difference between weather and climate is a measure of time; while weather is the condition of the atmosphere over a short period of time, climate is how the atmosphere behaves over relatively long periods of time.[2] Under its Public Weather Service (PWS) remit, the Met Office provides a range of weather information and severe weather warnings to enable the public "to make informed decisions" and "to mitigate against the impact of the weather" thereby contributing to "the protection of life, property and basic infrastructure".[3] Beyond the PWS, the Met Office provides contractual services to a range of government departments (see paragraph 9) and to commercial companies that utilise weather and climate information to inform business and operating decisions.[4] Underpinning these services is the science at the heart of the Met Office; remaining at the cutting edge of modelling and prediction should allow the Met Office to "provide an increasingly accurate and reliable service".[5]

The inquiry

2. We announced our inquiry into "Science in the Met Office" on 19 July 2011, inviting written submissions addressing the following questions:

i. How effectively is the Met Office fulfilling its Public Weather Service remit?

ii. Is the Met Office's Science Strategy 2010–15 robust and achievable and how will the strategy help to deliver a better service?

iii. What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?

iv. How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?

v. How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

3. In the course of our inquiry we visited the Met Office in Exeter, where we toured the facilities and met representatives from senior management; we are grateful to them for

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1 Ev 36, para 1.1 [Met Office]

2 NASA website, "What's the difference between weather and climate?", www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

3 Ev 66, para 1.1 [Government]; A full list of the services provided by the Met Office under the PWS can be found at Annex A.

4 Ev 36, para 1.5 [Met Office] and Ev 47, para 3.a-c [Met Office]

5 Met Office, *Met Office science strategy 2010-2015*, November 2010, p01

accommodating us. We received 20 written submissions to this inquiry and took oral evidence from a number of individuals and organisations.[6] We are grateful to all those who assisted us in our inquiry.

[6] Full list of evidence sessions and written submissions on pages 46–47.

2 The organisation

Ownership

4. The Met Office was founded by Vice-Admiral Robert FitzRoy in 1854 as the Meteorological Department of the Board of Trade; it has provided weather forecasting and related services for the UK for over 150 years.[7] It was established as an Executive Agency within the Ministry of Defence (MOD) in 1990 and has operated as a Trading Fund since 1996.[8] As a Trading Fund, the Met Office is "required to operate on a commercial basis and meet agreed targets as set by [its] Ministerial Owner".[9]

5. Over recent years there have been sporadic reports about successive governments considering privatisation of the Met Office.[10] During our visit to the Met Office facility in Exeter, we heard that privatisation would be almost impossible due to the Met Office's reliance on international partners to provide it with data, which in some cases would not be allowed if it were a commercial organisation. Mr Edward Davey MP, Minister for Employment Relations, Consumer and Postal Affairs, told us that "the Met Office only owns 4% of its data", its work is dependent upon huge amounts of data that are exchanged internationally and "therefore, one has to take account of global opinion" when thinking about the future of the Met Office.[11] The Minister confirmed that the Government had "no plans to privatise the Met Office".[12] He added that it would be "deeply irresponsible" to privatise the Met Office on the grounds of the need to "fill a hole in the Government's coffers".[13] The Minister explained that achieving efficiencies was another reason why agencies are sometimes considered for privatisation but that the Met Office was already "pretty efficient" and the Government was looking at "other models to drive efficiency".[14] **We welcome the Minister's comment that the Government has no plans to privatise the Met Office and agree with him that it would be deeply irresponsible to do so on the grounds of the need to fill a hole in the Government's coffers.**

6. On 18 July 2011, responsibility for the Met Office moved from the MOD to the Department for Business, Innovation and Skills (BIS).[15] While it may be too early to comment on whether this new governance framework is working effectively,[16] we heard that the move brings the Met Office closer to the Research Councils and provides the potential to further enhance the relationship between the Met Office and the research

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7 Met Office, "Met Office celebrates 150 years of forecasting for the nation", www.metoffice.gov.uk/media/pdf/g/m/150_years_video_script_01.pdf

8 Met Office, "Met Office Framework Document 2007", p 7

9 Met Office, "Management of the Met Office",www.metoffice.gov.uk/about-us/who/management

10 For example, Defence Committee, Tenth Report of Session 2005-06, *The work of the Met Office*, HC 823, paras 15-18; and The Guardian Online, "Conservatives may privatise Met Office", 18 October 2009, www.guardian.co.uk

11 Q 129

12 Q 128

13 Q 129

14 As above

15 Met Office Press Notice, "Met Office becomes part of the BIS family", 18 July 2011

16 Ev 65, para 17 [Royal Meteorological Society]

base.[17] Housing the Met Office within BIS may also be conducive towards greater coordination, collaboration and integration with partner institutions in both the public and private sectors at home and overseas.[18] The Minister added that within BIS, under the Shareholder Executive and the Public Data Corporation, there will be extra support available to the Met Office for commercial activities.[19] **We consider it too early to comment in detail on the Met Office's move from the Ministry of Defence (MOD) to the Department for Business, Innovation and Skills (BIS). However, we welcome the potential for closer links between the Met Office and the research base, as well as the opportunity for the Met Office to develop its commercial activities further.**

7. In 2006, Peter Ewins, former Chief Executive of the Met Office, noted during an inquiry by the House of Commons Defence Committee that there had sometimes been "confusion" between the Government's role as owner of the Met Office and its role as a principal customer.[20] Since the move to BIS, responsibility for the Met Office has been split between two Ministers, reflecting this concern.[21] Edward Davey MP is responsible for the "ownership function" and the Minister of State for Universities and Science, Rt Hon David Willetts MP, is responsible for the "customer function", including acting as the customer for the Public Weather Service (PWS).[22]

Costs and revenues

8. In 2010/11, Met Office costs were £186.7 million, and it generated revenues amounting to £196.1 million. The Met Office has a largely static fixed cost base which breaks down into three broad categories:

i. Staff costs;

ii. International obligations—the Met Office is the UK representative on a number of international treaties (primarily, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the World Meteorological Organization (WMO) and the European Centre for Medium-Range Weather Forecasts (ECMWF)) and has commitments to satellite programmes of 20+ years; and

iii. Infrastructure—primarily property, observing infrastructure and IT infrastructure, including supercomputing.[23]

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17 Ev 63, para 3.5.7 [National Oceanography Centre]; Ev w13, Executive Summary [Research Councils UK]; and Q 36 [Professor Alan Thorpe]

18 Ev w10 [Rowan Douglas]

19 Q 138

20 Defence Committee, Tenth Report of Session 2005-06, *The work of the Met Office*, HC-823, para 11

21 Q 127

22 Q 127; and Ev 37, para 2.2 [Met Office]

23 Ev 48, para 4a-c [Met Office]

9. Met Office revenues are secured and managed contractually. These contracts fall into three broad categories:

i. Government Customer Service Agreements (CSAs)

There are currently three CSAs:

- The PWS, funded by BIS, the Civil Aviation Authority and the Maritime and Coastguard Agency;
- The Defence Service, funded by the MOD;
- The Hadley Centre Climate Programme (HCCP), funded by the Department of Energy and Climate Change (DECC) and the Department for Environment, Food and Rural Affairs (Defra).

ii. Other Government contracts

Contracts to provide other specific weather-related services and products to government departments.

iii. Commercial contracts

A range of value added products and services delivered across a number of market sectors with open competition (these include contracts with broadcasters).[24]

The breakdown of revenues across these categories in 2010/11 is shown in figure 1.

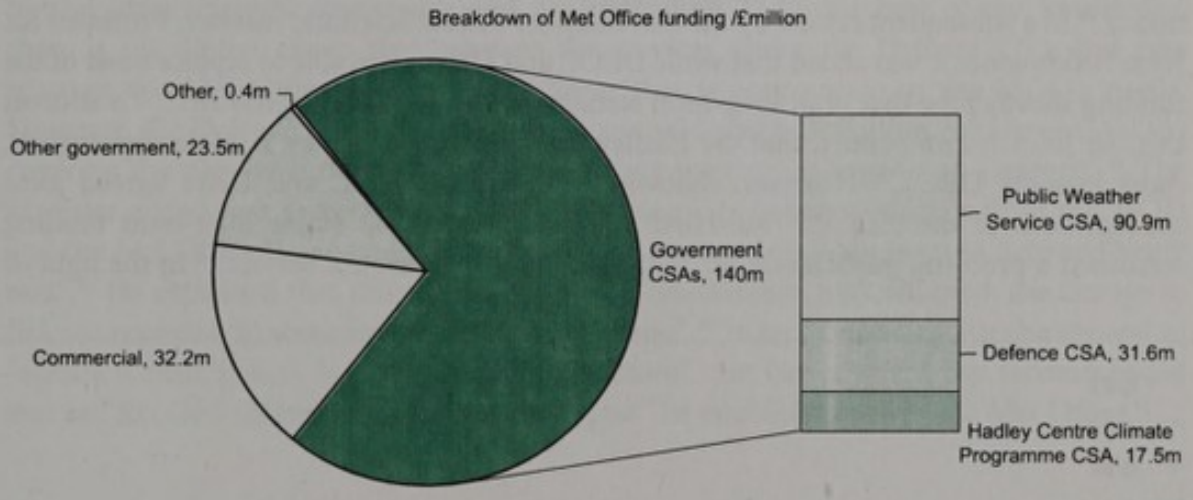

Figure 1: Met Office Revenues, financial year 2010/11 (CSA – Customer Service Agreement)[25]

Government contracts

10. Government CSAs are supposed to be multi-year contracts covering primary Met Office services.[26] However, John Hirst, Chief Executive of the Met Office, told us that

[24] Ev 47, para 3a-c [Met Office]

[25] Ev 48, para 3 [Met Office]

[26] Ev 47, para 3a [Met Office]

currently, only the PWS contract runs for more than a year, the HCCP has an unsigned contract, and the Defence contract is "for no fixed term".[27] He explained that this creates "uncertainties and difficulties in resource allocation" and that as the Met Office "requires a long-term perspective" for "scientific and operational development", this results in some "tensions".[28] Mr Hirst added that it would be better if the Met Office had a slightly longer-term perspective of two or three years funding to which its customers were clearly committed.[29] While the Minister was sympathetic about these concerns, he stated that "there have never been very long funding arrangements" for the Met Office and that the current financial climate made it "more challenging".[30] He added that while it was difficult to specify exact levels of funding, following the Spending Review in 2010, the "big totals" were "there for all to see" and that "that should give some comfort".[31] Given that the Spending Review provides headline figures for spending in Government departments for the next three years, we conclude that it is not unreasonable for the Met Office to expect clearly defined funding commitments from the Government over that period. **As a matter of urgency, the Government should ensure that its Customer Service Agreements (CSAs) with the Met Office are signed and that these CSAs are truly multi-year agreements. Furthermore, we recommend that the Government sets out its minimum funding commitment to the Met Office for each year of the current Spending Review period by the end of this financial year.**

11. The benefit of having a contractual relationship between the Government (as customer) and the Met Office (as supplier) is that it focuses both parties on providing products and services that match the customer's exact requirements.[32] However, Government CSAs are not legally enforceable.[33] This caused problems in 2009, when the MOD withdrew £4.3 million funding from the Met Office's HCCP with only three months' notice.[34] In a subsequent review by the Government's Chief Scientific Adviser, Professor Sir John Beddington, it was stated that while DECC and Defra were able to replace most of the funding shortfall for that year, long-term stability continued to be a problem.[35] To address this, Sir John recommended that the Hadley Centre be governed by a single department, most logically DECC.[36] However, following the review, DECC and Defra agreed joint management of the HCCP.[37] Mr Hirst suggested to us that stable long-term funding remained a problem, particularly for the HCCP and the Defence Service.[38] In the light of

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27 Q 83

28 As above

29 Q 85

30 Q 134

31 Q 137

32 Q 83 [John Hirst, Met Office]

33 Ev 49, para 5 [Met Office]

34 Ev 49, para 6 [Met Office]; and Nature Online, "Funding cut for UK climate research", 25 June 2009, www.nature.com

35 Government Office for Science, *Review of climate science advice to Government and Met Office Hadley Centre role, governance and resourcing*, September 2010, p 5-6 and p 23

36 Government Office for Science, *Review of climate science advice to Government and Met Office Hadley Centre role, governance and resourcing*, September 2010, p 6

37 Ev 49, para 7 [Met Office]

38 Q 83

this, we asked the Minister whether he thought the HCCP would be better managed by a single Government department, as recommended by Sir John. In response, he indicated that DECC and Defra would be signing a Memorandum of Understanding (MoU) in order to give the Hadley Centre reassurance.[39] In a supplementary written memorandum, the Government stated that the MoU approach would "provide a greater level of stability than the current contractual relationship".[40] We were also told that signing of the MoU was deferred in 2011 due to uncertainty over the future status of the Met Office.[41] Another option to provide greater stability would be for the Hadley Centre to be governed by a single parent department. The strong customer relationship between the Hadley Centre and non-parent departments could then be maintained through, for example, the Hadley Centre Science Review Group (or a similar Hadley Centre Climate Programme Customer Group, see paragraphs 14 and 25), which already includes representatives from DECC and Defra, and is tasked with asking whether the Met Office is delivering science that is appropriate to their needs.[42]

12. It is our view that the Hadley Centre Climate Programme (HCCP) should be managed by a single Government department, as previously recommended by the Government Chief Scientific Adviser. A less satisfactory alternative would be for the Government to ensure that the Memorandum of Understanding between DECC and Defra is signed as a matter of urgency.

13. In BIS, the customer relationship with the Met Office is managed through the Public Weather Service Customer Group (PWSCG). The PWSCG's wide remit is to ensure that "Government is obtaining best value for money, setting and measuring performance against focused targets and ensuring that the public are afforded the protection provided by the latest scientific knowledge and understanding".[43] To the best of our knowledge, there is no similar group that oversees the services under the Defence CSA and asks whether the Met Office is delivering science that is appropriate to the MOD's needs. However, the Defence CSA is "supported by annual Service Definition Agreements (SDA) covering the provision of meteorological and oceanographic support to Defence".[44] The Minister added that there were also quarterly meetings between officials from the MOD and the Met Office "to ensure that the customer service agreement is up to date and being met".[45] He explained that this was an "historical relationship, and, although the change to BIS has broken it to some extent, it is still very close".[46] In recognition of this change and to "ensure a close liaison is maintained in the future", the Government has recommended that an "RN OF5 (Meteorological Specialist) post" be established within the Met Office.[47]

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39 Q 135

40 Ev 78, para 1

41 Ev 78, para 1 [Government]

42 Q 72 [Professor John Pyle]

43 Ev 63, para 2 [Royal Meteorological Society]

44 Ev 73, para 5.9 [Government]

45 Q 131

46 As above

47 Ev 73, para 5.10 [Government]

14. We recommend that the Government and the Met Office reassess whether the existing mechanisms intended to support a strong customer relationship between the Met Office and departments such as MOD, DECC and Defra are effective. Specifically, we invite the Government and the Met Office to consider, and report back to us, on whether there is a need for a Defence Customer Group and a Hadley Centre Climate Programme Customer Group, analogous to the current Public Weather Service Customer Group. One of the benefits of introducing these new customer-focussed groups would be that scrutiny of Met Office science could be streamlined under one review group, as we discuss later in paragraph 25.

Commercial contracts

15. In 2010/11, commercial income made up approximately 16% of all Met Office revenue (see figure 1). The Met Office's major commercial customers come from a range of different areas, including water utilities, power utilities, and the insurance industry.[48] The services provided to commercial customers are widely appreciated: for example, Rowan Douglas, CEO of Global Analytics for the global insurance broker Willis Group Holdings, told us that the Met Office was "an institutional asset for the continued position of the UK insurance sector".[49]

16. During the course of our inquiry we were keen to explore whether or not the Met Office should seek to increase the proportion of income it generates from commercial sources. Mr Hirst told us that the Met Office continues to make "steady progress" in this area.[50] Furthermore, the Met Office is also encouraging other national meteorological services across the world to take on its products under licence.[51] When we questioned the Minister about the extent to which the Met Office should be expanding its commercial activities, he told us that the Government had "no target figure to work toward, but there would be attractions to having one if the Met Office were to develop its commercial arm".[52] He acknowledged, however, that this would need to be done carefully.[53] As discussed earlier (see paragraph 6), the move to BIS may provide the Met Office with opportunities to develop its commercial activities. The Minister told us that under the Shareholder Executive and the Public Data Corporation, extra support, advice and guidance would be available for these activities.[54] He was, however, clear that the services that the Met Office provided to the public sector were "absolutely critical" and that while it was possible to expand the Met Office's commercial activities, that should not put services for the public sector at risk.[55] This was a concern also raised by Professor John Pyle, Chair of the Met Office Hadley Centre Science Review Group, who stated that there needed to be "continued scrutiny" to ensure that the balance between Government and commercial

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48 Q 84 [John Hirst, Met Office]

49 Ev w10

50 Q 84

51 Q 84 [John Hirst, Met Office]

52 Q 138

53 As above

54 As above

55 As above

funding was right.[56] **We recommend that the Met Office continue to expand activities that generate commercial income; however, mechanisms must be in place to ensure that these activities do not put core services for the public sector or the Met Office's international reputation at risk. We invite the Met Office to explain in its response to us how this will be achieved.**

56 Ev 57, para 11 [Professor John Pyle]

3 Science to service

The science strategy

17. The *Met Office science strategy 2010–2015* outlines the "top-level science strategy" for the Met Office, responding to the increasing demand for "seamless prediction systems across all timescales" for the atmosphere, oceans and land surface.[57] The strategy focuses the Met Office research agenda around four major science challenges:

i. forecasting hazardous weather from hours to decades;

ii. water cycle and quantitative precipitation forecasting on all scales;

iii. monthly to decadal prediction in a changing climate; and

iv. sensitivity of the Earth system to human activities.

The strategy proposes a new research structure within the Met Office, which aims to deliver efficiencies and set in place "mechanisms for greater integration and innovation in the science base". It also advocates "a more strategic approach to partnerships [...], delivery of the necessary infrastructure for research and services, improved processes for staff recruitment and development, and better methods for communicating and disseminating [Met Office] science".[58] These themes are discussed throughout this chapter.

18. Broadly speaking, the science strategy has been very well received across the meteorology community.[59] However, Research Councils UK (RCUK) commented that it "would have appreciated a greater opportunity to be consulted on [the strategy's] development".[60] Professor Julia Slingo, Met Office Chief Scientist, was surprised by this.[61] She explained that there was consultation through the Met Office Science Advisory Committee (MOSAC),[62] and that the director of the National Centre for Atmospheric Science (NCAS)—who was the "most obvious" representative from the Natural Environment Research Council (NERC)—was a member of MOSAC.[63] Professor Slingo was confident that the level of consultation was appropriate for the job of developing a strategy that was suitable for the Met Office, as an organisation that has a specific "public task" to fulfil.[64] John Hirst, Met Office Chief Executive, added that he would follow-up with RCUK its concerns about particular areas of the strategy it would have liked to be consulted on.[65]

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57 Met Office, *Met Office science strategy 2010–2015*, November 2010

58 As above

59 For example: Ev 61, para 3.2.1 [National Oceanography Centre]; Ev 64, para 7 [Royal Meteorological Society]; Ev w7, para 3 [Australian Bureau of Meteorology]; and Ev w10 [Rowan Douglas]

60 Ev w15, para 14

61 Q 101

62 Q 99

63 Q 101

64 Qq 99–100

65 Q 101

19. RCUK also expressed concerns that:

> The strategy contains a series of "recommendations" rather than a description of what will be done. In this respect it has something of the feel of an internal recommendation to the Met Office board rather than a set of goals towards which the Met Office is committed. Implementation is only addressed at a very high level.[66]

A formal implementation plan was in fact later published by the Met Office, during the course of our inquiry.[67] Professor Slingo acknowledged that the role of partners, such as NERC, would be "critical" in the implementation phase.[68] The importance of collaboration and partnership is discussed in greater detail later in this report (paragraphs 60-72).

The new research and development structure

20. The science strategy "recognises the unique position of the Met Office in having world-class weather forecasting and climate prediction in one place".[69] While the Met Office considered it "essential" in the short-term to maintain clearly identifiable programmes in both weather and climate research, it was proposed in the science strategy that integration across these programmes could and should be improved. This would be achieved by:

- Bringing together all research and development under a single Director of Science;
- Forming a new directorate in Foundation Science; and
- Establishing a programme of integrating and innovating activities.[70]

The lack of integration across weather and climate research was noted in the past as a key weakness that "did not readily facilitate common developments" across these areas.[71] Professor John Pyle, Chair of the Hadley Centre Science Review Group and a member of MOSAC, told us that the new structure looked like a "good model but only time will tell".[72] The National Oceanography Centre considered that the new structure may also "foster a closer research partnership" with the broader research community in the UK and abroad.[73] Professor Pyle particularly welcomed the establishment of the new Foundation Science directorate, which he considered might "ease some of the tensions in developing a single Unified Model [...] for both weather forecasting and climate research".[74]

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66 Ev w15, para 13

67 Met Office, *Met Office science strategy 2010–2015: Implementation Plan*, November 2011

68 Q 101

69 Met Office, *Met Office science strategy 2010–2015*, November 2010

70 Met Office, *Met Office science strategy 2010–2015*, November 2010, p 8

71 Ev w7–8, para 3 [Australian Bureau of Meteorology]

72 Ev 56, para 4

73 Ev 61, para 3.2.2

74 Ev 56, para 4

Oversight of Met Office science

21. MOSAC was set up 15 years ago to oversee Met Office science, following the change to Trading Fund status (see paragraph 4).[75] We took evidence from the Chair of MOSAC, Professor Sir Brian Hoskins, who is also the atmospheric scientist on the Met Office Board.[76] We questioned Sir Brian about whether there was a potential conflict of interest between his role as Chair of MOSAC and as a member of the Met Office board, particularly given that, as the Chair of MOSAC, he is required to report to the Met Office Board.[77] In response, he told us that the current arrangement provided a "very good conduit" from the science to the board, and that as "a pretty independent sort of guy" he felt "no conflict whatsoever".[78]

22. Sir Brian explained that he was responsible for selecting the other members of MOSAC, in consultation with the Met Office.[79] Its membership comprises top atmospheric scientists in the UK and the equivalent of chief scientists from a number of Met Services around the world.[80] Sir Brian told us that while this may look as if MOSAC was "parading [its] programme in front of [its] competitors", he personally ensured that MOSAC got valuable input from all its members.[81]

23. In the past, MOSAC's remit covered only weather prediction.[82] Under the new science strategy, the remit has been expanded to include both weather and climate science.[83] The strategy also states that existing Science Review Groups (SRGs) for reviewing specific areas will "continue for as long as required by the relevant Customer Groups" and that the Chairs of those groups would also be members of MOSAC.[84] The Government said in its memorandum that:

> In considering changes to the remit and terms of reference of MOSAC we would encourage the Met Office to reflect on the independence of the Committee and the Principles on Scientific Advice to Government, noting the revised Code of Practice for Science Advisory Committees (CoPSAC) to be published in the Autumn. This identifies best practice guidelines and provides practical advice on the operation of Science Advisory Committees.[85]

We were not clear, however, from the conversation we had with the Chairs of MOSAC and the Hadley Centre SRG, whether they adhere to the principles set out in CoPSAC, although

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75 Ev 59, para 7

76 Ev 60, paras 8-9

77 Met Office, *Met Office science strategy 2010–2015*, November 2010, p 9

78 Q 70

79 Q 71

80 Ev 60, para 8 [Professor Sir Brian Hoskins]

81 Q 71

82 Ev w8, para 6 [Australian Bureau of Meteorology]

83 Ev w8, para 6 [Australian Bureau of Meteorology]; and Met Office, *Met Office science strategy 2010–2015*, November 2010, p 9

84 Met Office, *Met Office science strategy 2010–2015*, November 2010, p 9

85 Ev 70, para 3.4

Sir Brian did inform us that they "act in a very independent manner".[86] We are also unclear as to whether either group's terms of reference are published in the public domain as a matter of course.

24. Professor Pyle raised the question about whether Met Office science was being "over-reviewed". He explained that there have been a number of ad-hoc reviews recently and in addition to being formally reviewed by MOSAC, the Met Office is also overseen by the Hadley Centre SRG. Unlike MOSAC, the Hadley Centre SRG is not a Met Office committee; the role given to it by DECC and Defra is to ensure that the Met Office is delivering science that is appropriate to the needs of Government. However, it operates in much the same way as MOSAC, with a rotating membership of scientists from the UK and overseas. While the Hadley Centre SRG deals with work under the climate programme, Sir Brian indicated that the equivalent in weather was the Public Weather Service Customer Group (PWSCG) (see paragraph 13). He added that PWSCG representatives were present at MOSAC discussions and were sent a copy of the MOSAC Chair's report.[87]

25. **Given the move towards integrating weather and climate science, and with the Met Office Science Advisory Committee's (MOSAC) remit being expanded to include both areas, we question whether it is sensible to impose additional scrutiny by the Met Office Hadley Centre Science Review Group (SRG). We recommend that the Met Office consult with DECC and Defra to determine whether the Hadley Centre SRG is required in its current form. Our view is that it would be more sensible to formally review all science under MOSAC, whilst retaining a Hadley Centre Climate Programme Customer Group, as described in paragraph 14, to ensure that customer needs are being met.**

26. **We recommend that the Met Office publish MOSAC's terms of reference on its website. We also advise MOSAC to consider the Code of Practice for Science Advisory Committees (CoPSAC) at its next meeting, specifically considering whether MOSAC would benefit from adhering to the principles contained within it.**

Weather and climate forecasts

27. Creating weather and climate forecasts is a complex process involving the application of science and technology to predict future atmospheric conditions from observations.[88] These observations are recorded around the world, from a variety of sources (from land, at sea, in the air and from space). Each day the Met Office receives and uses approximately half a million observations. This includes data on temperature, pressure, wind speed, wind direction and humidity. The process of 'data assimilation' then uses these observations to provide a "best estimate of the current state of the atmosphere".[89] How this state evolves over time is then calculated using a computer model, producing an estimate of the state of the atmosphere at some point in the future—a 'forecast'.[90] Forecasting involves making

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86 Q 72 [Professor Sir Brian Hoskins and Professor John Pyle]

87 Q 72

88 Met Office website, "Science", www.metoffice.gov.uk/learning/science

89 Met Office website, "First steps", www.metoffice.gov.uk/learning/science/first-steps

90 Met Office website, "Ensemble forecasting", www.metoffice.gov.uk/research/areas/data-assimilation-and-ensembles/ensemble-forecasting

billions of mathematical calculations; therefore powerful supercomputers are required in order to carry out these calculations as quickly as possible.[91]

Observations

28. The importance of observational data in modelling future weather and climate is clear.[92] Indeed, the Government told us that it:

> recognises that the robustness of Met Office models is contingent on the accuracy and adequacy of supporting observational data. Observations directly input to models and to model development (through enhancing our scientific understanding) and are the only means of verifying model outputs.[93]

However, the UK generates and owns less than four per cent of the observational data on which it relies to deliver the Public Weather Service; this value drops to less than one per cent if satellite data are included.[94] As a result "international collaboration is essential to provide the observations on which the Met Office depends".[95] This is a subject we will return to in paragraph 68.

29. In addition to the vast quantities of data available from international sources, there is also a network of volunteer observers in the UK. Stephen Burt, a freelance science writer and Fellow of the Royal Meteorological Society, told us that the voluntary observing network has declined by approximately 50 per cent: in 1975, there were 6,220 rainfall observing sites in the UK; by 2010, the figure had dropped to 3,214.[96] He attributed this decline, in part, to "very little ongoing support from the Met Office".[97] We understand, however, that the Met Office is now beginning to address this concern. During our visit to Exeter, Met Office officials demonstrated the new Met Office Weather Observations Website (WOW), which "is helping to co-ordinate the growth of the weather observing community in the UK, by asking anyone to submit the observations they are taking".[98] The Met Office WOW includes guidance on setting up a weather observation site and submitting observations online.

Modelling

30. The Met Office uses essentially the same "Unified Model" (UM) for modelling "across all timescales from daily weather forecasting to centennial climate change predictions, and for all space scales from the local to the global".[99] Many of the organisations we heard from

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91 Met Office website, "First steps", www.metoffice.gov.uk/learning/science/first-steps

92 Ev w15, para 13 [Research Councils UK]; Ev w8, para 4 [Australian Bureau of Meteorology]; Ev 62, paras 3.2.12-3.2.13 [National Oceanography Centre]

93 Ev 71, para 4.9

94 Ev 45, para 6.10 [Met Office]

95 Ev 45, para 6.8 [Met Office]

96 Ev w20, para 3.4

97 As above

98 Met Office Weather Observations Website, "General Support", wow.metoffice.gov.uk

99 Ev 42, para 5.1 [Met Office]

regarded the Met Office's models very highly.[100] The European Centre for Medium-Range Weather Forecasts (ECMWF) told us that there were "extensive objective international comparisons carried out continuously regarding the skill of global numerical weather prediction models from the Met Office and [others]. The ECMWF and the Met Office models are in the world-leading category".[101]

31. A testament to the quality of the Met Office's models is that the UM is licensed to other national meteorological services for operational use. Current users include: Norway, Australia, South Korea, South Africa, India, New Zealand and the US Air Force.[102] The Australian Bureau of Meteorology wrote to us explaining that it was "particularly well informed to be able to comment on the point of model robustness, having done a deep 'due diligence' on the Met Office and its modelling system before seeking a collaborative arrangement".[103] The Bureau explained that its decision was "strongly driven by [its] assessment that the Met Office systems are state-of-the art in modelling" and that it had "no reservations in stating that its decision has been completely vindicated by its first-hand experience operationally with the Unified Model over more than two years. These are excellent models, well-conceived, well built, and well up to the task".[104] As a result of adopting the UM, Australian forecasts have improved.[105] The accuracy of UK forecasts is discussed in paragraphs 45-51.

32. In addition to the clear benefit to those countries using Met Office models, there are also considerable benefits for the Met Office itself. For example, Professor Ed Hill, from the National Oceanography Centre, told us that by operating the UM in different countries, with different weather and climate environments to our own, Met Office models "get tested in different regimes".[106] He added that more people using the models would allow users to learn lessons collectively.[107] The Australian Bureau of Meteorology indicated that feedback of this kind "facilitate[d] model improvements that would otherwise be beyond the focus of the Met Office".[108] The Bureau described it as:

> "one plus one equals three" territory, where a strategic alignment of the intellectual capital of British and Australian meteorologists in the use and development of the UM yields added benefit in terms of improved forecasting capability to the citizens of both nations.[109]

33. As well as looking at the use of Met Office models by international partners, we were keen to find out more about the extent to which the models were used by the wider

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100 For example: Ev 58, para 15 [European Centre for Medium-Range Weather Forecasts]; Ev w4, para 4.1 [US National Oceanic and Atmospheric Administration National Weather Service]; Ev w8, para 10 [Australian Bureau of Meteorology]; and Ev w15, para 17 [Research Councils UK]

101 Ev 58, para 13 [European Centre for Medium-Range Weather Forecasts]

102 Ev 43, para 5.9 [Met Office]

103 Ev w8, para 10

104 As above

105 Ev w7 [Australian Bureau of Meteorology]

106 Q 32

107 As above

108 Ev w7, Introduction

109 As above

meteorology community within the UK. We heard conflicting views about this. The Department of Meteorology at the University of Reading stated that:

> The whole suite of models used by the Met Office is used within the University community, and particularly at the University of Reading, in research projects. This means that the models are subjected to a very high level of scrutiny, often in ways unanticipated by the development teams at the Met Office. This level of scrutiny substantially increases the robustness of the models.[110]

However, Professor John Pyle, Chair of the Hadley Centre SRG, told us that:

> The Unified Model architecture is often difficult to negotiate and many UK academic meteorologists employ other, easier-to-use numerical models for specific research projects (e.g. mesoscale modelling). The Met Office needs to consider this seriously. I believe the intellectual exchange with the academic community will be increasingly important for the Met Office; if instead, UK academics use other, rival models, this will certainly be to the detriment of the Met Office, and UK science, in the medium and longer term. More thought needs to be given to making their models "user friendly".[111]

Professor Sir Brian Hoskins, Chair of MOSAC, explained that one of the reasons for the Met Office model not being particularly user-friendly might be that it has historically been used mostly for operational purposes. He added that there would be "an overhead" associated with making it more usable by the community.[112] John Hirst, Chief Executive of the Met Office, accepted that the models needed to be easier to use.[113] It was his view that collaboration on modelling had historically been better in climate forecasts than in weather forecasts but that the Met Office was "now working with the weather academic community" on this issue.[114]

34. Throughout the course of our inquiry, we heard of one collaborative computer modelling initiative that was working particularly well. The Met Office and Natural Environment Research Council (NERC) joint supercomputing system, "MONSooN", allows scientists to collaborate on research into a number of modelling issues.[115] MONSooN has been credited with greatly improving the extent to which the Met Office collaborates with the wider research community.[116] For example, the National Oceanography Centre told us that MONSooN has been used by scientists from the Met Office and NERC to analyse and improve the common ocean modelling system, "NEMO", which is now a "world-leading system".[117] Professor Pyle welcomed MONSooN and stated

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110 Ev w18, para 4

111 Ev 57, para 10

112 Q 50

113 Q 87

114 As above

115 Met Office website, "Met Office and NERC joint supercomputer system (MONSooN)", www.metoffice.gov.uk/research/collaboration/jwcrp/monsoon-hpc

116 Q 49 [Professor John Pyle]; and Ev 62, para 3.4 [National Oceanography Centre]

117 Ev 62, para 3.4

that he would like to see it expanded.[118] He acknowledged, however, that this would require more money.[119] Mr Hirst told us that the Met Office would expand MONSooN, and was "already in discussions with NERC about the next phase".[120]

35. Met Office models are highly regarded across the UK and around the world. It is a testament to the Met Office that its Unified Model is licensed to other national meteorological services. Collaboration with these international partners helps the Met Office to further test and develop its models and should be encouraged. Similarly, collaboration with the wider UK meteorology community should be encouraged to stimulate the development of Met Office models. We note that the MONSooN project has been held up as a particularly good example, providing a joint supercomputing system that allows scientists to collaborate on research into modelling issues. We encourage the expansion of MONSooN and recommend that NERC work closely with the Met Office to develop plans for the next phase that are suitable for the research community's needs.

Supercomputing

36. In addition to using supercomputers to facilitate collaborative research, they are also used for the operational delivery of forecasts. As explained in paragraph 27, forecasting uses powerful supercomputers, these are computers that are optimised to make billions of mathematical calculations as quickly as possible. The Met Office Science Strategy explained that:

> The difference between operational and research computing requirements needs to be recognised. Operational delivery requires the appropriate capacity to deliver a suite of weather forecasts on a 24-hour, 7-day a week basis, without interruption. Increasingly it will also need to accommodate an operational suite of climate predictions. Consequently, operational supercomputing needs to be robust and under our control, and it needs a substantial partition for preoperational development and testing. [...]
>
> Research, on the other hand, requires access to advanced computing capability in order to make further progress in model resolution and complexity, data assimilation and process-based research.[121]

37. In 2010 the Government Chief Scientific Adviser, Professor Sir John Beddington, published a review of government's needs for climate science advice. The review recommended that "a step-change increase in supercomputing capacity [...] would be required to most effectively meet the Government's key evidence and advice needs".[122] More recently, the House of Commons Transport Committee also stated that benefits would be realised if an additional £10 million funding were made available for

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118 Ev 57, para 9

119 Q 49

120 Q 89

121 Met Office, *Met Office science strategy 2010–2015*, November 2010, p 12

122 Government Office for Science, *Review of climate science advice to Government and Met Office Hadley Centre role, governance and resourcing*, September 2010, p 4

supercomputing resources.[123] Many of the witnesses we heard from agreed that such a step-change in supercomputing capacity was necessary.[124] However, Sir John recognised in his review that this step-change would involve a four-fold increase in supercomputing costs, which was "not currently affordable".[125] While others also recognised affordability was an issue,[126] the point was made that the Met Office had already "slipped down the league table in terms of its computing resource" and that it would be "impossible to deliver world class weather and climate science without access to adequate computing capacity".[127] However, we have not in the course of our inquiry assessed historical investment in supercomputing resources. The Met Office told us that it currently:

> has developments available which have been demonstrated in research-mode to deliver more accurate forecasts. However, it is not possible to implement these improvements in the Met Office's operational forecast model because of limited supercomputing resource.[128]

In the Met Office Chief Scientist's words, "the science is ready and waiting" and as a result, there would be "a very rapid return" on investment in supercomputing.[129] We asked the Met Office to explain what operational improvements it could deliver if additional investment in supercomputing was made. In response, it provided case study examples of how enhancements would deliver improved advice to users, and affect their response in severe weather.[130] For example, intense downpours caused localised incidents of surface water flooding in parts of Dorset on 18 August 2011, resulting in the Fire Service dealing with over 100 incidents in a two hour period.[131] The Met Office told us that the short lead-time warning and low confidence extreme rainfall alert were "very likely to have contributed to limited preparedness".[132] Enhanced supercomputing power "would probably have allowed more confident warnings, better indications of possible peak rainfall intensities, and longer lead time information on the potential risk, to be issued".[133] Other case studies highlighted by the Met Office included the snowstorms in the South of England in February 2009 and the Cumbrian floods in November 2009.[134] In addition to improved short-range weather forecasts, increased supercomputing capacity would also improve operational monthly to decadal predictions and climate services.[135]

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123 Transport Committee, Fifth Report of Session 2010–12, *Keeping the UK moving: The impact on transport of the winter weather in December 2010*, HC 794, para 15

124 Q 30 [Professor Paul Hardaker, Professor Ed Hill, Professor Alan Thorpe]; and Q 91 [John Hirst]

125 Government Office for Science, *Review of climate science advice to Government and Met Office Hadley Centre role, governance and resourcing*, September 2010, p 4

126 Q 30 [Professor Paul Hardaker]

127 Ev 56, para 5 [Professor John Pyle]

128 Ev 50, para 1.3

129 Q 91 [Professor Julia Slingo]

130 Ev 50, para 2.2 and Ev 52, Annex A [Met Office]

131 Ev 54, Case Study 4 [Met Office]

132 As above

133 As above

134 Ev 53-54, Case Studies 3 & 2 [Met Office]

135 Ev 50, para 3 [Met Office]

38. As well as producing case studies, the Met Office has also calculated the socio-economic benefit delivered by investment in supercomputing capacity. This was carried out in 2008, "in accordance with best practice as set out in the HM Treasury's Green Book: Appraisal and Evaluation in Central Government".[136] In compliance with these best practice policies, it was estimated that "for a £50 million five year whole-life cost, net UK socio-economic benefit totalling £0.5 billion would be delivered through provision of enhanced weather and climate services".[137] John Hirst, Met Office Chief Executive, told us that this ratio, a ten to one return on investment, "still exists" today.[138] This aggregate benefit ratio was calculated by "combining the PWS (13:1) and climate science (6:1) ratios", suggesting that investment in supercomputing capacity would provide greater benefits for weather forecasting than for climate forecasting.[139] The Government told us that "further economic benefit as a consequence of ongoing advances in the science will be delivered through the routine scheduled replacement of the current supercomputer currently planned for 2015".[140] However, the Royal Meteorological Society considered that "a further significant investment in computing resources is required, over and [above] the current commitments".[141]

39. The Met Office wrote to us to explain that delivering improvements, consistent with the socio-economic benefits outlined above, "would require a supercomputer with at least twice the capacity of the near one petaflop[142] facility now being implemented at the Met Office".[143] The cost of this—including associated infrastructure, depreciation, power, service and maintenance charges, and staff costs for developing modelling infrastructure—would be £14 million per year, over each of the next three years.[144] This was consistent with estimates from Professor Sir Brian Hoskins, Chair of MOSAC, and Professor John Pyle, Chair of the Hadley Centre SRG, on the required level of investment in the future.[145] Edward Davey MP, the Minister for Employment Relations, Consumer and Postal Affairs, acknowledged that "a very good case" had been made for increased supercomputing capacity and that BIS was "building a business case" for the next generation of supercomputing capacity.[146] He added that this was "happening with a degree of urgency".[147] However, we later discovered that "the current timetable sees this process taking up to 18 months".[148]

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136 Ev 51, para 4 and Ev 55, Annex B [Met Office]

137 As above

138 Q 97

139 Ev 55, Annex B, para 6 [Met Office]

140 Ev 78, para 2

141 Ev 64, para 8

142 A petaflop is a measure of a computer's processing speed.

143 Ev 51, para 5.1

144 Ev 51, para 5.1 [Met Office]

145 Q 57 and Q 59

146 Q 140; and Ev 78 [Government]

147 Q 140

148 Ev 78

40. It is of great concern to us that scientific advances in weather forecasting and the associated public benefits (particular in regard to severe weather warnings) are ready and waiting but are being held back by insufficient supercomputing capacity. We echo the recent conclusions of the Government Chief Scientific Adviser and others, that a step-change in supercomputing capacity is required. We acknowledge, however, that affordability is an issue. The Met Office has over recent years built a good case for increased investment. However, we have not in the course of our inquiry assessed investment in supercomputing over recent decades. We recommend that the Met Office provide an overview of historical investment in supercomputing resources in its response to us. We encourage BIS to complete a formal business case on supercomputing, however, we do not consider that this process should take anywhere near the 18 months suggested by the Government. In our view, the Government should finalise the business case in the next six months.

41. Given the current economic climate, we considered it prudent to discuss with the Met Office and other witnesses what low-cost options there were for increasing supercomputing capacity. The Government told us that Sir John's review recognised "the need for greater collaboration on supercomputing resources, including internationally, stressing that long term development of modelling capability would likely require a European solution".[149] However, Professor Sir Brian Hoskins, Chair of MOSAC, warned us that Japan and Korea have their supercomputing capacity now, while there was still no sign of a European solution within the next few years.[150] In any case, a European solution would be more suitable for collaboration in climate forecasting than in operational weather forecasting, which is carried out to very tight timescales.

42. Professor Julia Slingo, Met Office Chief Scientist, suggested that collaboration on supercomputing "has been looked at over many years by the international community in weather and climate science".[151] She explained that the nature of some problems does not lend itself to, for example, distributed computing (the use of multiple computers communicating through a network). Professor Slingo explained that in weather forecasting, models have to run very efficiently on supercomputers and also gather and process huge amounts of data, all within a very short timeframe. This requires a specific type of machine architecture as well as a very large bandwidth to get the data out of the machine and on to a huge data archive. Professor Slingo added that the Met Office looks at this issue every year.[152]

43. The Met Office told us that "remote supercomputing options, such as third party facilities, grid computing and cloud computing, [were] not suitable at the current time".[153] While Sir John, in his recent review, agreed that Earth system and high-resolution models could only be run on supercomputers, he also stated that "in a limited number of instances

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149 Ev 70, para 2.5

150 Q 62

151 Q 93

152 As above

153 Ev 51, para 6.1

grid or network computing may offer a viable and cost-effective approach, such as for low resolution ensembles".[154]

44. Given that supercomputing capacity for weather and climate forecasting is a recurring issue, we recommend that the Met Office work with the Research Councils and other partners in the UK and abroad to develop a ten-year strategy for supercomputing resources in weather and climate. This should include an assessment of which areas in weather and climate research and forecasting might benefit from low-cost options to enhance supercomputing capacity.

Assessing forecast accuracy

Weather

45. The meteorology community tracks collectively the accuracy of forecasts.[155] The Met Office told us that:

> The accuracy of Met Office forecasts are evaluated against observations on a daily basis. The PWSCG [Public Weather Service Customer Group] specify accuracy targets for forecasts of maximum and minimum temperatures, rain, sun, wind speed and wind direction. In 2010/11 all targets were met. As of August 2011, on average (over a 36-month period) the percentage of forecasts accurate to within ± 2 °C is:
>
> - 87.6% of maximum temperature forecasts on the day the forecast is issued (target for 2011/12 85%) and 78.5% of minimum temperature forecasts (target 76.5%);
>
> - 81.1% of maximum temperature forecasts on the second day of the forecast (target 79.5%) and 71.7% of minimum temperature forecasts (target 69.0%).[156]

The PWSCG also "routinely undertakes public perception surveys to assess satisfaction with the forecast and warnings service".[157] In November 2010, it found that "nine out of ten people found weather forecasts useful and just over three quarters found them accurate".[158]

46. Professor Alan Thorpe, from the European Centre for Medium-Range Weather Forecasts (ECMWF), told us that "the distance that you can predict into the future has been advancing at about a day per decade".[159] For example, a five-day weather forecast today is as accurate as a three-day forecast was 20 years ago and a three-day forecast today is as accurate as a one-day forecast was 20 years ago. The Met Office attributed this increase in skill to "more sophisticated atmospheric physics, higher model resolution and more

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154 Government Office for Science, *Review of climate science advice to Government and Met Office Hadley Centre role, governance and resourcing*, September 2010, p 4

155 Q 2 [Professor Alan Thorpe]

156 Ev 38, para 2.9

157 Ev 38, para 2.7

158 Ev 38, para 2.7 (a)

159 Q 2

comprehensive observations, especially from meteorological satellites".[160] Professor Thorpe explained that as a result, over the years, more "local specificity" was available in forecasts.[161]

47. The ECMWF told us: "All global weather prediction models are routinely evaluated by the World Meteorological Organisation using independent and objective measures of skill".[162] The Met Office added that "a range of metrics are used and all show that the Met Office is consistently within the top three centres internationally".[163] However, similar metrics are "not yet available for longer range forecasts" because the appropriate methodologies are not in place and also because "verification statistics are much more limited due to the short length of the observational base".[164] The Met Office explained that "the quality of its performance against other centres is assured by including the Unified Model (UM) in all model comparisons and in the European Seasonal to Inter-annual Prediction (EUROSIP) ensemble of models"[165]—EUROSIP is a project that aims to strengthen collaboration on seasonal forecasting.[166] There is, however, a "common public perception" that the Met Office does not provide reliable seasonal forecasts.[167] The National Oceanography Centre (NOC) told us that this was "largely due to sensationalist media reporting and shortcomings in how 'probability' and 'risk' are understood by non-experts".[168] These are issues we discuss in paragraphs 52-56. The NOC added that:

> Private weather forecasting companies are now often called upon to make these seasonal predictions, suggesting that this is an aspect of the Public Weather Service remit where the Met Office service could be improved. The accuracy of forecasts by these private companies needs to be carefully evaluated on a long-term basis.[169]

48. The accuracy of independent forecasters in comparison to the Met Office is an issue that is also of interest to the BBC. Roger Harrabin, BBC Environment Analyst, told us that BBC News initiated the Weather Test "to compare publicly for the first time the accuracy of weather forecasters in the UK."[170] The Met Office is co-operating with this initiative.[171] However, John Hirst, Met Office Chief Executive, pointed out that this was "not a trivial exercise".[172] Professor Julia Slingo, Met Office Chief Scientist, added that particularly with seasonal forecasting, which are probabilistic forecasts (forecasts that assign a probability to each of a number of different outcomes in order to allow uncertainties to be quantified), there is no right or wrong forecast and therefore a whole history of forecasts is needed to

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160 Ev 43, para 5.5

161 Q 3

162 Ev 58, para 7 [European Centre for Medium-Range Weather Forecasts]

163 Ev 43, para 5.6

164 Ev 43, para 5.7 [Met Office]

165 Ev 43, para 5.7

166 Ev w5, para 4.4 [US National Oceanic and Atmospheric Administration National Weather Service]

167 Ev 60, para 3.1.2 [National Oceanography Centre]

168 Ev 60, para 3.1.2

169 As above

170 Ev w24

171 Q 124 [John Hirst]

172 Q 122

decide the level of skill and reliability.[173] Professor Slingo explained that the international community was still working out how to do this in a way that makes sense.[174]

Climate

49. We were also keen to know how accurate climate forecasts have been over the past few decades, and whether they were improving. We note that the climate model did not accurately predict the extent of the flattening of the temperature curve during the last ten years.[175] Professor Alan Thorpe, from ECMWF, told us that:

> In 1990, when the scientific assessment was made, there were real-time predictions of what the climate, subsequent to 1990 going forward, would be. We are now in a position of having a record of what actually happened relative to the predictions that were made then of the climate from 1990 to the present time. Those comparisons show that the models of the day—of course, the models have improved since then—if anything, under-estimated the amount of global warming that has subsequently happened. We are able now, because we have done this climate prediction for a number of years, to start to assess that.[176]

Professor Paul Hardaker, from the Royal Meteorological Society, agreed that "what the early models predicted is largely what has come to pass in terms of our observations".[177] Mr Hirst added that there was "a difference between making a forecast for tomorrow when you experience tomorrow very quickly" and "going back and modelling how the climate has evolved in history to make sure that our models replicate what actually happened".[178] The Royal Meteorological Society added that there was "no more computationally complex problem in science" than simulating the climate.[179] Despite the difficulties in assessing climate models, both the Royal Meteorological Society and the ECMWF considered that the Met Office was widely acknowledged as a world-leader in climate modelling and prediction.[180]

Atmospheric dispersion

50. The Met Office uses its Numerical Atmospheric-dispersion Modelling Environment (NAME) model to "predict how material will be dispersed in the atmosphere and deposited on the ground".[181] In recent years, NAME has also been used for events such as the 2005 Buncefield oil storage depot incident, the 2008 Bluetongue outbreak over Europe,

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173 Q 125

174 As above

175 Qq 27-29 [Professor Paul Hardaker and Professor Alan Thorpe] and Qq 94-95 [Professor Slingo]

176 Q 27

177 Q 29

178 Q 95

179 Ev 65, para 16

180 Ev 65, para 14 [Royal Meteorological Society]; and Ev 58, para 14 [European Centre for Medium-Range Weather Forecasts]

181 Ev 43, para 5.10 [Met Office]

the 2010 and 2011 volcanic eruptions, and the 2011 Fukushima nuclear incident.[182] The Met Office told us that it was difficult to verify the accuracy of dispersion models "because dispersion events occur infrequently and it can be difficult to obtain reliable, quantifiable observations of the distribution and concentration of material".[183] This was an area of particular interest to us following our recent report, *Scientific advice and evidence in emergencies*, in which we questioned the suitability of the Met Office's dispersion predictions in relation to volcanic ash.[184] In response to our report, the Government told us that an independent review of the NAME model had been commissioned by the Civil Aviation Authority.[185] This review concluded that NAME "represents a state of the art dispersion model".[186] In its submission to us, the US National Oceanic and Atmospheric Administration National Weather Service agreed, stating that "NAME is robust, peer reviewed, and good for ash dispersion modelling".[187] We note that the Met Office continues to work with its American counterparts to improve collaboration during future volcanic eruptions.[188]

51. The Met Office is consistently within the top three centres internationally in weather prediction and is widely recognised as a world-leader in climate prediction. However, we note that the climate model did not accurately predict the extent of the flattening of the temperature curve during the last ten years. We have heard that the accuracy of short-term forecasts is easier to assess than the accuracy of longer term forecasts and infrequent events, such as volcanic ash dispersion. We encourage the Met Office to work with partners in the UK and internationally on developing metrics to assess the accuracy of longer-term forecasts of weather and climate and of forecasts based on infrequent events.

Communication of forecasts

52. A forecast, however accurate it is, is of little use if it is not communicated well and understood by the customer.[189] The National Oceanography Centre told us that most of the public perception of forecasts is via television broadcasts.[190] Professor Paul Hardaker, from the Royal Meteorological Society, considered that it was the responsibility of both the forecaster and the broadcaster to ensure that forecasts are accurately communicated.[191] Given the inherent uncertainty in forecasting, one of the ways in which communication could be improved would be through providing more information about probability. Professor Brian Hoskins told us that MOSAC has "always encouraged the Met Office to

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182 Ev 43, para 5.10 [Met Office]

183 Ev 43, para 5.11

184 Science and Technology Committee, Third Report of Session 2010–11, *Scientific advice and evidence in emergencies*, HC-498, para 224

185 Science and Technology Committee, Fourth Special Report of Session 2010–12, *Scientific advice and evidence in emergencies: Government Response to the Committee's Third Report of Session 2010–12*, HC 1042, para 113

186 Ev 43, para 5.12 [Met Office]

187 Ev w5, para 4.3

188 Ev w6, para 5.3 [US National Oceanic and Atmospheric Administration National Weather Service]

189 Ev w21, para 3.1 [Philip Eden]

190 Ev 60, para 3.1.2 [National Oceanography Centre]

191 Q 37

produce more information about likelihood" but that "media pressure" on weather forecasts meant that there was only a short period of time to communicate forecast information.[192] Sir Brian did not consider that there was an easy way to get this information across in a 30 second broadcast.[193] However, the use of the Internet and digital technology, such as the BBC's "red button" facility, means that more detailed forecast information could easily be made available to those who want it.[194]

53. Professor Hardaker told us that "many countries make much greater use of probabilistic information in their forecasts than we do, even in their broadcasts".[195] Sir Brian cited a recent example:

> Let us take [...] the hurricane that was likely to inundate New York. US television was showing 12 possible tracks provided by 12 different models for the hurricane. I do not believe that that sort of information is difficult for the public to assimilate, and we should not underestimate the public's ability to take on odds and make their own decisions based on those.[196]

We asked the Minister whether he considered that the communication of such detailed information could be improved in the UK. In response he told us that the Met Office was considering the matter.[197] The trade union, Prospect, confirmed that the Met Office "has recently invested significantly in enhancing the presentation of site-specific information on its public website".[198] The Met Office is currently testing these changes on the beta version of its public website.[199] Prospect added that the Met Office "is also seeking to enhance the presentation of probabilistic weather forecast information".[200] The Royal Meteorological Society told us that "if the Met Office was able to provide more information about uncertainty in its forecasts, it may be less subject to the criticism it has seen from time-to-time from public and media alike".[201]

54. An area where the Met Office has been particularly heavily criticised in the recent past is in seasonal forecasting, for example, during the bad weather that followed its 2009 prediction of a "barbecue summer".[202] Philip Eden, a Fellow of the Royal Meteorological Society, told us that predictions like this "go to the very heart of what weather forecasts are for"; he questioned whether they were a public service, or entertainment.[203] Nick Baldwin,

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192 Q 79

193 Q 80

194 Q 38 [Professor Paul Hardaker]; and Qq 79-80 [Professor Brian Hoskins]

195 Q 38

196 Q 79

197 Q 166

198 Ev w3, para 4

199 www.metoffice.gov.uk/public/beta/

200 Ev w3, para 4

201 Ev 64, para 11

202 Mail Online, "As millions of Britons holiday at home after that promise of a 'barbecue summer', how did the Met Office get it so wrong?", 30 July 2009, www.dailymail.co.uk

203 Ev w22, para 5.1

Chair of the Public Weather Service Customer Group (PWSCG) told us that following the barbecue summer prediction, the PWSCG was:

> heavily involved in a discussion about withdrawing the previous seasonal forecasting approach. The consultation we undertook showed that people did not find it very useful in the way it was presented, and that they would rather have received a shorter-term forecast so that the three-month forecast was replaced with a 30-day rolling forecast. A lot of work has gone on since then with the Met Office, and over the next week or so it will introduce a new seasonal forecasting methodology for civil contingency communities, which includes a better explanation of the uncertainty facing us. [...] It is important that people are organised and have a good understanding of that forecast. We have been funding that information and it will be released through the Cabinet Office.[204]

While it may be the case that seasonal forecasts with an accompanying explanation of the uncertainty are more useful for civil contingencies than, for example, the general public, the Met Office is bound by clear rules that state that if it makes this information available to the Government, it must also be made available publicly.[205] It was also suggested that seasonal forecasts were useful across a wide range of industries, for example, insurance, power generation, construction, agriculture, tourism and retail.[206]

55. **The Met Office should continue to produce longer term ("seasonal") forecasts as they are useful for civil contingencies and a wide range of industries. These forecasts should always be communicated carefully and accompanied by explanatory notes describing the uncertainty. We recommend that the Met Office develop a communications strategy that sets out, for example, how it intends to enhance the ways in which it presents probabilistic weather forecast information.**

56. **The Met Office should also work closely with broadcasters, such as the BBC, to ensure that forecasts are communicated accurately. In particular, we are keen to see broadcasters make greater use of probabilistic information in their weather forecasts, as is done in the United States. Broadcasters should also make more use of digital technology to ensure that probabilistic forecast information is available to those that want it.**

Access to data

57. In generating weather and climate forecasts, the Met Office generate huge quantities of data. The Government told us that:

> The PWSCG require the Met Office to provide a meteorological library and archive service available to anyone with an interest in the weather or climate and an approved place of deposit for meteorological information under the public records Act (1958). [...] There is also a legal requirement handed down to the Public Weather

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[204] Q 79

[205] Q 119

[206] Q 7 [Professor Ed Hill]

Service from the Lord Chancellor's office to archive meteorological data on behalf of the UK Public.[207]

We heard contrasting views on how well the Met Office is meeting its requirement to provide public access to library services and to historical data. Among those who thought the Met Office was doing well were Research Councils UK and the National Oceanography Centre;[208] while the Committee on Climate Change and others appeared to be less satisfied with the current arrangements for accessing data from the Met Office.[209] Issues raised by the latter group included that the Met Office charges heavily for access to electronic records and that while some older records are available in paper form for photocopying, this was not the case for more recent data, which often originated in digital format.[210] Nick Baldwin, Chair of the PWSCG, told us that the Met Office was looking at ways in which to expand the data that were publicly available but that this needed to be done in a cost-effective way.[211] Mr Hirst added that the Met Office tried to address every specific request or issue that was raised with it on data accessibility.[212] In order to gather views on how historical data could best be provided online, we heard that the Royal Meteorological Society and the Met Office were running a consultation with the wider community.[213] It was also suggested during the course of this inquiry that the Met Office could learn from other countries—including the United States and Australia—where data were considered to be more freely accessible.[214]

58. We heard from a number of witnesses that freeing up access to data might help to grow a more vibrant private sector that could, for example, develop specialist weather and climate services.[215] This view was shared by the Minister.[216] Driving innovation and growth by freeing up public data is one of the main aims of the Government's plans for a Public Data Corporation (PDC).[217] The Met Office has been consulted by the Government on the development of the PDC.[218] Further details on the PDC were outlined following the 2011 Autumn Statement by the Chancellor of the Exchequer, when the Government announced that it would establish a Data Strategy Board and a Public Data Group that would "maximise the value of the data from the Met Office" and other organisations. The Government stated that the release of Met Office data under the Open Government Licence represented "the largest volume of high quality weather data and information

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207 Ev 69, para 1.29

208 Ev w14, para 8 [Research Councils UK]; and Ev 61, para 3.1.4 [National Oceanography Centre]

209 Ev w12, para 9 [Committee on Climate Change]; Ev w19, para 2.1 [Stephen Burt]; and Ev w23-24, para 6.2 [Philip Eden]

210 Ev w19, paras 3.1–3.2 [Stephen Burt]; and Ev w23–24, para 6.2 [Philip Eden]

211 Qq 66–67

212 Q 105

213 Q 34 [Professor Paul Hardaker]; and Q 105 [John Hirst]

214 Ev w12, para 9 [Committee on Climate Change]; Ev w20, para 5.3 [Stephen Burt]; and Ev w23-24, para 6.2 [Philip Eden]

215 Q 68 [Nick Baldwin]; Q 107 [John Hirst]; Ev w12, para 10 [Committee on Climate Change]; Ev 63, para 4 [Royal Meteorological Society]; Ev w20, para 5.2 [Stephen Burt]

216 Q 151

217 Cabinet Office press notice, "Public Data Corporation to free up public data and drive innovation", 12 January 2011, www.cabinetoffice.gov.uk

218 Qq 109–110 [John Hirst]

made available by a national meteorological organisation anywhere in the world".[219] However, the possibility of the PDC adding "an unnecessary and unhelpful level of bureaucracy" was raised by Professor Hardaker, from the Royal Meteorological Society, as a potential problem.[220]

59. **We note that there are contrasting views on how easy it is to gain free access to Met Office data. While we take some reassurance from the fact that the Met Office tries to address specific concerns about this as and when they arise, we consider that the current consultation in collaboration with the Royal Meteorological Society on access to data should help the Met Office to deal with the problem in a more strategic manner. We recommend that the Met Office also look to other countries for best practice on making data more freely available. Alongside this, we welcome the Government's initiative under the Public Data Corporation to make more Met Office data available to drive innovation and growth. The Government should continue to work with the Met Office to ensure that the new arrangements are effective and do not add an unnecessary level of bureaucracy.**

Collaboration and partnership

60. Throughout this report, we have touched on the subject of collaboration between the Met Office and the wider meteorology community, both in the UK and abroad. In this section we look in more detail at the ways in which the Met Office collaborates with the research base, with the Government and other public bodies, and with international partners.

Research base

61. Professor Sir Brian Hoskins, Chair of MOSAC, told us that "collaboration in the UK was quite rocky 20 or 30 years ago" but that this had improved significantly.[221] The Met Office now appears to be well connected to the research base.[222] John Hirst, Met Office Chief Executive, told us that a "head of [science] partnerships" post had been created and that the Met Office was acting on the need to collaborate.[223] The Met Office stated that in 2010, its scientists served on 39 committees related to the UK research base and that representatives of the UK research community were included on MOSAC and the Hadley Centre SRG.[224] The Met Office's Chief Scientist is also a member of the Natural Environment Research Council's (NERC) council.[225] The Met Office's science strategy recognises the importance of collaboration and outlines the activities that the Met Office will undertake.[226]

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219 Cabinet Office, *Further Detail on Open Data Measures in the Autumn Statement 2011*, 29 November 2011, p 10

220 Q 34

221 Q 74

222 Ev w16, para 22 [Research Councils UK]

223 Q 111 and Met Office, *Met Office science strategy 2010–2015*, November 2010, p 10

224 Ev 45, para 6.3

225 Ev 45, para 6.4

226 Ev 45, para 6.3 [Met Office]; and Met Office, *Met Office science strategy 2010–2015*, November 2010, p 10

62. One activity we heard a lot about during the course of our inquiry was the Joint Weather and Climate Research Programme (JWCRP).[227] The JWCRP is a joint programme between the Met Office and NERC which aims "to ensure that the UK maintains and strengthens its leading international position in weather and climate science".[228] Professor John Pyle, Chair of the Hadley Centre SRG, told us that while the intentions of JWCRP were "excellent", it would be "foolish to underestimate some of the practical difficulties".[229] He explained that such a collaboration, on an institutional level, would "entail some loss of sovereignty [and] effective management of joint programmes [would] be a challenge".[230] He implied that progress with the JWCRP was understandably moving slowly,[231] but that a more strategic approach was now being taken.[232] Other activities include the Met Office's work with NERC on the cross-Government, cross-Research Council programme, Living with Environmental Change,[233] and its collaborative relationship with individual universities.[234]

63. The Government told us that it fully endorsed the Met Office's proposal for stronger partnerships and collaboration; however, it added that "the proposed science partnerships should also include representation from government to provide additional context to proposed research programmes".[235] In response, Mr Hirst told us that he didn't understand the thoughts behind this and that the Met Office needed to understand precisely what these representatives would want to do.[236] Professor Julia Slingo, Met Office Chief Scientist, noted that the Met Office needed to be careful, particularly with its academic partners, that this did not conflict with the Haldane principle (the traditionally accepted view that detailed decisions on research should be made by researchers, not government).[237] The Haldane principle does not apply to research funded by the Met Office; it does, however, apply to research that is funded by the Research Councils.[238] The JWCRP, for example, is jointly funded by the Met Office and NERC. Government representation on the JWCRP might therefore be questionable. We sought clarification from the Minister; he explained that "the suggestion that the Government should be represented on the science partnerships was, frankly, to ensure the links between the Government and policy-relevant research and that any potential research overlap is minimised" and added that he did not believe there was a conflict with the Haldane principle.[239] The Government subsequently wrote to us clarifying that it did "not necessarily envisage Government representation in all

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227 For example: Q 32 [Professor Alan Thorpe]; Q 33 [Professor Ed Hill]; and Q 36 [Professor Paul Hardaker]

228 Natural Environment Research Council, "Joint Weather and Climate Research Programme", www.nerc.ac.uk

229 Ev 57, para 8

230 As above

231 Q 74

232 Q 77

233 Ev 63, para 3.5.3 [National Oceanography Centre]

234 Ev w17 [Department of Meteorology, University of Reading]

235 Ev 70, para 2.6

236 Q 113

237 As above

238 Ev 79, para 4 [Government]

239 Qq 153–154

scientific collaborations engaged in by the Met Office" and that where representation was desirable, it would most likely be at the Chief Scientific Adviser or official level.[240]

64. We recommend that the Government consult with the Met Office on the need for Government representation on Met Office science partnerships. While such representation may be desirable to ensure strong links between the Government and policy-relevant research, care must be taken to ensure that there is no conflict with the Haldane principle—particularly where partnerships are co-funded by the Research Councils.

Government and public bodies

65. The Met Office works with the Government and public bodies to deliver the operational services required by the public sector under a range of contracts (see paragraph 9). For example, under its Public Weather Service contract, the Met Office produces severe weather warnings and works with the emergency planning and responder communities (see Annex A). This is an area in which it is especially important to have good coordination with the Government and public bodies. Prospect told us that Met Office links with the emergency responder community had "greatly improved" in recent years. As a result, the Met Office has a better understanding of "how improved forecasts and warnings can help to mitigate some of the impacts from severe weather".[241] The Government added that "the Met Office [had] also developed the 'traffic light' system of four colours which highlights the weather maps and advisories it sends out. This simple system alerts emergency planners and the public to the level of risk and certainty of the weather event".[242]

66. A good example of effective collaboration that was raised by a number of witnesses was the Flood Forecasting Centre (FFC), which is a partnership between the Met Office and the Environment Agency, staffed by members of both organisations. The FFC was set up in 2009 following the report by Sir Michael Pitt, *Learning lessons from the 2007 floods*, known as the "Pitt Review", which recommended that the "Environment Agency and Met Office should work together, through a joint centre, to improve their technical capability to forecast, model and warn against all sources of flooding".[243] Professor Paul Hardaker, from the Royal Meteorological Society, told us that it was important for the Met Office to be effectively joined up with other agencies that were involved in issuing warnings.[244] The Government stated that the 'traffic light' system "is now used across all early warnings distributed by the Met Office, Flood Forecasting Centre and Environment Agency".[245] Professor Hardaker considered that while it was still "early days", the FFC appeared to be working well.[246] Mr Hirst told us that the Cumbrian floods occurred just after the FFC had been established and as a result, the Met Office and Environment Agency "were able to give 24 hours' better notice than we had ever been able to do for a level of rainfall that was

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240 Ev 79, para 4

241 Ev w3, para 2 [Prospect]

242 Ev 67, para 1.10

243 Sir Michael Pitt, *Learning lessons from the 2007 floods*, June 2008, p 56

244 Q 12

245 Ev 67, para 1.10

246 Q 13

beyond any historic record of rainfall in this country".[247] Other examples of collaboration include the relationship of the Met Office with the aviation industry to improve the understanding of the spread and effect of volcanic ash,[248] and with the Highways Agency on the impact of weather on the road network.[249] A number of other examples were given by the Government in its submission.[250]

67. Following the success of the FFC in providing joined up scientific advice to Government and emergency responders and in recognition of the need for a similar approach to other potential natural hazards, the Met Office has set up the Natural Hazards Partnership (NHP).[251] The NHP brings together thirteen collaborative government agencies to coordinate advice through a single contact point.[252] Within a year of being established, the NHP has "piloted a multi-hazards warning service and the expertise is being integrated into the Cabinet Office National Risk Assessment process to ensure the best use of scientific evidence in planning and preparing for natural hazard events".[253]

International partners

68. In order to achieve the scientific advances required to improve weather and climate services, it is important to collaborate both nationally and internationally.[254] International collaboration is particularly important "to provide the observations on which the Met Office depends" (see paragraph 28).[255] The Met Office represents the UK in the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), a collaboration that funds and operates a coordinated satellite network, which provides weather and climate data 24 hours a day, 365 days a year.[256] There are also "intergovernmental arrangements" between Europe and other countries, "for the real time exchange of weather and climate related satellite data".[257] While there are clear advantages in sharing the cost of obtaining satellite data, there are also some problems with relying on international partners for crucial meteorological observations. For example, on 24 October 2011, the *Guardian* reported that budget cuts in the United States Congress could affect a "critical weather satellite" that is relied upon by the Met Office and other national meteorological services around the world.[258] When we asked the Minister about the extent to which the UK Government could influence its international counterparts in such a situation, he responded:

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247 Q 92

248 Ev w4, para 13 [Prospect]

249 Q 12 [Professor Paul Hardaker]

250 Ev 72-75, paras 5.1-5.28

251 Ev 46, para 6.17 [Met Office]

252 Ev w17, para 29 [Research Councils UK]

253 Ev 74, para 5.18 [Government]

254 Q 111 John Hirst; and Ev 58, para 9 [European Centre for Medium-Range Weather Forecasts]

255 Ev 45, para 6.8 [Met Office]

256 Ev 45, para 6.9 [Met Office]; and Ev 58, para 17 [European Centre for Medium-Range Weather Forecasts]

257 Ev 45, para 6.9 [Met Office]

258 The Guardian Online, "Weather satellite budget cuts a 'disaster in the making' - Obama official", 24 October 2011, www.guardian.co.uk

> I am not sure whether it is a question of Ministers phoning their counterparts and having strong discussions; it is more a question of ensuring that strong collaboration and co-operation across the globe is maintained. We certainly recognise that various Governments are under many cost pressures. The best way to apply pressure is to work together through those cost pressures and to understand their longer-term implications.[259]

We also asked how the specific problem highlighted in the *Guardian* article was being dealt with. The Minister was initially uncertain about the discussions occurring between the UK and the United States, but was eventually able to clarify that Mr Hirst was in discussions with his American counterpart and that exchanges were not taking place at a Ministerial level.[260] The Government also later added in a supplementary memorandum to us that "this is a US political issue and therefore Ministerial involvement is unlikely to be of assistance at this time, however support has been offered to Mr Hirst on this matter should the situation change".[261]

69. Beyond EUMETSAT, there are also close links between the Met Office and Europe through the European Centre for Medium-Range Weather Forecasts (ECMWF), a part of the "European Meteorological Infrastructure", which coordinates meteorological activities in Europe.[262] The Met Office is one of 19 Member States of the ECMWF.[263] The ECMWF provides a "complementary" service to the Met Office as it looks at longer-range forecasts.[264] Professor Sir Brian Hoskins, Chair of MOSAC, told us that MOSAC had called for the Met Office to improve its collaboration strategy with the ECMWF and that there were now moves in that direction.[265] While there is no mention of the ECMWF in the Met Office's science strategy, we note that it is referred to in the science strategy implementation plan.[266]

70. The Met Office also represents UK interests at the World Meteorological Organization (WMO).[267] The Met Office plays an "active role" in the WMO and "participates in a number of the WMO Commissions and Working Groups".[268] For example, Met Office scientists are actively engaged with the WMO's World Climate Research Programme, World Weather Research Programme and The Observing System Research and Predictability Experiment (THORPEX).[269] The WMO is also used as a forum in which to discuss collaboration on severe weather events, such as space weather.[270]

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259 Q 159

260 Qq 160–162; and Ev 79, para 3 [Government]

261 Ev 79, para 3

262 Ev 58, para 16 [European Centre for Medium-Range Weather Forecasts]

263 Q 32 [Professor Alan Thorpe]

264 Q 4 [Professor Alan Thorpe]

265 Q 74

266 Met Office MOSAC Paper, "Met Office Science Strategy 2010–2015: Implementation Plan", 9–11 November 2011, www.metoffice.gov.uk/media/pdf/5/2/MOSAC_16.1.pdf

267 Ev 45, para 6.11 [Met Office]

268 Ev 45-46, paras 6.13–6.14 [Met Office]

269 Ev 46, para 6.14 [Met Office]; and Ev w9-10, para 18 [Australian Bureau of Meteorology]

270 Ev w6, para 5.2 [US National Oceanic and Atmospheric Administration National Weather Service]

71. As previously discussed, the Met Office also collaborates with international partners on modelling: specifically, by developing and testing its Unified Model with those countries using it under licence (see paragraph 32). Amongst those working with the Met Office in this way is the Australian Bureau of Meteorology. The Bureau told us that "based on several years of experience, the Met Office is very well planned, efficient and effective in the way it structures and manages its side of the relationship".[271]

72. The Met Office collaborates well with a number of partners, both in the UK and internationally, to improve the accuracy of its modelling and predictions, and also to enhance the effectiveness of its advice to responders dealing with severe weather events. The Met Office is well respected internationally and it was able to provide us with a number of examples of how its work is feeding through to improved services.

271 Ev w9, para 14 [Australian Bureau of Meteorology]

Conclusions and recommendations

Ownership

1. We welcome the Minister's comment that the Government has no plans to privatise the Met Office and agree with him that it would be deeply irresponsible to do so on the grounds of the need to fill a hole in the Government's coffers. (Paragraph 5)

2. We consider it too early to comment in detail on the Met Office's move from the Ministry of Defence (MOD) to the Department for Business, Innovation and Skills (BIS). However, we welcome the potential for closer links between the Met Office and the research base, as well as the opportunity for the Met Office to develop its commercial activities further. (Paragraph 6)

Contracts and customer relationships

3. As a matter of urgency, the Government should ensure that its Customer Service Agreements (CSAs) with the Met Office are signed and that these CSAs are truly multi-year agreements. Furthermore, we recommend that the Government sets out its minimum funding commitment to the Met Office for each year of the current Spending Review period by the end of this financial year. (Paragraph 10)

4. It is our view that the Hadley Centre Climate Programme (HCCP) should be managed by a single Government department, as previously recommended by the Government Chief Scientific Adviser. A less satisfactory alternative would be for the Government to ensure that the Memorandum of Understanding between DECC and Defra is signed as a matter of urgency. (Paragraph 12)

5. We recommend that the Government and the Met Office reassess whether the existing mechanisms intended to support a strong customer relationship between the Met Office and departments such as MOD, DECC and Defra are effective. Specifically, we invite the Government and the Met Office to consider, and report back to us, on whether there is a need for a Defence Customer Group and a Hadley Centre Climate Programme Customer Group, analogous to the current Public Weather Service Customer Group. One of the benefits of introducing these new customer-focussed groups would be that scrutiny of Met Office science could be streamlined under one review group, as we discuss later in paragraph 25. (Paragraph 14)

6. We recommend that the Met Office continue to expand activities that generate commercial income; however, mechanisms must be in place to ensure that these activities do not put core services for the public sector or the Met Office's international reputation at risk. We invite the Met Office to explain in its response to us how this will be achieved. (Paragraph 16)

Oversight of Met Office science

7. Given the move towards integrating weather and climate science, and with the Met Office Science Advisory Committee's (MOSAC) remit being expanded to include both areas, we question whether it is sensible to impose additional scrutiny by the Met Office Hadley Centre Science Review Group (SRG). We recommend that the Met Office consult with DECC and Defra to determine whether the Hadley Centre SRG is required in its current form. Our view is that it would be more sensible to formally review all science under MOSAC, whilst retaining a Hadley Centre Climate Programme Customer Group, as described in paragraph 14, to ensure that customer needs are being met. (Paragraph 25)

8. We recommend that the Met Office publish MOSAC's terms of reference on its website. We also advise MOSAC to consider the Code of Practice for Science Advisory Committees (CoPSAC) at its next meeting, specifically considering whether MOSAC would benefit from adhering to the principles contained within it. (Paragraph 26)

Models and supercomputers

9. Met Office models are highly regarded across the UK and around the world. It is a testament to the Met Office that its Unified Model is licensed to other national meteorological services. Collaboration with these international partners helps the Met Office to further test and develop its models and should be encouraged. Similarly, collaboration with the wider UK meteorology community should be encouraged to stimulate the development of Met Office models. We note that the MONSooN project has been held up as a particularly good example, providing a joint supercomputing system that allows scientists to collaborate on research into modelling issues. We encourage the expansion of MONSooN and recommend that NERC work closely with the Met Office to develop plans for the next phase that are suitable for the research community's needs. (Paragraph 35)

10. It is of great concern to us that scientific advances in weather forecasting and the associated public benefits (particular in regard to severe weather warnings) are ready and waiting but are being held back by insufficient supercomputing capacity. We echo the recent conclusions of the Government Chief Scientific Adviser and others, that a step-change in supercomputing capacity is required. We acknowledge, however, that affordability is an issue. The Met Office has over recent years built a good case for increased investment. However, we have not in the course of our inquiry assessed investment in supercomputing over recent decades. We recommend that the Met Office provide an overview of historical investment in supercomputing resources in its response to us. We encourage BIS to complete a formal business case on supercomputing, however, we do not consider that this process should take anywhere near the 18 months suggested by the Government. In our view, the Government should finalise the business case in the next six months. (Paragraph 40)

11. Given that supercomputing capacity for weather and climate forecasting is a recurring issue, we recommend that the Met Office work with the Research Councils

and other partners in the UK and abroad to develop a ten-year strategy for supercomputing resources in weather and climate. This should include an assessment of which areas in weather and climate research and forecasting might benefit from low-cost options to enhance supercomputing capacity. (Paragraph 44)

Accuracy of forecasts

12. The Met Office is consistently within the top three centres internationally in weather prediction and is widely recognised as a world-leader in climate prediction. However, we note that the climate model did not accurately predict the extent of the flattening of the temperature curve during the last ten years. We have heard that the accuracy of short-term forecasts is easier to assess than the accuracy of longer term forecasts and infrequent events, such as volcanic ash dispersion. We encourage the Met Office to work with partners in the UK and internationally on developing metrics to assess the accuracy of longer-term forecasts of weather and climate and of forecasts based on infrequent events. (Paragraph 51)

Communication of forecasts

13. The Met Office should continue to produce longer term ("seasonal") forecasts as they are useful for civil contingencies and a wide range of industries. These forecasts should always be communicated carefully and accompanied by explanatory notes describing the uncertainty. We recommend that the Met Office develop a communications strategy that sets out, for example, how it intends to enhance the ways in which it presents probabilistic weather forecast information. (Paragraph 55)

14. The Met Office should also work closely with broadcasters, such as the BBC, to ensure that forecasts are communicated accurately. In particular, we are keen to see broadcasters make greater use of probabilistic information in their weather forecasts, as is done in the United States. Broadcasters should also make more use of digital technology to ensure that probabilistic forecast information is available to those that want it. (Paragraph 56)

Access to data

15. We note that there are contrasting views on how easy it is to gain free access to Met Office data. While we take some reassurance from the fact that the Met Office tries to address specific concerns about this as and when they arise, we consider that the current consultation in collaboration with the Royal Meteorological Society on access to data should help the Met Office to deal with the problem in a more strategic manner. We recommend that the Met Office also look to other countries for best practice on making data more freely available. Alongside this, we welcome the Government's initiative under the Public Data Corporation to make more Met Office data available to drive innovation and growth. The Government should continue to work with the Met Office to ensure that the new arrangements are effective and do not add an unnecessary level of bureaucracy. (Paragraph 59)

Working in partnership

16. We recommend that the Government consult with the Met Office on the need for Government representation on Met Office science partnerships. While such representation may be desirable to ensure strong links between the Government and policy-relevant research, care must be taken to ensure that there is no conflict with the Haldane principle—particularly where partnerships are co-funded by the Research Councils. (Paragraph 64)

Annex A: Public Weather Service remit

The Met Office provides the following services under its Public Weather Service remit:

- Monthly, 15 day, five day and daily forecasts
- Site specific UK and global forecasts
- A range of other forecasts available via the Met Office website
- A range of specialist forecasts for interest groups (mountaineering, gardening etc.)
- Seasonal Forecasts (three-monthly)
- National Severe Weather Warning Service
- UK and global response services
- Public weather service advisers
- Hazard manager—a web portal for emergency responders showing current and near future weather conditions
- Forecasting guidance from the Met Office Operations Centre
- General help and advice from the Met Office Customer Centre
- National Meteorological library and Climatological Advice
- Use of the Met Office plane[272]

[272] Ev 66-67, para 1.6 [Government]

Annex B: List of abbreviations

BIS	Department for Business, Innovation and Skills
CoPSAC	Code of Practice for Scientific Advisory Committees
CSA	Customer Service Agreement
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
ECMWF	European Centre for Medium-Range Weather Forecasts
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUROSIP	European Seasonal to Inter-annual Prediction
FFC	Flood Forecasting Centre
HCCP	Hadley Centre Climate Programme
JWCRP	Joint Weather and Climate Research Programme
MOD	Ministry of Defence
MOSAC	Met Office Science Advisory Committee
MoU	Memorandum of Understanding
NAME	Numerical Atmospheric-dispersion Modelling Environment
NCAS	National Centre for Atmospheric Science
NERC	Natural Environment Research Council
NHP	Natural Hazards Partnership
NOC	National Oceanography Centre
PDC	Public Data Corporation
PWS	Public Weather Service
PWSCG	Public Weather Service Customer Group
RCUK	Research Councils UK
SDA	Service Definition Agreement
SRG	Science Review Group
THORPEX	The Observing System Research and Predictability Experiment
UM	Unified Model

WMO	World Meteorological Organization
WOW	Weather Observations Website

Formal Minutes

Wednesday 8 February 2012

Members present:

Andrew Miller, in the Chair

Stephen Metcalfe	Pamela Nash
Stephen Mosley	Graham Stringer

Draft Report (Science in the Met Office), proposed by the Chair, brought up and read.

Ordered, That the draft Report be read a second time, paragraph by paragraph.

Paragraphs 1 to 72 read and agreed to.

Summary agreed to.

Annexes A and B agreed to.

Resolved, That the Report be the Thirteenth Report of the Committee to the House.

Ordered, That the Chair make the Report to the House.

Ordered, That embargoed copies of the Report be made available, in accordance with the provisions of Standing Order No. 134.

Written evidence was ordered to be reported to the House for placing in the Library and Parliamentary Archives.

[Adjourned till Wednesday 22 February at 9.00 am

Witnesses

Wednesday 26 October 2011

Wednesday 2 November 2011

Wednesday 9 November 2011

List of printed written evidence

List of additional written evidence

(published in Volume II on the Committee's website www.parliament.uk/science)

List of Reports from the Committee during the current Parliament

The reference number of the Government's response to each Report is printed in brackets after the HC printing number.

Session 2010–12

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Oral evidence

Taken before the Science and Technology Committee

on Wednesday 26 October 2011

Members present:

Andrew Miller (Chair)

Stephen Metcalfe
Stephen Mosley
Pamela Nash
Graham Stringer
Roger Williams

Examination of Witnesses

Witnesses: **Professor Paul Hardaker**, Chief Executive, Royal Meteorological Society, **Professor Ed Hill OBE**, Director, National Oceanography Centre, and **Professor Alan Thorpe**, Director General, European Centre for Medium-Range Weather Forecasts, gave evidence.

Q1 Chair: For any members of the public who are a little confused about the rapid change of subject, there is no connection between our previous set of witnesses and our next set of witnesses, who are here to help us in our exploration of the effectiveness of the Met Office. I would be grateful if the three new witnesses could, first of all, introduce themselves.
Professor Hardaker: I am Paul Hardaker. I am the Chief Executive of the Royal Meteorological Society. I am a visiting professor in the Department of Meteorology at the University of Reading.
Professor Hill: I am Professor Ed Hill. I am the Executive Director of the National Oceanography Centre, which is owned by the Natural Environment Research Council.
Professor Thorpe: I am Alan Thorpe. I am the new Director General of the European Centre for Medium-Range Weather Forecasts.

Q2 Chair: Before we proceed, I have to declare a small interest in that my daughter is employed by the National Oceanography Centre. There is inherent uncertainty to any "forecast". How often can the Met Office and other organisations be expected to get their weather forecasts right?
Professor Thorpe: The skill of forecasts depends how far into the future the predictions are made for. We make an assessment of how accurate weather forecasts are using a set of metrics compared with what actually happens. We track, collectively as a meteorological community, the accuracy of the forecasts. The distance that you can predict into the future has been advancing at about a day per decade. For example, a five-day weather forecast today is as accurate as a three-day forecast was 20 years ago. This demonstrates the development of the science, computational power and observations of the atmosphere and oceans that go into making up a weather forecast. Which aspects of the weather you can predict depends on which aspects you are talking about and on what time ranges.
Professor Hardaker: Some of the things that define the improvements in accuracy are the quality and amount of observations that you have, how appropriate they are for the forecast and the resolutions of the model that you are using. Most of the developments that we have seen, that Alan was talking about, in terms of decade on decade, have been the result of more resolution, which has come with more computing resources, better data and better use of that data with the models.

Q3 Chair: One of the frustrations of living in the north-west, as I do, is that when one listens to the television forecast it tends to be a bit London-centric, like many things. Do forecasters take into account local factors that influence weather patterns? What level of local or regional information is it reasonable to expect national forecasters to provide, or is it just that the media are very selective in what they take off you?
Professor Hardaker: It is very much the case that you would expect forecasters to be building into their forecasts local knowledge about the nature of the area, the geographic features and how that will affect the weather. That is very much taken into consideration. The other significant thing we have seen in the Met community over recent years is that the Met Office models have now come down to a much higher resolution. That has happened only in the last 12 to 24 months; so the ability to forecast at that high resolution has been very much improved. It sounds a trivial thing to say that we take something that is, say, a 10 km grid and bring it down to 1 km—that is just more grid points—but, in doing that, a lot of science goes into being able to predict individual features like thunderstorms at high resolution. That move down to this high resolution is probably as big a step as the introduction of some of the early modelling capabilities that we had many years ago. Our ability to forecast at a local level is much improved now.
Professor Thorpe: The European Centre is now forecasting globally and the effective resolution of the model is about 16 km globally. The Met Office, for example, has a fine scale model that is embedded just over the UK. At the moment it is 4 km resolution, and they are looking to improve that down to about 1½ km. As Paul has said, over the years more and more local specificity in terms of the forecast is available, but also there are more local observations as we brought in new technology, such as radar measurements, which are able to define more

accurately the starting conditions for these forecast models.

Professor Hill: That is about the weather. Of course, the weather has impacts and some of those relate to the seas, in particular storm surges, which can be generated by weather conditions. It is very important to be able to forecast the impacts of those locally. Coupling storm surge models of the right scale with the right resolution enables one to get forecasts of some of the impacts of that weather on events like storm surges.

Q4 Chair: To what extent does the Met Office use forecasts from the European Centre for Medium-Range Weather Forecasts and other groups? Is it common for different groups to contradict each other?

Professor Thorpe: Perhaps I had better pick this one up. The European Centre for Medium-Range Weather Forecasts exists to provide forecasts in the time range from three days ahead to 10 days and beyond. The Met Office, like many countries in Europe that are part of this consortium, gets these forecast products which complements what the Met Office's own models are producing. We provide a complementary part of what the Met Office needs to look at the slightly longer range, going forward, and the forecasters regularly use ECMWF's predictions. They also see the forecasts from other international forecasting offices, such as the United States, Japan, Australia and so on. The advantage of having this range of predictions is being able to look at the risk that any one model is more or less extreme. By having that range of models, you can start to assess what the most likely weather will be but assess the risk of it being more or less extreme. Having this range of rather competitive quality models is very helpful to the Met Office in being able to forecast most accurately.

Professor Hardaker: Meteorology is a very collaborative science, so it is quite common for the national met services in different countries to share the data and model information with each other, because the heart of it is about providing warnings for the protection of life and property. By exchanging all of this information, we are able to inter-compare with each other and it is a valuable part of that process. In addition, in the UK, most people will probably have heard of the Met Office and they will have seen the forecasts on the BBC, but they may not know that there are over 30 private sector providers in the UK. From time to time, it is not uncommon that among that broader community you might get some contradiction in the forecasts.

Q5 Chair: In terms of the sharing of data, one point was made to me by a research fellow who was paired with me under the Royal Society's Pairing Scheme this year—I was out in Liverpool Bay with him—and we were talking about one of the wind farms. I said, "What's that mast over there?", and he said, "That's their data collection point." I asked him, "Do they share it with you?", and the answer was "No." Is that common? Are there data sets out there that you ought to get your hands on to help improve your capacity to do your job?

Professor Hardaker: It is not common to my knowledge that there are data sets out there that are not exploited, but others might know.

Professor Thorpe: There is a global collection of measurements of the atmosphere and oceans that is taken every day and is shared by all countries that are within the world meteorological organisation network. There is a tremendous international co-operation in sharing the raw observations.

Q6 Chair: This is private sector information.

Professor Thorpe: Okay. Those data—the raw observations—are, I believe, freely available[1].

Chair: That is interesting.

Professor Hardaker: I was looking at some statistics, trying to estimate broadly what percentage of data is collected by the Met Office compared with what they use. About 2% or 3% of what is used in producing these forecasts is collected by the Met Office. The rest of it is exchanged with other organisations. A tremendous amount of leverage is going on as part of that process.

Professor Hill: The private sector certainly contributes to the collection of weather data. For example, out in the oceans, ships of opportunity regularly collect met data. It is an important part of the data stream. It would not be possible without them. They do contribute.

As to the particular case of the wind farm that you were talking about, I do not know whether that data are available via the Met Office or not, but it would appear that it was not directly available to the researchers concerned. That is not to say that it is not available indirectly.

Q7 Stephen Mosley: May I ask about seasonal forecasts, because I know that Philip Eden, who is a former Vice President of the Royal Meteorological Society, has asked: "Are they a public service or entertainment?" What are seasonal forecasts for?

Professor Hardaker: Seasonal forecasts are used for many things. We tend to think of their value in a UK context, but the nature of how seasonal forecasts are produced means, at the moment, that they are much more useful in certain parts of the world like the Tropics where they have much more inherent skill. As you come towards our latitudes, the skill level does tail off. That is, in large part, because we have these weather systems in the mid latitude that can change the seasonal characteristics quite markedly. We have had a good example of that in the past couple of weeks where we had this high pressure that was blocking the weather patterns coming in and changed the nature of our weather for two or three weeks. Because of this they do have less skill in our latitudes. We often forget that seasonal forecasts are used quite a lot around the world in British interests: in defence, international development, aid programmes and trade events in which we are involved. They have a significant value in those activities.

[1] Note by witness: I believe that on the day I misheard or misinterpreted what the Chair was asking here. I thought he was asking whether the observations were available to the private sector—but on reading this transcript it appears he may have been asking about the availability of observations collected by the private sector.

In the UK they are valuable provided the people who are using them—the end users—understand the limitations for our latitudes and how to use them. They tend to be more probabilistic in nature. That can be harder for people to interpret and understand without some clear guidance on how to make use of that information. They are much more than entertainment value, for sure.

Professor Thorpe: It is not a static situation. We are doing a lot of research internationally on exactly what is predictable on that seasonal time scale. Predictability comes from patterns, for example, in sea surface temperature, which influences the atmosphere not only locally but globally. For example, one big source of potential predictability comes from the El Niño phenomenon in the Pacific, which is a big change to the sea surface temperature. That affects weather patterns around the world. As Paul says, it does not necessarily mean that it affects north-west Europe particularly to give predictable signals. A lot of research is going on to understand those remote connections and whether they allow us to be able to predict on seasonal time scales. It is not a static position. It is something that the research is developing all the time.

Professor Hill: They certainly are more than entertainment. If one could have reliable seasonal forecasts, the potential is enormous. The kinds of users would be everything from the insurance sector, the power generation industry, construction, agriculture, tourism, the retail industry—understanding what products to put on the shelves at what time—manufacturing and transport. The potential is enormous. Particularly where large investments are at stake, any information that can add some level of insight into what is going on on those time scales is worth having. In particular, if you are into activities which are a little akin to betting, then something that is a good deal better than evens may well help out with those investments. I am thinking of some of the insurance business in that respect. This is why it is a really important area for research, to see if one can improve the skill and be able, as Professor Thorpe has said, to try and understand how we can do this in some of the more difficult regions of the world, including our latitudes.

Professor Hardaker: The interesting conclusions that we have come up with in fairly recent times in the research community is that resolution, although it is not the whole answer, is going to help us a lot in terms of understanding some of these global connections, both in the oceans and the atmosphere.

Q8 Stephen Mosley: Can I pick on something you said in your first answer about there being less skill at our latitudes? Did you mean less skill, or did you just mean that it is a lot more difficult to predict in our latitudes?

Professor Hardaker: We are looking at patterns and relationships. Those patterns and relationships are much stronger in certain parts of the world than they are at our latitudes. In the meteorological language, you call it a signal. You are looking for a signal above the noise. The signal is much weaker at our latitudes for some of these connections.

Q9 Stephen Mosley: There is a perception among the general public that the Met Office's seasonal forecasts are not all that reliable. We all remember 2009, was it, when they were predicting a barbeque summer and it poured down with rain pretty much the whole time? You have explained the difficulties at our latitudes. Are there any organisations, for instance, the ECMWF, that provide better seasonal forecasts than the Met Office?

Professor Thorpe: We are working in collaboration. There is a project that the Met Office, ECMWF and some other met services are involved with called EUROSIP, which is a seasonal prediction project, to bring together seasonal forecasts from our model, from the Met Office's model, from Météo France and from others as well. We are trying not only to inter-compare the predictions from different systems, but there is benefit in having that range of models because it gives you a more risk-based prediction. From time to time, some models will be better in certain regions. By having a range of models, you can get a better feeling for the risk of certain outcomes. There is regular interaction and collaboration on this, but I emphasise the fact that this area of forecasting is still emerging and a lot of research is still being done on it. Whatever state we are in at the moment in terms of the skill of those models and forecasts, the potential exists for this to improve as research results come on stream. Whatever the position is today in terms of the relative capability, it is an area that, I am hopeful, can improve in the future. We will have to wait and see what the research shows.

Q10 Stephen Mosley: Is the effort going in to make this happen?

Professor Thorpe: Absolutely. A big effort is going on in the research community, in the UK, internationally and among the major meteorological services, including ECMWF and other major centres, such as Canada, United States, Japan, France, Germany and the UK. Quite a bit of activity is going on.

Professor Hill: You prefaced your remarks by referring to the public perception. This is an issue that is both about the science needed to improve seasonal forecasts and an issue about communication. Many of these seasonal forecasts are offering probabilities such as a 60%—a two in three—chance of this kind of event happening. That is useful for some people for some industries. When the third event does not happen, that is very easily misinterpreted as, "They got it wrong". It was a two in three chance of the circumstances arising. One does have to understand the situation in those terms. For example, if someone offered that they could give you a chance that two out of every three horses that you bet on would come in as a winner, you would, probably, take that pretty seriously, and you would feel a bit churlish, if that was indeed the success rate, to go and complain about the one third of your horses that were predicted to win but did not. That is the kind of setting. You need to understand it. Where sophisticated industries are prepared to operate at those levels of probability, they will not perceive the situation in quite the same way.

Q11 Stephen Mosley: The probability issue is something we have picked up in previous inquiries. It might be worthwhile our taking that off separately afterwards for consideration.

Professor Hardaker: May I come back to your question about whether one is better than the other, because there are a number of organisations out there providing seasonal predictions? A number in the private sector do that as well. One of the challenges of assessing whether one technique is better than the other is that you do not have many seasonal predictions. You only get four a year. The spring and autumn ones tend not to be as reliable as the summer and winter ones. We do not get many and it takes a long time to collect some sensible statistics to do a comparison that has any real science in it which says, "This method is better than that one." It is a long haul in understanding where significant improvements are coming in this area.

Q12 Roger Williams: We have heard already how important it is for private individuals and commercial organisations to have some indication about extreme weather that they may be going to experience. How robust are the forecasts of extreme weather events as done by the Met Office?

Professor Hardaker: One of the challenges of extreme weather events is, thankfully, that they happen far less frequently than much of our weather. You have less hazardous weather to deal with and, therefore, fewer case studies that help you improve your prediction in these areas.

The point we mentioned before about improving the resolution of the models, to make them much higher resolution, is helping a lot in terms of improving the capabilities to forecast hazardous weather. It is a priority for the Met Office science programme. I have seen some research runs of the model looking at the Boscastle floods that show that with the very high resolution models you can pick up the convergence and the formation of the rainfall much easier. That is not to suggest that we will capture all such cases, but at these higher resolutions we are more likely to be able to pick up these local features that can often cause significant weather events.

As you move to dealing with these significant weather events, you have to do two things. The first is that you become more probabilistic in terms of what you are trying to provide in terms of information. There is a deal of uncertainty that needs to be represented in a probabilistic fashion. The second is that you need to work closely with other agencies. It is not just about the Met Office being accurate in terms of its forecast unless it is joined up with the other agencies involved that are issuing those warnings. An example is the bringing together of the National Flood Centre with the Met Office Operations Centre. That is a good example in terms of getting those warnings more effectively and efficiently out to the public. Again, there is a close relationship between the Met Office and the Highways Agency, which is also helpful for those cases that are impacting on the road network. It is a real partnership in predicting and communicating hazardous weather.

Professor Thorpe: I would entirely agree with that. It is important to say that the Met Office is one of the world-leading weather services in the world in terms of the skill of its forecasts from extreme weather right up to other aspects of the weather that we have been talking about. There is regular intercomparison of the international and national weather services, and the Met Office is one of the leading met services. Therefore, the general answer to how good their forecasts are is that they are as good as anybody else in terms of being close to world leading. It is improving all the time as well, as I was trying to say at the beginning. Of course, we would like the forecasts to be better. As the computational power, the observations and the models improve, it is improving. As Paul said, it is something that the research is focusing on, because it is critical for the public.

Q13 Roger Williams: I sat on a previous inquiry into the flooding that we experienced in this country a couple of years ago. One of the criticisms then of the Met Office was that it was not well integrated into the Environment Agency and other agencies. Has that integration been achieved? Is it working well?

Professor Hardaker: It is early days. My perception from the outside is that it is working very well. The establishment of the new National Flood Forecasting Centre, which is a partnership between the Environment Agency and the Met Office and bringing all that together into the operations centre in Exeter, has had significant benefits. Sitting hydrologists and meteorologists next to each other has been a real positive. The Met Office and the Environment Agency have come to the Society to ask us if we can provide help and support to them in terms of professional development, to give a development path for those working in hydrology to come through to gain professional charter status in the meteorological qualifications and vice-versa. That is a real positive and there is a real ambition to do more with it.

Q14 Roger Williams: Are there any limiting factors within the Met Office as to future improvements in forecasting extreme or hazardous events?

Professor Thorpe: There are limitations for all centres in terms of the ability to have the computational power to analyse the increasing volumes of measurements and also to make the predictions using the numerical weather prediction models. It is a challenge for all centres, including mine and the Met Office, to keep competitive in terms of the amount of computer power that we have to devote to this. In many respects, we can have more finely resolved models and, therefore, a better description of smaller-scale events, such as extreme weather, if we have the best and most powerful computers. Of course, this comes at a cost. There is an issue about being able to afford the most powerful computers. Meteorology and weather forecasting has been a prime driver of super-computer capability worldwide. It remains a challenge to be able to afford the amount of computational power we need.

Q15 Roger Williams: It is the computation of the data rather than the collection of the data that is the more limiting factor.

Professor Hardaker: I would say that it is a mixture of the two.

Professor Thorpe: It is a mixture. There are many more observations than there used to be, particularly because of the satellite component. We are getting access routinely in the met offices to the majority of those data. Of course, then it is a matter of analysing those data and doing the weather forecasting. That is where the computational power comes in. As Paul says, we need both. I was just highlighting that to give you an example when you asked where the limitations are, and that is certainly one of them.

Professor Hardaker: The lack of computing resources is by far a greater limitation than the lack of data in the current environment, although there are some areas, particularly in oceanography, which Ed might want to say something about, where we are a bit too data- sparse. We have fallen a long way behind the curve in terms of the computer capability keeping pace with the science. The problem as well is that it does not scale linearly. Every time we increase the resolution, we must do that in three dimensions. There is a time element to this as well. It is an exponential increase in the requirement of computing power.

Professor Hill: I would like to comment on ocean data. It is probably more relevant not so much for extreme and short-term events as it is for longer time scales, such as climate time scales and seasonal forecasting that we were referring to before. Ocean observations, particularly on those longer time scales, to which you might want to return, is an important limiting factor and will be going forward.

Q16 Roger Williams: Professor Hill, in your written contribution you stated that the insurance and re-insurance industries benefit from robust forecasts of extreme events. Do they contribute to the cost of those forecasts in terms of data or computational processes?

Professor Hill: I do not know the details of what they do and don't contribute in terms of observations. It would be pretty fair to say that it is very unlikely that they contribute significantly to the underpinning observations. There is a much wider issue here. You picked on one particular sector, but the beneficiaries of weather information, whether it be on short time scales right out even to climate time scales, are numerous and varied. Some of the beneficiaries probably do not even know that they are benefiting and possibly care even less about where the data are coming from. We probably have a situation where, if left to those who directly benefit, you would end up with a classic market failure if you were going to expect them to pay. Indeed, you can very rarely, if ever, draw a golden thread from some particular measurement system to a particular forecast that has some indirect benefit. This is an area where, traditionally, the public purse is called upon to provide the underpinning datasets, on the understanding that there is benefit, including real economic growth benefit, somewhere downstream from the direct observation. That is ultimately where the cost is recouped from through taxation and so forth.

Q17 Roger Williams: The further you can look forward, the greater mitigation you can put in. It is not just the insurance industry, is it?

Professor Hill: Absolutely. It is health, retail, transport, energy and the whole thing. Indeed, the further one can forecast ahead, the greater is the ultimate prize. Clearly, there is a lot of economic benefit to be had if those forecasts are reliable and actionable.

Professor Hardaker: A lot of focus is going into decadal prediction at the moment. That is the time scale where some of these big capital expenditure issues are most important. Replacing the capital asset and how you design and equip that is a big challenge.

Q18 Graham Stringer: Professor Hardaker, I will read a short sentence from your submission: "However, for climate prediction and its application to Climate Change Risk Assessment (CCRA), there remains a fundamental unsolved question of whether the estimated" United Kingdom Climate Projection 09 "probabilities are actually reliable (for example, does an estimated 90% probability of an event mean the event is somehow very likely to happen?)." Whatever does that mean?

Professor Hardaker: The point we were trying to make there is that the way the predictions were produced this time was based on variations of a single model with a statistical generator of weather associated with it. We think a better approach going forward for the next generation of these scenarios might be to look at a combination of a range of models that are representing the different physics of what is going on in the atmosphere, and that will give you a more realistic representation of what the probabilities are rather than using just a single model. I agree that the language is a bit confusing.

Q19 Graham Stringer: I am no statistician, but it says "an estimated 90% probability". Does that mean it is likely to happen? I would have thought it was self-evidently true that it was.

Professor Hardaker: The point is about how you are creating that probability distribution. Are you doing that in the most efficient way that is representing the full range of probabilities of what you are trying to get to the bottom of? I can create a probability distribution by tossing a coin and getting heads and tails. The more coins I use or the more intricate method I use, the more chance I have of sampling the full range of probabilities. Have we really exploited our current understanding, knowledge and models to represent the full range of probabilities?

Q20 Graham Stringer: Is it fair to say that you are looking to put together more models in order to get a better prediction?

Professor Hardaker: More models and, perhaps, a more robust way of creating our probability distributions than we did last time round. To say "last time round" sounds a bit over-critical of UKCP09, but those model runs were the first time we moved to probabilistic predictions. That was a major step forward and we learned a great deal from that process.

This time round we can move that on more significantly.

Q21 Graham Stringer: How would that be moved on?
Professor Hardaker: Because we have a lot more understanding about how to work with these probabilistic projections than perhaps we had when we began that process some time ago. The report in 2009 was a three or four-year programme in creating those scenarios. We are a long way on. In terms of the science, we have moved on. Now there is a move to be much more engaged with the communities who will use those predictions to get a sense from them about what they look to the science community to provide them.

Q22 Graham Stringer: Is any work being done on the theoretical limits to predictions? You are dealing with a linked chaotic system, are you not?
Professor Hardaker: Yes.

Q23 Graham Stringer: Is there any theory that says you can go so far but no further?
Professor Hardaker: The chaos theory suggests there are some limits to predictability. There is no suggestion, interestingly, that we are anywhere near reaching those at the moment. The other complication of that process is that some weather conditions are more predictable than others. There is not a single limit that bounds everything. The nature of the atmosphere and the oceans is such that sometimes there is a greater degree of predictability in the atmosphere than at others. It does vary depending on the state of—

Q24 Graham Stringer: Do you know when that is?
Professor Hardaker: There are obvious examples. If you are getting very varied local conditions, lots of thunderstorms and the weather is changing rapidly, the predictability is less easy compared with when you get stable pressure patterns in place which give you more long-term predictability.
Professor Thorpe: One of the scientific advances in my centre has been to create what is called an "ensemble prediction", which means that, by looking at the chance that the forecasts could be more or less extreme than the central estimate, depending on the shape of that distribution, we are able to give a prediction of whether the future weather is predictable or not. So we can predict the predictability. As Paul was saying, the signals on some occasions are inherently stronger and it is more predictable. By using these techniques we can distinguish those events where it is more predictable from those events where it is less predictable. That is a big advance in the science. It is critical to know, not only regionally but locally and, from time to time, that the predictability varies hugely in terms of what you can predict.

Q25 Graham Stringer: That predictability of the predictions is done on an empirical basis and not a theoretical basis.
Professor Thorpe: No. It is done in terms of using the mathematical physical models that we use for weather forecasting. The European Centre, for example, every day produces 50 parallel forecasts where we have slightly different starting conditions for the forecast, and also we vary within the range of uncertainty some of the representations of the physics in the model. We then start to build up a much better description of the uncertainty and are able to predict when it is predictable and when it is not. It is not empirical in that sense. It is using the physics that we know about and the range of uncertainty in that physics that we know about.

Q26 Graham Stringer: Both you and Professor Hardaker talked about recording and testing how accurate the predictions had been on three, four and five-day weather forecasting and on seasons. Have you tested the predictions since you have been using models for climate change? Have you tested whether those models are predicting what is happening on an annual or a biannual basis? I do not know when they started, but have they predicted what has been happening over the last 10 years?
Professor Thorpe: Absolutely. The Hadley Centre for Climate Prediction and Research, which is part of the Met Office, has been producing detailed hindcasts of the climate of the 20th century, for example, to look at the fluctuations in the climate. We know what has happened, but we can use our prediction models to see how accurate they are relative to what happened.

Q27 Graham Stringer: I am asking something slightly different from hindcasts. Since 2000, the climate has shifted a bit over that period of time. In 2000, were the predictions accurate or to what level were they accurate?
Professor Thorpe: I will give an initial answer and others may want to contribute. As you know, there have been several IPCC scientific assessments on climate change going right back to 1990. In 1990, when the scientific assessment was made, there were real-time predictions of what the climate, subsequent to 1990 going forward, would be. We are now in a position of having a record of what actually happened relative to the predictions that were made then of the climate from 1990 to the present time. Those comparisons show that the models of the day—of course, the models have improved since then—if anything, under-estimated the amount of global warming that has subsequently happened. We are able now, because we have done this climate prediction for a number of years, to start to assess that.

Q28 Graham Stringer: It is often said that they did not predict the flattening out that happened after 2000. Is that true or not true?
Professor Thorpe: Two processes are going on here. There is the slow trend due to the fact that greenhouse gases are increasing, which is the trend that we are interested in in terms of global warming. Then there is the year-to-year variability that comes from a phenomenon such as the El Niño. We know that El Niño variations can lead to fluctuations in the warmth of the planet on these time scales of decades. What we think has been happening is the slow trend of global

warming but superimposed on that are the fluctuations on year-to-year.

Q29 Graham Stringer: That is only part of the point. Did you predict the change in the gradient?
Professor Thorpe: Not me personally.
Graham Stringer: But as a profession.
Professor Thorpe: I think I am speaking too much.
Professor Hardaker: As Alan said, the continuation of the assessment report studies have shown that what the early models predicted is largely what has come to pass in terms of our observations. In the very early days of the climate models, that intercomparison with the observations was very important. By doing that intercomparison in the early stages of the process is how we discovered that we were missing the aerosol component in our models, which was a cooling effect on the climate.
Professor Thorpe: The slow trend of global warming is a forcing from something we are doing to the atmosphere gradually and in a secular way over time. Some of these fluctuations from year to year, to come back to our earlier discussion about seasons, are more predictable using these models than others. Seasonal to decadal is an area where we are doing a lot of research. To answer your specific question of whether we can predict year on year the variation of El Niño going forward five or 10 years into the future, probably, not yet, but this is an area on which there is active research. We can get the sort of statistical variation, but the precise future chance of a particular El Niño or La Niña happening is still very challenging.

Q30 Pamela Nash: The Government Chief Scientific Adviser in the review of the Government's needs for the Climate Science Service has recommended that a step-change increase in supercomputing capacity is required within the UK. Would each of you agree with that statement? Professor Hardaker, you are nodding.
Professor Hardaker: Those who use supercomputers will say more, but yes, absolutely. I recognise that there is an affordability issue and we have to make priorities, but it is a significant limitation on our capability at the moment, in terms of what we can do with the modelling of the oceans and the atmosphere.
Professor Hill: I would certainly endorse that. I am particularly concerned with the ocean parts of the problem, which on these longer time scales is a crucial component of it. We believe that increasing ocean resolution will take out a number of well-known biases that exist in things like sea surface temperature, which, when coupled to atmospheric models on longer time scales, produce biased effects. One classic example is that low resolution models tend to cause the Gulf Stream to break off from the coast at lower latitudes than they should, leaving that area of the north Atlantic anomalously cold compared with what we observe. This then feeds through when you couple it into atmospheric models. As you increase model resolution, as we are at the moment, to a quarter of a degree and, in due course, to one twelfth of a degree and Gulf Stream separation happens in the right place, the sea surface anomaly issue starts to resolve itself. There are many other examples like that where increased resolution, being able to resolve eddies in the system, has an important effect as you start to couple it with atmospheric models. To achieve those resolutions certainly needs increasing computing power.
There are things that we would like to do with ocean models in the future which are a little beyond weather forecasting but are important for marine forecasting. For example, to forecast harmful algal blooms, which is very important, would involve coupling ecosystem models to ocean models. Once you start to do that, you get into a whole new ballgame in terms of the computing power required to represent the different biogeochemical processes and plankton species as well. From both the climate and weather point of view but also from ocean forecasting, the answer is most certainly yes. We also need—this is a crucial point—the data to go with it. You cannot separate these two issues.
Professor Thorpe: The answer from me is yes.

Q31 Pamela Nash: So that I am clear, you mentioned funding being a limiting factor. Are we talking about funding for the purchase of technology or purely for research and development in creating that supercomputing capability?
Professor Hardaker: It is always a combination of the two. You need to have the technology in the first place and then you need to be able to exploit that by putting the science on to that technology platform. It is a mix of the two. I sense that the biggest cost in this is in the physical computing itself because, as we mentioned before, when you start trying to look at the whole-earth system, the biosphere, the ecosystem, the chemistry and the carbon cycle, the complications of that are such that you need to make a step-change in current capabilities.
Professor Thorpe: You can see very easily that it is the technology. There was a time when weather forecasting applications in terms of the use of the world's top computers were high upon that list. It has slid gradually further and further down from the highest capability to much lower. That change has prevented us from advancing as quickly as we could have done. I fully endorse the fact that this is a real limitation now. It is very challenging from a financial point of view because of things as mundane as exchange rates, for example. When purchasing computer power in pounds, it depends on the relative exchange rate with respect to the dollar and so on, because many of the computer manufacturers are international. Our purchasing power is also a factor as well.
Professor Hill: One should not underestimate what a complex problem this is. It is not just about more computer power and more calculations per second. It is also about disc storage, mass storage for storing the results, post-processing facilities to analyse them, high bandwidth communications to move data around, and there is also a people dimension to it. In respect of the oceans, one of our problems is having the manpower to be able to process, analyse and interpret the data. Then there is the question of re-engineering some of the software, the codes in the models, so that they are able to run on massively parallel machines. It is not

just a question of buying a big box with lots of processors in it. All of those dimensions require the investment.

Q32 Pamela Nash: Thank you for those answers. The partnerships that the Met Office has with international meteorological organisations have already been alluded to in this session. To what extent is the Met Office working and pooling its human and computing resources with those of institutions across the world?

Professor Thorpe: From my point of view, the Met Office is incredibly connected internationally to all of the most important networks in weather prediction, forecasting and meteorological science more generally. It is a major member state within my own organisation, which is a co-operation among 19 European countries. The Met Office is a major partner in that capability. That is on the operational weather forecasting side. On the research side, there is strong collaboration between Met Office scientists and, for example, the academic community in the UK, supported by the Natural Environment Research Council. There is a relatively new initiative called the Joint Weather and Climate Research Programme, which joins together, in a much more structured way than before, research in the Met Office and in UK institutes and academia. My answer to your question is that the Met Office is highly connected and clued into that international science and forecasting network.

Professor Hill: One particular example of how they have been working internationally and strategically is that a number of countries, including Korea and Australia in particular, have adopted the unified model, which is their workhorse code for weather forecasting. This has a number of benefits for those countries that have adopted the model, which is a very good computer code. Also, because those are being operated in different weather and climate environments from our own country, they get tested in different regimes. That means there are more hands, eyes and experience in using that particular code to be able, collectively, to learn the lessons. That is a very good example of working strategically with other countries to get leverage and benefit from that development.

Professor Hardaker: I mentioned earlier about the percentages of data that are collected locally versus those that are used. I said that 97% or 98% of the data that we use is collected elsewhere. If you look at the modelling function, only about 50% is developed in-house by the Met Office. The rest is obtained through the types of collaborations that we have talked about in terms of driving and developing these models. You can get a sense, both from the data and modelling, that it is a very collaborative programme. The Met Office, as Professor Thorpe said, is one of the world's leading met services. You can imagine that as part of this international network it plays a very important role not just in the UK but in international meteorology.

Q33 Pamela Nash: Just to move on from that, Professor Hill, the evidence from the National Oceanography Centre states: "Supercomputing is a fundamental requirement for understanding ocean and atmospheric processes and will require continued funding, collaboration and 'joined-up' working to maximise potential." As you said, Professor Hardaker, there are challenges. What are the particular challenges in encouraging this collaboration and how can we overcome them?

Professor Hill: A number of these are being addressed already. It is fair to say that the Met Office, over the last five or 10 years, and five years in particular, has shifted in being much more open to collaboration. For example, in the ocean area, we have worked together on lining up the model code we use. The oceanographic community and the meteorologists were using completely different models. We have now converged on that, which is a European model, so we have a wide community of users. We have a joint ocean-modelling programme, which is part of the Joint Weather and Climate Research Programme, where scientists are defining a clear set of objectives and programme of work. They are working together in order to maximise the impact across the science community. That is a very good example of things that are happening already.

Could we do more of it? Probably, yes. There are barriers. There are funding issues. There are also, I guess, some real cultural barriers as well. The Met Office is an operational forecasting agency and works to rigid timelines and works in a very methodical way, which is what you would expect from an operational agency. The research community operates on different time scales. Bringing these things together does not always quite mesh. The research community has to work in more disciplined ways when working with the Met Office, which is good, but perhaps that is at the expense of some innovation at times and having to work with existing operational systems. For me this is an example of something which, in other circles, is called "translational research". It is the process by which basic research—a fundamental understanding of the system—gets turned in a systematic way into something that is usable and operationalised. Probably, a much more explicit recognition of the role of translational research would do a lot to break down the barrier that sometimes exists, which is as much cultural as anything in terms of the basic science getting into operational use in a timely way. That is one area to work on.

Chair: We have three more very important questions that we need to get through fairly quickly.

Q34 Stephen Metcalfe: I will try to be as quick as possible. I would appreciate it if you could keep your answers quite brief. I want to talk about access to the historical data that are held by the Met Office. We have had conflicting reports about how readily available they are. I would be interested in your comments on what you think. Also, regardless of how readily available they are now, do you think they should be made freely available to all at no charge?

Professor Hardaker: For some context, the Met Office is operating within the rules bounded by the Government's policy on data, and it is also guided by some international agreements that exist on this

subject. Of all the European met services, I would say that the Met Office makes more of its data available than any other European met service, and it has tried to go a long way to do that. We are working with the Public Weather Service at the moment to run a consultation for them with the wider community in the UK about what will be the requirements for more of that historical data online and how could it best be provided. The Met Office and the Public Weather Service components are mindful of the fact that there is a demand for more data out there. Of course, there is a cost in providing that. It would be a valuable thing to make more of that data available, but somewhere someone needs to pick up the cost of making that possible. That is a barrier in itself.

Putting much more data out into the community may help to grow the markets for meteorological services, but we, in the Society, have a real concern that it might help to grow very poor, low-quality services, because technology is such that you can easily take low- quality raw data and produce products and services of not very good quality. We want to focus on the idea of developing a quality standard for the sector that would identify those quality providers. There has been a strong push from the big customers of weather services in the UK to establish, in partnership with us, a quality mark for the sector.

Professor Hill: The principle is that publicly funded basic data should be available at minimal cost and that the value is generated by the creation of added value products. The caveats to which Paul has referred do apply. The creation of the Public Data Corporation, which is being trialled, is about doing that, trying to make more data more accessible.

In terms of accessibility to the research community, we have very effective means of working with the Met Office. That is generally not an issue. Their data are generally widely available for research purposes.

Professor Thorpe: I am not sure that I have anything to add.

Professor Hardaker: I would like to make a quick point about the Public Data Corporation. I am not up to speed on the full detail of it, but I have seen some of the developments. I have some concern that we need a clear policy and statement on how the Government are dealing with data. I get the sense from the outside that bits of Government are pulling in different directions in terms of where they want to go with this. My hope is that the Public Data Corporation is not going to add an unnecessary and unhelpful level of bureaucracy. We need some simple form of clarity that does not add an unhelpful layer of bureaucracy.

Q35 Stephen Metcalfe: You said that, by making the data more freely available, there are potential services and spin-offs, and commercial activity could come from that. Is there any way of putting a value on that commercial activity, in making sure that a quality standard is in place to make sure that it is not abused? How would one even begin to understand how someone might make money and what that would be worth to us as an economy?

Professor Hardaker: There have been a couple of goes at this over recent times. We had a piece of work published fairly recently by the European grouping of private sector meteorologists. I cannot recall the figures, but I could certainly send the Committee the paper—it was published about two years ago—which highlighted some figures associated with what was expected from this. In some regard, there was a vested interest. It was created by a community that stands to benefit from that process. There is no reason not to trust the figures and they are a helpful guideline. It would be helpful to have an independent review of the value that this data might add.

Q36 Graham Stringer: I will roll all my questions into one, if I may. First, will the Met Office move to BIS and its new research structure help with collaboration with the research base in this country and elsewhere? What will the changes be? Secondly, you have talked glowingly about the collaboration that goes on. There must be problems. Where could that be improved? Where is there a lack of collaboration?

Professor Thorpe: The BIS move will help from two points of view. One is the connection into the research base, which is located, as you know, in BIS. At some level, it seems a more natural home. As we were saying just now, there is great potential from weather forecasts for commercial and business activity in the economy in general, including opportunities to reduce costs and mitigate risks, as well as genuinely new business that can emerge, which is a clear focus of BIS as a Department. For me, it seemed to be a good move to bring the Met Office into BIS. It will help with the connection to the research base. I would not want to characterise that to mean that, in any sense, there was a major problem before. We worked hard, as Ed has mentioned, during the last five years or so to up our game in connecting the Met Office research with the general research base in the UK, even when it was in the MOD. That is already bearing fruit. I can only see the move to BIS as helping that process.

Professor Hill: In terms of lack of collaboration, I would point to one issue that is, probably, not lack of collaboration but it is a lack of join-up. As we have said before, important new observations are crucial in order to improve seasonal and climate issues, which, essentially, centre around the oceans. Ocean science has become sufficiently mature now that we have the technologies to make reliable measurements, whereas probably even a decade ago we did not. There is a whole new stream of data that is potentially available through new technology such as Argo floats and other automated systems, which will make, in due course, a significant impact.

The problem is that we do not yet have a sufficiently joined-up mechanism in Government to do a number of things. First, there are multiple Departments that are interested in the outcomes of this, so the idea of sharing the costs of this is not well developed. Second, we have the issue of translating measurement techniques which, essentially, have been in the domain of basic science into the operational arena. Some of these ought to fall, ultimately, within the remit of the Public Weather Service, but that simply cannot be at the expense of displacing existing vital measurements. We have something new coming on stream here. There is a real challenge about how to resource new

things that are adding value. The ultimate answer, in my view, is that they are adding new value to the forecasts. An increased economic value can be put on them. We have not yet discovered, as a nation, the mechanism to translate these measurements from basic science to operational and, indeed, to share the resources fairly across multiple Departments of Government that benefit.

Professor Hardaker: We mentioned earlier the Joint Weather and Climate Research Programme (JWCRP). That is helping to bring these two different communities and their cultural differences together. It is early days for that. Some of the limiting factors within that framework are that we need to be able to get the models and data on to a common platform so that those two communities can work together effectively. We have some resources to do that, but it is the start of a process. Until we can get all of that on to those platforms and being used actively, we are not leveraging that partnership as strongly as we could be. However, we are moving very much in the right direction.

Q37 Roger Williams: I was brought up in a farming family and the weather forecast was sacrosanct. Everybody would be quiet and listen to it. It is not quite so much a national treasure now but it is still a very important part of our lives. Who is responsible for accurate communication of the forecast? Is it the Met Office or the broadcasting company?

Professor Hardaker: The answer to that is both of them and as well as organisations like us in terms of educating the public about how to get best value from those forecasts. We talked a lot about accuracy and how good we are in the UK at producing those forecasts, but it is wasted if we cannot communicate that to the public. It means that organisations have to work together to get the message across.

Q38 Roger Williams: Is there a place for jokes? Some of the tourist operators get very upset when they hear, "Here comes another Bank Holiday. Here comes another downpour", or, "Don't go to Wales because it's always wet."

Professor Hardaker: I am not going to comment on the Wales bit because my wife is Welsh. I will not make any comment on that. What is interesting is the development of the internet as a way of providing weather information and the move to digital channels. I know that organisations like the BBC are exploring the potential that has to add a whole layer of new information that will provide a detail that they cannot offer in a single broadcast. The public will be able to watch a national and a local forecast and then use the red button functionality or the internet to drill down into more and more detailed information that might be useful and specific to them. That is a really interesting innovation. Many countries make much greater use of probabilistic information in their forecasts than we do, even in their broadcasts. Perhaps with some of this digital technology and the internet, we have not been bold enough to explore the potential of that in terms of delivering more probabilistic information and then working to help the public better understand it and how better to make use of it. That is a role that, perhaps, we could play a part in as well.

Professor Hill: It is certainly the case that there is no shortage of weather information. That is not the issue. Indeed, the Met Office website is excellent in terms of the sheer depth and range of information you can get if you are looking for it. The issue is about communication, using new technologies and so forth to be able to get information to people in the form that they want and when they want it. This is a social problem as much as one of information, generation and dissemination.

Q39 Roger Williams: Professor Hardaker, you are the chairman elect of Sense About Science, are you not?

Professor Hardaker: Yes, that is right.

Q40 Roger Williams: Has that organisation something to contribute in terms of public understanding about the things we are talking about—probabilities and those sorts of issues?

Professor Hardaker: I hope so. That group has been working a lot on trying to help the public with statistics. We have published a book on weather and climate. We are hoping to publish something next year on working with uncertainty. That is a big issue. Science looks at uncertainty as knowledge and focus, whereas often the public look at uncertainty as "Well, they don't know. They haven't got an answer for me." That is a big gap to bridge. A better explanation of how science works and how the public can make better use of uncertainty information is of real importance in terms of their making use of it and the media communicating it more effectively.

Chair: Gentlemen, this has been a very informative session. We are very grateful for your time this morning. We are looking forward to our visit to Exeter to see how you produce all this fantastic data. Thank you.

Wednesday 2 November 2011

Members present:

Andrew Miller (Chair)

Gavin Barwell
Stephen Metcalfe
David Morris
Stephen Mosley
Pamela Nash
Graham Stringer
Roger Williams

Examination of Witnesses

Witnesses: **Nick Baldwin**, Independent Chairman, Public Weather Service Customer Group (PWSCG), **Professor Sir Brian Hoskins CBE**, Chair, Met Office Scientific Advisory Council (MOSAC), and **Professor John Pyle**, Chair, Met Office Hadley Centre (MOHC) Science Review Group (SRG), gave evidence.

Q41 Chair: Welcome, everyone. I welcome in particular the Royal Society peers who are sitting in the audience. I hope that they find it a fruitful sitting. Will the first three witnesses kindly introduce themselves?
Nick Baldwin: I am Nick Baldwin, the independent chair of the Public Weather Service Customer Group.
Professor Hoskins: I am Brian Hoskins. I am at Imperial College and the University of Reading. I am also a non-executive director of the Met Office and chair of its scientific advisory committee.
Professor Pyle: I am John Pyle from the University of Cambridge and the National Centre for Atmospheric Science. I chair the Met Office Hadley Centre Science Review Group.

Q42 Chair: Thank you very much indeed. May I start with you, Mr Baldwin? In your role, you are both intelligent customer, and watchdog and guardian of the Public Weather Service. Is that a difficult balance to achieve?
Nick Baldwin: I don't think that it is a difficult balance to achieve. Perhaps it would help if I elucidate each role. We are the intelligent customer on behalf of the Government and the general public for free at the point of use weather forecast and information services. We have a group of people who are mostly from the resilience community, and are therefore experts in the area of the services that we are buying and using. As a customer, we are responsible for buying service from the Met Office through a customer-supplier agreement, which essentially defines the outputs we get. It defines performance measures so that we know that we are getting what we paid for. It defines a price, and it also sets the Met Office a 3% annual efficiency target to reduce the costs of the service that it provides. I am supported by a very small secretariat, which keeps in day-to-day contact with the Met Office to ensure that it is aware of developments as the informed customer.
As a watchdog, we conduct consultations with both the general public and our users to ensure that we are getting what we ask for, and that we are aware of the needs for future developments in certain areas. The final part of our role as the guardian leads, in part, to the inquiry of the Committee in that we hold the funding of the Public Weather Service. We're the ones who sign off the invoices and ensure value for money, and we're doing that to ensure that the Met Office maintains its core underpinning of its operational capacity and its research and development programme. So I think we are well established to conduct those three roles.

Q43 Chair: You set the key performance indicators, and I understand that last year the PWS achieved all of them. Does that mean that the indicators were not challenging enough?
Nick Baldwin: That's an interesting debate, which we have at every one of our meetings as we go through the year. We are running a rolling scorecard in the course of the year, using the traditional traffic light colours of red, amber and green. We tend to find that we start with a number of reds and ambers and a proportion of greens and, as the year goes on, the focus is brought to bear on all those that are not hitting their milestones or are not at the level of quality that is expected. It is for the Met Office to hit those targets and it's up to the Met Office to reallocate its resources to ensure that it does hit the targets. We put the pressure on it to make sure it gets there, rather than this being a case of soft targets.

Q44 Chair: Notwithstanding any external pressures, what would be on your wish list to add to the pressures that you'd like to put on the system?
Nick Baldwin: I don't have a wish list of additional pressures that I would like on the system. I have a wish list of what I want more from them—

Q45 Chair: What improvements do you want?
Nick Baldwin: I want more accurate forecasts and longer lead times on severe weather events, because those are the two fundamental things that we're about: providing accurate and timely forecasts and ensuring that severe weather events are forecast in advance so that the resilience community can prepare for them and take action.

Q46 Chair: Why can't you have that?
Nick Baldwin: It takes time, basically. The Met Office has a scientific research programme, which is all the time improving its methodologies of forecasting. In the time that I've been doing this job—since 2007—we've been able to see improvements in forecast accuracy. But my understanding—my illustrious colleagues next to me will have a better understanding—is that we are dealing with emerging

research and cutting-edge technologies in the forecasts that we are producing, so I do not feel that the Met Office is falling behind; it is leading the way.

Q47 Chair: Some of us who were at the Met Office yesterday heard about the expansion of the site-specific forecasts up to 5,000. Has that led to improved forecasting at local level and, all other things being left out of the equation—just looking at the objectives of the service rather than dealing with costs and so on at the moment—do you think that should be further expanded?

Nick Baldwin: We have encouraged the Met Office to move from what was, only a few years ago, 400 sites to 5,000 sites. It will soon increase that again with further forecasts for beaches around the country—an area where there are particular safety concerns. That is on the back of its increased computer capability. So we've moved quite a long way forward in being able to provide much more local information for people. We're down to the resolution of the computer programmes now to enhance the position further.

Q48 Roger Williams: Sir Brian, in your written submission, you said that the Met Office was very well placed to pursue the seamless approach to modelling. Could you tell us first what the benefits of that approach are?

Professor Hoskins: I am very happy to do so. I should perhaps declare my bias to start with, because I think I created the name "seamless" in the international sphere. The idea is that the atmosphere knows no particular bounds at any particular time scale. There are phenomena that occur on daily time scales and weekly. I'm thinking of the low pressure systems and the blocking highs. These things occur on all sorts of time scales. Equally, the models that we use to look at those phenomena have very much common ingredients, so there's a lot to be gained by using, as much as possible, the same system to look on all sorts of different time scales. You can evaluate a model that may be used mainly for seasonal, but make sure it works well with a daily weather system, because if it doesn't, can you trust it for the seasonal? Then, by looking at a model on a seasonal time scale, you can perhaps learn something about the land surface that turns out to be useful for a few days. The idea—from even below a day right through to a century—is that there is no boundary between the phenomena and the models used. A lot of the techniques and information are much better if you are using a common system and can learn from one scale to another.

The Met Office is uniquely well placed to deal with this. I don't think there are any other centres around the world that have developed in terms of the weather and the climate to the extent that it has. I was not pushing this on an international scale because my home institution—the Met Office in the UK—was going to be the one to really flourish, but by accident or design, the Met Office is in a great place to do this. It has the same basic model in terms of the atmosphere that it uses for less than one day out to a century.

Q49 Roger Williams: Thank you for that. Professor Pyle, you have described the success of the MONSooN project in facilitating joint development. Can you tell us what the barriers are to expanding this project?

Professor Pyle: Let me just clarify. First, MONSooN is a facility outside the firewall of the Met Office computer. It is used to develop work co-jointly by the academic community and the Met Office. Prior to MONSooN, when we did develop work together, it was very slow, very laboured and not particularly efficient, so MONSooN has made a huge difference to the academic community's ability to contribute to what the Met Office delivers to Government. Equally, of course, there have been benefits to the academic community.

There are strategic issues, of course, as to the direction of computing in academic circles, and those are important, but financial issues constrain what happens. Initially, MONSooN is a relatively small additional component to the Met Office computer and is paid for jointly by the Met Office and the Natural Environment Research Council. I think NERC is contributing a little less than £1 million a year. If you want to make it bigger, you have to put more money in, and the question is where the money comes from—that is the issue. The Met Office will upgrade a computer next year, and MONSooN will become bigger along with that, but I suspect that the demand, particularly from the academics, which, as I say, helps the Met Office, will not be met by that service. So this is largely a development service; it is not being used in large part to do very long integrations—it is about proofing code.

Q50 Roger Williams: Can you tell us how the Met Office could make sure that its models are more user-friendly?

Professor Pyle: Again, I think it is a question of somebody being able to find the resource to make models more user-friendly. The reference I made was to mesoscale models, which Professor Hoskins has just mentioned, in this range. Some of the academic community have found using mesoscale models quite difficult. In consequence, they have been picking up codes from north American sites, which probably are not as good, but are easier to use, and the academic, like everybody else, has targets to meet, and wants to publish papers. A number of people in the UK community have gone down that route.

My own feeling is that we ought to be investing substantially in the unified model—the Met Office's model—as an academic community, but that is a little more difficult to do. Because of that, some people vote with their feet. Essentially, you would need to devote more effort, more people and more resource to making those models portable and therefore usable by the academic community.

Professor Hoskins: May I come in on that? It is worth looking at the history on this. The Met Office provides an operational effort for the UK. There are places in the world whose aim has been to produce a community model, so those places that have the community models—in general, those are developed to be easy to use. The Met Office model started off being for the operational purpose; what we are seeing is an attempt to move across to make them more like

those community models. But there is an overhead with it: if you have something that is only being run for today's weather forecast all the time, it comes streamlined for that and it just runs like that. If it is going to be used by all sorts of users, it has to be maybe slightly less efficient at that, and it is a lot of work to make it more usable.

Q51 Roger Williams: What more could the Met Office do to ensure that it has access to more reliable data to put into the model?

Professor Hoskins: There is a continuing programme of looking for observations that are both different and more accurate on all time scales. The MOSAC committee that I chair, for instance, when the 1.5 km model—a very detailed model of the UK—was coming forward, put pressure on to say, "Do you have the right observational capability to make the most of that model?" As always, one would like more and more observations, but there is a question of getting the right mix so that, together with the model, you can actually interpret what is really there in the atmosphere and it is enough for initial data.

All the time the continuing satellite programmes are incredibly important, as is searching for new data sources and the ability to use those data sources. To use radar, to put into a model, for instance, the model has to be good enough that you almost have the right answer, and then the radar information can slightly correct it. So there is an iteration between the model and the observations, and the range that is available; but it is incredibly important that the observational system that is currently available is continuous, and that we look for ways of getting new information all the time, but there is no golden bullet of, "This is the more accurate data that could be available."

Q52 Chair: Just for clarity, those observational points can belong to anyone, and the key is that we have good co-operation.

Professor Hoskins: Absolutely. I think meteorology has been unique in the world. Even in wartime, countries have communicated their meteorological observations to one another. The world system that produces that observational capability is unique and it is so important to the whole operation. Clearly, if you are looking at the details of the UK, it becomes, "Do we provide enough observations for our locality, as well?" So if we are looking at the Olympics, do we have enough observations to really get the detailed forecasting for the Olympics? That has been something that we on the MOSAC committee have pushed the Met Office to look at, to which the Met Office has responded very positively.

Q53 Roger Williams: Would anyone like to add anything to that?

Professor Pyle: The global data sets that Brian has just been talking about are crucial and, of course, they are provided without the Met Office. They are provided internationally and continued provision, as has just been said, is absolutely essential. The Met Office then has a great record of interpreting those data sets and developing usage of those data sets.

It is also worth saying—this is something that the Science Review Group has been pushing the Hadley Centre on—that, as the models become more complex and as they contain more types of processes, then testing those models at a process level—not necessarily with global data sets but by high-quality local data sets so that you can understand the process—becomes more important. That is one of the things that we have been pushing very hard: to make sure that the Met Office tries to access appropriate data sets to test individual elements of its new models.

Q54 Roger Williams: Do you agree that representing uncertainties in modelling is a critical area for future research?

Professor Hoskins: I think that it is incredibly important for future research, and it is important in communicating the results of the models to the users and the public in general. One of the developments in the subject over the past decade or so is to try to get a real handle on the uncertainty that is present in forecasts. The running of the single model is not sufficient to give you that. Just giving one answer is not sufficient. One needs somehow to see the range of possible answers, given the chaotic nature of the atmosphere. Even if the model were perfect, the butterfly would flap its wings and it would be different.

The techniques are there now to explore the range of possible outcomes. MOSAC has been putting pressure on the Met Office to try, first, to produce that uncertainty. There have been great strides in that: the MOGREPS system at the Met Office has made great strides. The fine resolution model that is to be put in place for the UK will again have a measure of the uncertainty. So, we have techniques for exploring that. If you are going to look at those for the uncertainty in extreme weather, for instance, then you have to calibrate the system. Suppose you run 50 models—50 realisations—and 2 of them say there is going to be extreme rainfall, you have to be able to interpret that. That is only by using your same system over past data. You can then say, "Well, in the past, when it said this would happen 2 times out of 50, it has happened maybe 5 times or not at all." By looking at the past you get a way of calibrating what that model system is telling you.

MOSAC has very much encouraged the actual production and the communication—maybe you are coming on to that later. Communicating that uncertainty to people in a realistic manner is very important.

Q55 Roger Williams: Would the other two gentlemen like to comment on how the Met Office is addressing this particular issue?

Nick Baldwin: We have spent a lot of time discussing with the Met Office how to represent to the general public uncertainty. One development we recently funded was the "Invent" section of the Met Office website, where it puts up experimental methodologies to try to represent what is going on. We have been using that to show variability in temperature associated with different areas, to get people to start understanding that. As we go into longer-term

forecasting it becomes more important to explain. The Met Office is currently working on ways to represent the uncertainty with its longer-term seasonal forecasts. With our support, it will soon publish material to help people understand.

One problem we find is that the populace at large is not well educated in probabilities and how you measure uncertainties. People completely misunderstand the risks they are taking or not taking in regular day-to-day events. For instance, it is more dangerous to drive to the airport than fly, yet most people would think it is the other way round. We have the same problem explaining weather forecasts. People do not understand when you say that probability is attached to it. That is part of the education that we are encouraging the Met Office to do.

Roger Williams: I think we will be coming on to that in a few questions.

Q56 Stephen Metcalfe: Good morning, gentlemen. On our visit yesterday we heard about the importance and the dependence on supercomputing capacity, and that the science is available now but not necessarily the computing power to realise that science. Do you consider that a step change in supercomputing capacity is required, as opposed to just an upgrade?

Professor Hoskins: In the past, meteorology and its application in both weather and climate had available to it the cutting-edge computers. That is no longer the case. It is a job to argue that weather and climate are now less important than they were in the past. There is no doubt that big advances could be made, pushing the science to the limit, if the supercomputer power took that step change. For instance, with global models we know there are real advances to be made if you can take the grid down to 10 km or so. We know that is needed for weather. Again, we come to whether we can be confident of seasonal or climate time scales, if we are not resolving the scale that we know is essential for weather. If you are going to run models, either on a very fine resolution for one or two days on a kilometre scale or even smaller or on the 10 or 20 kilometre scale for centuries, and not just do one—because of uncertainty you need to do many—then you need the step change in computer power. We would know how to exploit it. It is not just to do the runs, it is also to analyse the results of the runs. Sometimes it seems as if it is just going to produce results, but you need the whole system, which enables you to look at those results as well.

Professor Pyle: Again, I agree very strongly with what Brian is saying. If you look at the Met Office, it has an absolutely fantastic record, and is something of which I think the UK ought to be very proud. It seems to me that it has also delivered very important products for Government. You have to ask yourself whether you want to maintain the position whereby the Met Office covers that range of activities, in terms of the product that it delivers for the forecast and how it delivers information about climate change and the importance of that. Do you want the Met Office to continue to play that leading-edge role? I do, and I think that if you want that to happen, you have to invest in the appropriate computing, because, as Brian says, the challenge has become trying to understand things at a finer and finer resolution.

There is no point forecasting for 5000 sites if you have only one grid box covering the UK. You have to have models that run at very fine resolution to be able to forecast at that kind of number of sites. I am speaking as a scientist, and the science drive is to those higher resolutions. The interesting science, interesting questions and interesting answers come out of running the models at very high resolution, and for that, the Met Office has slipped down the league table substantially in terms of the computer power to which it has had access. I would like to see it right up at the top again.

Q57 Stephen Metcalfe: What level of investment would be required to get it right back up to the top again and over what period would that investment need to be?

Professor Hoskins: It is not just a single slug of money and that is it. It has to be a strategy, whereby you say, "We're going to keep to this level." These days, you do not usually buy computers with a load of banknotes and that is it; it is a more continuous process. I have not looked at the details of the costs these days, but one must think in the order of £10 million to £20 million per year as an ongoing thing, if you are to stay at that level. As John said, it is the UK staying there and I believe it is the UK in terms of the Met Office and academia. We have a leading role in the world and we have been acknowledged as having that, and that is partly because we work together very well, but the whole community needs this sort of thing to stay at that cutting edge. Japan and Korea have this, and, yes, we can do our little bits of theory or whatever, but we will not be at the top table unless we have that sort of support.

Q58 Stephen Metcalfe: Do you agree with that, Professor Pyle?

Professor Pyle: Absolutely.

Q59 Stephen Metcalfe: And do you agree with the amount of investment required? Is that a number you would recognise?

Professor Pyle: Yes, I guess it is. John Beddington's report talked about a factor of four, and what Brian says is consistent with that.

Q60 Stephen Metcalfe: Who should fund that? There's the crunch.

Professor Hoskins: The UK.

Q61 Stephen Metcalfe: Okay. As simple as that.

Are there any economic benefits that you can identify that come back into society by investing in this, by improving the resolution and the accuracy of predictions? Is there a benefit to the wider economy that would justify the investment?

Professor Hoskins: Well, I think you can take this on various scales. I have mentioned extreme weather. If we are to make progress on the floods that have occurred in the past few years, the snowstorms and the high wind events—you name it—there is clear economic benefit on that time scale from the extra

information that you can give to the user. They can then say, "Well, you're telling me now that there is a 60% chance of this event somewhere in this location." You are refining gradually as we get closer to the event, and you should be able to take measures to combat it.

On the longer time scales, climate change is clearly such an important issue, whatever the economic situation, and there are decisions to be made on infrastructure in terms of adaptation, and mitigation in terms of actually knowing the latest. The amounts of money involved in putting in that infrastructure are just too large. Last year, for instance, the Department for Transport was asking, on the shorter time scale, "Are we going to get more winters like this?" That would have huge implications for the roads, the airports and the railways. If one could get more information to help in such decisions, the economic benefits have got to be huge.

Professor Pyle: I am just looking at the John Beddington report. He says that "external research on the value of the Met Office's public weather service has shown that the service contributes at least £614m to the economy, based on a sample of the services".

Q62 Stephen Metcalfe: Assuming that we can't make that economic argument convincingly enough to persuade the UK to top up the cash, are there any lower-cost alternatives that could provide the computing capacity needed to get up to the levels that you are talking about?

Professor Hoskins: I said UK, Met Office and academia, so one could imagine there being a shared facility in that way, which would slightly reduce the costs for one organisation. The facility would not be for academia in general, because the weather/climate problem is rather different from any of the other supercomputing problems. So I don't think it would be a joint-purpose academia machine; it would be a shared dedicated weather/climate machine. That would be a way of reducing costs for one organisation. There has always been discussion about a European solution, which seems to remain as far away as ever. One can imagine that it might happen at some time in the future, but there doesn't seem to be any immediate prospect of a European solution. But on a decadal time scale there may be a reduced number of centres around the world that have such computational power available to weather and climate, which would then be shared with the region. I don't think we can look on that as the solution now. Japan and Korea have their power now, and there is no sign that Europe will find such a solution within the next few years.

Professor Pyle: The Met Office already does come up with this. Brian mentioned Korea, and there is a substantial collaborative programme with Korea. There are benefits, in terms of a bit of computing power, that that brings. The Koreans do some things in collaboration with the Met Office. A long-term solution that relies on that rather piecemeal approach—a bit of Europe, a bit of Korea and a bit of Australia—is not sustainable, in my view.

Q63 Stephen Metcalfe: Are there technical barriers to doing that that you would identify? Or is it that you would rather have the capacity here?

Professor Pyle: I think there are logistical barriers. It takes effort to put a code on a different machine. For example, the unified model was put on a very high-power machine in Japan a few years ago by scientists from the University of Reading. It was a big effort to move the code from there to somewhere else. If you say, "Well, let's try to do that in several places," you need several groups of people to be making that effort, which is not very cost-effective.

Professor Hoskins: There is running a model and there is actually looking at the results, which is often the more difficult thing if it is run remotely because you have this huge mass of data—this is very much the weather and climate problem—and you have to look at them and analyse what is going on. Do you bring those data back from the remote computer? That has difficulties, so where we are going to analyse those data is a real problem, too.

Q64 Graham Stringer: I shall ask a couple of questions in this area. Professor Hoskins, you are dealing with non-linear chaotic systems, aren't you? Is there a limit, a theoretical limit at least, to what you can predict?

Professor Hoskins: There are different questions that one must try to answer on different time scales. If you are thinking about a projection through to the late 21st century, you would not try to predict the weather on 1 January 2080. So the idea that the system is chaotic and our ideas of what may be predictable and what is not, change on the different time scales. There is no particular limit that we know of in terms of slightly improving on different time scales. There are phenomena that occur on all sorts of time scales and the more we can understand those phenomena, the more we have the data to initialise those states of the climate system, the better one can hope for the prediction.

Let me give an example: on the multi-decadal time scale, there is an overturning circulation in the Atlantic that may well have predictable parts to it. We think there are and if we can have data, understand it better, get data for the ocean in the Atlantic and maybe the global ocean, one can hope to have an element of predictability on the decadal time scale, even though the weather will fluctuate around that.

So there is no time at which everything disappears into a chaotic mass. There are predictable items that we can pick out and try to use those ideas of uncertainty and get more predictive power for them. Whether that predictive power in all time scales will be useful, we don't know until we have explored it.

Q65 Graham Stringer: May I put a case against what you are saying for the investment? I should be interested in hearing your or your colleagues' comments. You want extra computing power. Computing power gets cheaper over time according to Moore's law, so if you wait nine years, it is a lot cheaper, so you have to give the benefit of doing it now as opposed to over nine years.

The scientific community has come to a consensus, as far as climate modelling is concerned, that there is a 90% certainty that climate change is happening. Given those two factors and the fact that you are competing for money against, say, stem cell research, which could provide a cure for Parkinson's disease, or the search for the Higgs boson, which could give us knowledge that was known before so we do not know where that is leading, where is your case? It is very weak when you talk about being at the top table or at the leading edge. Where is the hard benefit in that?

Professor Hoskins: On the mitigation side, I would agree that we know enough that we should be reducing our greenhouse gas emissions. In terms of the international discussions, it will be very useful if we could say, "These are the implications for China and these are the implications for India." That could be quite persuasive. At the moment those ideas are rather vague.

But I talked about adaptation where the decisions are being made now for the next Thames barrier for all sorts of infrastructural things with huge amounts of money associated with them. If we say, "Okay, we'll go out of the race for 10 years and we'll rely on what information we can get from others around the world", I don't think they will be too keen to provide their information for our infrastructural decisions. On shorter time scales down to seasons, and if you are thinking about the benefit to humanity, then I would suggest that if we could refine the seasonal forecast and the implications for regions in Africa, it would have huge implications—perhaps more than some of the other things you have discussed.

On the daily time scales, again, with extremes, there are major human decisions that have to be made and benefits that could be attained. So it is not that we could just put this off and other things are more beneficial; I think this is as beneficial as any.

Professor Pyle: The science question has changed. It is no longer a question of whether greenhouse gases will warm the climate; it is about what will happen, for example, to areas of the United Kingdom in 2030. What will climate change look like at that kind of scale? That is why we need an investment. We cannot do that with our current modelling infrastructure. We can't do it very well. We would like to do it much better.

Q66 Pamela Nash: Mr Baldwin, while customer satisfaction with the meteorological library and archive service is reported as being extremely high, the Committee has heard evidence that the bulk of the available data is only accessible to the public on payment of very high data charges. In the US, however, that data is more widely and freely available. Is that a complaint that you have heard often? Do you think it is possible for the Met Office to make that information more widely and freely available?

Nick Baldwin: It is not a question that I have heard often, but I have heard it from a number of sources. The important thing to recognise first is that we already provide a lot of data via the Met Office website that is free and downloadable. We also provide a lot of historical records through the archives. If people want to get large amounts of data from the archives and want it put into an electronic form, that costs money. Therefore, we have to have a process to recover those costs. We do not have budgets to fund all requests from people who are after large amounts of historical data. The intention is that people are charged the recovery cost for that.

We have been in long discussions with the Met Office about what further data information we can make freely available. We would of course actively want to encourage that, because, from our perspective, the more information that people have and understand, the more useful it is to them. The question is how to do that in a cost-effective way. In the way we work at the moment, there is no bottomless pit from which we can fund everything that people want.

Q67 Pamela Nash: But it is being looked at—whether it is possible to expand the available information.

Nick Baldwin: It certainly is, yes.

Q68 Pamela Nash: If you could achieve improved access to the information, how do you think that would affect the private sector in this country?

Nick Baldwin: We have had a number of discussions with private sector providers about this, and it is quite clear that there are a number of areas where private sector providers believe that if more data was available to them, they could produce different and potentially better weather services than we currently provide. If they can, it is great idea, because the intention is that we are providing a national resource and if we can do that, that would be a good idea. It goes back to the point that you have to find a way of providing the data cost-effectively. The current way that we are structured and our funding does not mean that we are a bottomless pit able to provide everything that everybody wants.

Q69 Pamela Nash: If more funding was available to you, that would be something—

Nick Baldwin: Yes. I am sure that the Committee is aware of the ongoing discussions about the consultation on the creation of a public data corporation, and the debate about what is a financially viable business model to release more data is a key part of that consultation.

Q70 David Morris: Sir Brian, do you see a potential conflict of interest between your roles as chair of MOSAC and as a member of the Met Office board? If so, can you clarify how that would work in practice?

Professor Hoskins: I was chair of MOSAC before I was actually a member of the Met Office board. My membership of that board has provided a very good conduit from the science that occurs in the Met Office and the independent view of that science through to the board. Personally, I feel no conflict whatsoever. I am a pretty independent sort of guy, and I assure you that I do not let it hold me back in any way.

As a member of the Met Office board, I suppose you might think that my chairing of MOSAC might be influenced by that, but it certainly is not. Our discussions are frank and that is encouraged. They are constructively critical, and they are attended by more

than just those who are presenting to us. Many members of the Met Office come into those discussions. It all works, and I am pleased with the way it works. I produce a report at the end, which is agreed with the members of the committee, and I can then communicate that directly to the board with all the warts that it implies. I think that puts me in a very strong position to do that.

Q71 David Morris: How are members appointed to the various weather service groups—MOSAC, the Met Office Hadley Centre, the Science Review Group and the Public Weather Service Customer Group?

Professor Hoskins: I will answer for MOSAC first. I ask them to take part in it. I clearly consult the Met Office on who should be a member of it, but in the end it is my decision.

To tell you the membership, at the moment we have, I think, six academics, one of whom is a professor in a German Max Planck institute, and five are from the UK. The other seven members are the equivalents of chief scientists in met services elsewhere around the world. I sometimes have to explain to the rest of the board, who feel that this is actually parading our programme in front of our competitors, which is not normally done in industry, that this is the way that real progress is made in science, and in science-based organisations. I make sure that the input we are getting from these other chief scientists is real input, so that they are not just a sponge of what they are getting, and actually, the input that we get from academia and from these chief scientists at met services is very valuable.

Q72 David Morris: Do you think the different Met Office advisory groups maintain their independence from one another? For example, do they adhere to the code of practice for scientific advisory committees?

Professor Hoskins: I don't think anyone would say that we do not act in a very independent manner. I think we do, but perhaps I should defer to John.

Professor Pyle: It is worth explaining that the Science Review Group that I chair is tasked by the Department for Environment, Food and Rural Affairs and the Department of Energy and Climate Change, which are the primary funders of the climate programme at the Met Office, to ask whether the Met Office is delivering science that is appropriate to the needs of DEFRA and DECC. We are actually a DEFRA/DECC committee, looking at the Met Office programme; we are not a Met Office committee, which MOSAC is.

We are subtly different—well, not very subtle, but we are different. We operate in very much the same kind of way that Brian does. We have a rotating membership and people typically serve for three years. They are all scientists, half of whom are from overseas. Scientists like to argue and disagree with one another and that is where the health of the committee comes in. People are there because they enjoy being better than somebody else, and that is the way the committee works. It has been effective.

I think there is an issue, from the Met Office perspective, about whether it is being over-reviewed. It is reviewed by MOSAC, and there is an overlap with the annual review that happens through the Science Review Group that I chair. On top of that, the Met Office has had a number of ad hoc reviews in recent years, such as the Sir John Lawton review, the Beddington review, and so on. It is entirely appropriate that it should be accountable for what it does, but I wonder whether it is being asked to do the same thing too many times.

Professor Hoskins: May I add something to that? The equivalent for the Hadley Centre on the weather side is the Core Customer Group, so the manager of the Public Weather Service is present at our discussions, as is the head of operations. My chair's report goes through to the customer group, and I have presented it personally, or the Chief Scientist has presented it to them.

Q73 Chair: Before we move on, Sir Brian, you referred to the international players with whom you co-operate. I am intrigued by that, although it is not the core of our inquiry. In other sectors where UN treaties drive co-operation, the tendency is for things to move at the pace of the slowest. Why does that not happen in the met service?

Professor Hoskins: The drive to produce the forecast, which has been a collaborative operation often way before these UN bodies started to oversee it, has made everyone realise that this is the only way to progress the matter. The spirit of collaboration is probably unique in the weather/climate area. Everyone is competitive in the sense that they would like their model to be up there, but they are collaborative.

It very much reflects the mixture of competition and collaboration in academia—there is always an edge, a tension between the two. This is an operational area in which creative tension has managed to continue to the benefit of all. It has been a fantastic way of progressing. Research is shared and the research of today becomes the operations of tomorrow. The medium of journals and conferences is always a sharing operation of what we are doing. In weather and climate, it is a pretty short time from research taking place to its really making a difference at the coal face.

Q74 Gavin Barwell: I should like to ask questions about collaboration, which several of you touched on in answers to previous questions. To start with a general question, are there areas in which the Met Office could do more to collaborate either with the academic community or others in the UK, or on an international level?

Professor Hoskins: If you had asked me that 10 or 20 years ago, I would have come in with a load of comments, saying that the Met Office could be doing more. The collaborations and partnerships are so much better now, and they are progressing in the right way. Perhaps in the spirit of my previous answer, the individual scientists have always collaborated very well around the world. Met Office scientists have played a very important role in the international scene. Collaboration in the UK was quite rocky 20 or 30 years ago, but we have reached a point at which academia-Met service collaboration is probably just about the best in the world.

Internationally, again, in the past I would have said that the Met Office tended to be slightly, "Hands off! We've developed this model; we have the IP; we are not going to let you into this." There is a very different attitude now of realising that the partnership of others using your model is extremely important. A few years ago, MOSAC said that the strategy with the European Centre for Medium-Range Weather Forecasts should be rather better, with the scientists collaborating, but there are moves to get that in place.

So we are looking at a pretty good scene now. We are realising the values of collaboration and partnership. The UK is No. 1 helped by the collaboration in it, and internationally, that is essential to the Met Office place in the world scene. It is very productive to get the input of others into your framework as a way of having a bigger effort. This is realised now and there are very good programmes for doing it.

Professor Pyle: When I talked about MONSooN, I referred to the collaboration between the Met Office and the academic community. MONSooN is part of something called the Joint Weather and Climate Research Programme between the Met Office and the Natural Environment Research Council. As Brian said, that is a very new thing and we all welcome it. We are all aware that this is not moving quite as quickly as perhaps we would like. That is for perfectly good reasons on both sides as the Met Office and the academic community learn how to effect collaborations in the most effective way. Collaboration is great, and I am looking forward to seeing it get better and better.

Q75 Gavin Barwell: To pick up on a couple of specifics, Sir Brian, in the written evidence that you submitted to the Committee, you said that you thought the requirement on the Met Office to gain financial reward from its products might be damaging to collaboration. Will you elaborate?

Professor Hoskins: Certainly. Let me talk from the point of view of an academic, for instance, who might be collaborating with the Met Office to improve the ability to produce seasonal forecasts for India. Understanding the Indian monsoon would have tremendous impact on the ground, so that research is for the good of the subject and the good of humanity. But academics might not be quite as willing to share in the collaboration if they felt that the Met Office, at the next moment, would use that research to make money for itself. That is a tension that has to be handled. Recognising the difficulty is part of the solution. If, as the commercial pressures become stronger, this becomes more difficult, it becomes true with the data problem as well. If you make all your data freely available and do that before you exploit it yourself, you will not make as much money out of it as you would if you did it the other way round. There will always be a tension between the commercial operation and working for the good of all. We have to handle that tension.

Q76 Gavin Barwell: To probe a little on the example you gave, if in that situation the Met Office was looking to commercially exploit the model or forecast it had developed in relation to India, would the financial benefit from that be shared with the academic community that had been involved in developing that work?

Professor Hoskins: I am not sure I know of a particular example where that has happened. In general, we are talking about the academic working with the Met Office to do research that will be published. In general, the academic will get their reward in that way from that extra input to their career. That would be the natural way. There has to be a clear line between that and the commercial operation, which will exploit some of the benefits that have been obtained through that research and others.

Q77 Gavin Barwell: Professor Pyle, you said that the JWCRP was a good thing, but that it was not moving as quickly as you would like. Can you explore in a bit more detail for the Committee what you see as the barriers to making the progress that you want to see?

Professor Pyle: I think that there is just a bit of institutional inertia. As I have said, two sides have to come together to collaborate, although this is more than collaboration, essentially. In a sense, what happens is that if I was collaborating with another scientist, I would do something and the scientist would do something. We would pull those two things together and hopefully have something that is better than the two individual things.

What we need as part of this JWCRP is a more strategic consideration of the collaboration. As an example, I collaborate currently with the Met Office. We have been putting atmospheric chemistry schemes into the unified model—the climate model. The way that that has been done is that my group has done that work and we have then added it to the Met Office model. The best management way of doing that would instead have been to have somebody with sole responsibility for that, who could tell people in the Met Office or in my group at the university exactly what to do. At the moment, I tell my people what to do and people at the Met Office tell their people what to do and hopefully we build the thing that way.

I can see that there are big advantages to the United Kingdom, both for the academic community and the Met Office community, if we have a more strategic approach. That, in part, is how JWCRP is going. It is not that there is anything wrong; it is that people are perhaps gradually getting used to having to lose a little bit of their sovereignty. It is not just a question of collaborating; it is a question of being involved in the management structure rather more than they have been in the past. We scientists don't like management.

Q78 Gavin Barwell: I have one final question to probe further on how JWCRP works. Is there a programme director? To take your example, is there a single person that is directing that programme or is it a loose negotiation?

Professor Pyle: I am trying to remember exactly what the structure looks like. There is a committee responsible for science and there is a committee responsible for facilities—I cannot remember what they are called—and each committee has two chairs, one from the Met Office and one from the academic

community. There is the discussion currently about the development of a UK earth system model. There, the idea of this management structure that I have talked about will take place. There will be somebody who is responsible for that. This is starting to happen.

Q79 Stephen Mosley: In the evidence we received, the National Oceanography Centre stated that there is a common public perception that the Met Office does not provide reliable seasonal forecasts, largely due to sensationalist media reporting and shortcomings in how probability and risk are understood by non-experts. Do you think that is a fair assessment?

Professor Hoskins: It probably is, yes—we're putting in probabilities. The seasonal forecast is a very interesting scene. Any retired van driver can look at the berries in his garden and produce a forecast, and a newspaper can take that to get a headline that will sell newspapers. It is then a difficult space for the Met Office to be in and giving likelihoods of different outcomes, but that is the way it has to be done. It has to be done in the manner of probabilities based on the best possible science.

MOSAC—and I in particular—have always encouraged the Met Office to produce more information about likelihood than has tended to happen in the past. Again, all the media pressure tends to be on the weather forecast; it has a shorter time, and the manner of communication becomes more important. There is so much information to communicate now, which I believe the general public as well as more sophisticated users would find useful. Let us take the example of the hurricane that was likely to inundate New York. US television was showing 12 possible tracks provided by 12 different models for the hurricane. I do not believe that that sort of information is difficult for the public to assimilate, and we should not underestimate the public's ability to take on odds and make their own decisions based on those.

For many years we have encouraged the provision of more likelihood information, although I don't think the BBC was too keen on that. These days, with red buttons to press or websites, it is possible to provide sophisticated information for those who want to dig deeper, and the Met Office, with its great strength based on science, is well placed to provide that information. The tabloid headline will never be a good way of communicating the seasonal forecast. That leaves the Met Office vulnerable, but that is the world we have to live in.

Nick Baldwin: We were heavily involved in a discussion about withdrawing the previous seasonal forecasting approach. The consultation we undertook showed that people did not find it very useful in the way it was presented, and that they would rather have received a shorter-term forecast so that the three-month forecast was replaced with a 30-day rolling forecast. A lot of work has gone on since then with the Met Office, and over the next week or so it will introduce a new seasonal forecasting methodology for civil contingency communities, which includes a better explanation of the uncertainty facing us. I am sure that everybody is aware of the work that is going on at the moment in preparing for the winter, and the desire to warn people to be ready for potential extremes in the weather. It is important that people are organised and have a good understanding of that forecast. We have been funding that information and it will be released through the Cabinet Office.

Professor Pyle: I think the communication issues are quite difficult. If you say that there is a 60% probability that winter will be colder than average, it means there is a 40% probability that it won't be. How do you decide after one winter whether your forecast was right or not in a probabilistic sense?

Professor Hoskins: I totally agree with that. You can never say that you are right or wrong at the end of one winter, given a probability forecast. What you can do as a responsible organisation, however, is say that in the past, when we have said that there is a 60% chance of a cold winter, that has happened on 55% of those occasions. Unfortunately, that rigour of evaluating how good a forecast has been is not always present in those who produce the tabloid headlines.

Q80 Stephen Mosley: The way you have described it, it is very understandable, but part of the problem we have is that most people get their weather information, whether long term or short term, from the TV, and of course with the pressure on TV schedules, the amount of time that weather forecasts are on for has shrunk. Is there an easy way of getting that information across in, say, a 30-second weather forecast?

Professor Hoskins: I don't believe there is in a 30-second weather forecast, but I believe there is a way of opening it up to saying, "And if you want more information in the form that you are increasingly used to, you can find it here." That sort of likelihood information should be readily available to people. We now have the 5,000 sites with the information. There is no reason why we cannot give the probability information on all time scales and make that available to those who wish to delve. People are pretty good these days at pressing the red button or saying, "Yes, I want to find out more about this," and going to their computer. Then, a responsible organisation such as the Met Office can say, "We do evaluate these things, and this is the skill we have—the reliability of our forecasts." People will get this as an iterative thing and have confidence in it. We have to believe that the public are able to assimilate this sort of information. They do in their daily lives. I don't see why they can't for the weather.

Q81 Stephen Mosley: From time to time, I've seen American weather forecasts, which quite frequently say, "There's a 20% chance of rain here and a 40% chance of being sunny." Occasionally you see that on the UK channels, but not often. Do you think that sort of presenting might be a way forward?

Professor Hoskins: One of the points, of course, is that that television channel is probably beaming down only to the particular city you're in, so it's able to handle that detailed information, and those channels seem to think they have more time to handle it and that it's of more public interest, too, so you find that their weather forecasts are longer. As long as one can

access to what that 20% probability of rain means and that is communicated, it is extremely useful to have it.

Chair: Thank you very much, gentlemen. This has been a very informative session.

Examination of Witnesses

Witnesses: **Phil Evans**, Government Services Director, Met Office, **John Hirst**, Chief Executive, Met Office, and **Professor Julia Slingo OBE**, Chief Scientist, Met Office, gave evidence.

Q82 Chair: We now move on to our second panel of witnesses. I would be grateful if you introduced yourselves for the record.
John Hirst: My name is John Hirst, and I'm Chief Executive of the Met Office.
Professor Slingo: I am Julia Slingo and I'm the Chief Scientist at the Met Office.
Phil Evans: I'm Phil Evans, the Director of Government Services at the Met Office.

Q83 Chair: Thank you for coming before us today. I also place on the record our thanks for your very informative tour of the facility in Exeter yesterday. We have heard already this morning about issues relating to money, and I'll start at that messy end of the business. How should long-term funding for Met Office services be secured?
John Hirst: That is a very short question for a quite complex area. First, it is important to understand that we don't receive voted money. We sell our services to Government Departments and public sector customers, just as we sell our services to the private sector. We have contracts from the Public Weather Service Customer Group. That is the only contract that we have that runs for more than a year. The climate programme has an unsigned contract as yet, and the defence programme has a contract that is for no fixed term. That creates some uncertainties and difficulties in resource allocation over the medium to long term, and as we're in an area of activity that requires a long-term perspective for the scientific and operational development, that causes some tensions.
The benefit of having a contractual relationship is that it focuses the customer and us, as the supplier, on exactly what the customer requires and what the benefits are so that we are directing our activities to make sure they get what they want. We are bringing new ideas to their service. I can't think of anybody in the world who wouldn't want a longer-term perspective on the funding, so that we had a better planning horizon to operate in.

Q84 Chair: Are there ways in which non-governmental revenue could be increased? Some of the very sophisticated tools you have are of enormous value to the insurance industry and a wide range of sectors of the UK economy.
John Hirst: We have major customers in a whole range of different areas—utilities, for example; water utilities and power utilities. Insurance companies work with us, particularly the reinsurance sector where they are pricing their risk over the long term against historic climate records and frequencies of extreme weather events, and the destruction that they cause. We do build, and have built over the past few years, the revenues we get from those customers by deploying our expertise in their service.
It is a pretty tough economic time at the moment, so it is slightly harder to sell those things than it might otherwise be. But we continue to make steady progress. Moreover, because of the collaborations we do around the world and our sharing, we leverage other people's spend in the area that we have to reduce the burden of cost. We are also now drawing the attention of national met services around the world, which see that we can deliver benefits in terms of products and want to take advantage of the experience. We have got to help them and take our products under licence.
My current estimate from that funding is that we reduce the burden on the public purse by about £20 million to £25 million a year. Our ambition is to build on that so that we give the UK's Public Weather Service increasing value for money as we go.

Q85 Chair: In terms specifically of the Hadley Centre, has the DECC-DEFRA relationship provided a sensible, stable funding mechanism?
John Hirst: We have very good relationships with DECC and DEFRA. They have been very good in supporting our Hadley Centre programmes over many years. We do, of course, see their struggle with funding, challenges and the money that they have available to spend, so they are constantly challenging to see whether they can do things in a different way. I reiterate that it would certainly be better if we had a slightly longer term perspective over a couple or three years in the funding that was clearly committed and supported. It is not quite there at the moment.

Q86 Chair: In terms of things that could change, your plea would be for longer term time horizons?
John Hirst: That would be very welcome.

Q87 David Morris: Do you accept that the Met Office needs to make its models more user-friendly? If so, what will you do to address this issue?
John Hirst: We do, for a number of reasons. The more we can get people to collaborate with us, the more our science and our services will advance, because we bring in the scientific capabilities of other people who use our model to develop and do their experimentation. That could be in the academic community around the UK or internationally, or even between us and our national met service partners that use our models in South Korea, Australia, New Zealand, South Africa, Norway and others, who bring to us their expertise and some support in funding.
We have permanent stress that I think you have already heard about. We are having to run our model so that we deliver many thousands of forecasts for

various users every day, and do the scientific development and experimentation we need to do to roll the science forward. It is probably slightly better in the climate area than it is in the weather area where there have already been some commitments from the academic community to build that relationship and put in the resources to make sure that the things are translatable and easier to use. We are now working with the weather academic community to do the same thing and make it easier to use, recognising the constraint that we have to deliver the forecast every day.

Q88 David Morris: What more should the Met Office be doing to ensure that it has access to, and makes more use of, accurate source data to input into its models?

John Hirst: One of the benefits you have heard about is the fact that in the meteorological community, which is a subject of fascination to me coming from the private sector in the past, there is massive collaboration. Of the data we use to produce our forecasts, we ourselves produce something less than 4%. The rest comes from the world community of met services and academia.

We stretch continuously to find additional sources. One I use, for example, is that mobile phone companies try to remove the distortion from their signals. Quite a lot of that distortion is caused by atmospheric conditions, so we work with Ofcom to see whether we can get those distortions, which we will interpret to understand where moisture and atmospheric disturbance are. We do that all the time. We also work collaboratively to deploy buoys in areas of the ocean where we do not have good data, and there is a rolling programme of development. You will never satisfy any met service that it has enough, but we do work hard on building that network.

Q89 David Morris: Professor John Pyle described the success of the MONSooN project in facilitating joint model development. Do you intend to expand on the MONSooN project? How else can you encourage the joint model to develop?

John Hirst: Yes, we do. In our last procurement and in the delivery of new capacity in the second phase of that, we are building the size of the allocated space for the MONSooN project, and we are already in discussions with NERC about the next phase to develop that.

Q90 David Morris: Do you agree that representing uncertainties in modelling is a critical area of future research? How is that being addressed within the Met Office?

John Hirst: We have a number of serious challenges in the organisation. There are big scientific challenges. Representing and understanding the uncertainties in the science is an issue in itself. As you have already discussed, representing the uncertainties in a communications sense, so that people understand what it really means, is also a big area. I think it is an area we have addressed over the past few years much more intensively than in the past, because we have learned from focus groups, academic studies and work with experts at Cambridge University, how difficult it is for people to understand uncertainty and integrate it. I had conversations with international colleagues. A couple of weeks ago I was talking to the guy who heads the Canadian met service, where they have used concepts of uncertainties and probabilities a lot. In their survey work, although people are used to it, they do not always understand what is exactly communicated by those uncertainties and probabilities. That is an area that will keep us busy for some time.

Q91 Graham Stringer: You were in the room listening to a discussion about the case for increased supercomputing capacity making a big step change. How important is that?

John Hirst: It is vital. We have an aim in the organisation to provide to the UK the best weather and climate service in the world. The aim is not because it is a good thing in itself, but because the earlier you can give warnings of extreme weather events, the more you can give reliable indications of emerging weather and climate patterns, and the more Governments, communities, businesses can use that intelligence to plan their activities, save lives and cost, and build their businesses. Being the best is about pushing those barriers down, ensuring you can get more reliable information out earlier.

If you look at the insurance industry, which has done a lot of work on this, two-thirds of the world's insured losses are as a result of natural hazard events. Wind kills more people, water causes more cost. Curves on graphs show that the earlier you can warn makes a significant improvement to the losses that they engage in.

Professor Slingo: I was also sitting through that discussion, when the question was asked about possibly waiting nine years or whatever until Moore's law takes you to the power that you need. It is clear—as the panellists said—that the science is ready and waiting. We know we have science; we understand; we have models ready and waiting to roll out, and we are testing them.

Investment now will give a very rapid return on that in terms of the economic value to the UK and its interests nationally and internationally. That is perhaps distinct from other investments you could look at in research. This is not entirely for research; it is science ready and waiting. It just reinforces the comment that Sir Brian Hoskins made that weather forecasting and climate predictions sit very close to the bleeding edge of research. As an organisation and through our partnerships, we are now very skilled at taking the latest science through into our operational delivery, so you will get a very rapid return on the investment.

Q92 Graham Stringer: You talk about the insurance companies' curves that show the savings that can be made. As was discussed before, that is very difficult to communicate through the *Daily Mail* or the *Daily Mirror*. Is it possible to give a real example of where you have focused on an extreme weather event and—saving lives is particularly difficult to demonstrate—you have stopped damage to property and, in all likelihood, saved lives?

John Hirst: There are a couple. When the Cumbrian floods occurred a couple of years ago, we were working jointly with the Environment Agency and our—newly established at that stage—flood forecasting centre. We were able to give 24 hours' better notice than we had ever been able to do for a level of rainfall that was beyond any historic record of rainfall in this country. So the level of the confidence that we had from the quality of the science that we had gave the responding community there an opportunity to get things in place and manage the event much more effectively.

There is another example that Phil talks about, which is Tewkesbury, where the fire chief, having had three or four days' indication of likely floods, was able to bring boats and inflatables to that area from Cumbria and the Lake District. He was therefore able to get people out of their houses and to safety in a way that they would not have done had they not had that advance notice to shift the equipment to the right place.

Q93 Graham Stringer: Is it possible to get the extra computing power by collaboration, using something akin to the Airbus model, rather than just putting it all into one supercomputer in Exeter or anywhere else?

Professor Slingo: That has been looked at over many years by the international community in weather and climate science, and the problem is that the nature of the problem that we are trying to solve computationally does not lend itself to distributed computing. It has been tried and we cannot get either the efficiency, in particular, or the timeliness.

In weather forecasting, you have a very small time window before the forecast is out of date and beyond its shelf life, so you have to work within that very tight time window. That means that you have to be able to both run the model very efficiently and also gather and process huge amounts of data. That requires a very specific type of machine architecture.

The nature of the codes that we use means that we require large memories per processor, which is not true for many other sciences. We also require very fast interconnects between processors, because we exchange a large amount of data. Finally, we need very large bandwidth to get the data out of the machine, because we are producing huge amounts of data as the model runs, and on to a huge data archive. Those sorts of systems are not typical of the sorts of architectures that are around and available on group computing or other set-ups like that. That is the conclusion that we have come to, but it is one that all the major weather and climate modelling centres around the world have also come to. We look at it every year and assess these things.

Q94 Graham Stringer: That is very interesting. I have one final question. I can see how you can verify the accuracy of your forecasts over a day; you just see whether it has rained or not. Even seasonally, you can check the probability over a few years. In terms of your climate predictions, which you have only been doing for 20 years or so, Professor Hardaker told us last week that you had predicted the flattening of the temperature curve over the past 10 years or so. We have heard evidence at different inquiries before the Committee that doubts that. Can you give us documentation that shows that you got the shape of that curve for temperature change over the last 10 years right?

Professor Slingo: What you have to understand is that we have done a lot of work to understand how that flattening of the curve has arisen. It is part of the natural variability of the complete system. Professor Hoskins talked about the slow—

Q95 Graham Stringer: I understand that. What I am interested in is whether you have got it right in advance.

Professor Slingo: When we initialise, this would have to be only through our decadal prediction system because that flattening was a result of the current state of the full coupled climate system at the end of the 20th century, in the 1990s. If you initialise the model from that state and run it forward then, yes, we got some of that flattening.

If you are running a free-running climate change prediction model, it would not exactly replicate that particular 10-year period, but what it would have, within the richness of its projections, is decadal periods where the rate of change in temperature would slow down or it might be a bit faster. That is all within the natural variability of the climate system. So the attribution of that flattening is that it is part of the natural system.

There may also be a contribution from increased aerosol loading. Again, if you were predicting that ahead of time we would not know that. That is an anthropogenic forcing, but looking back we can reproduce that and say, "Yes, the aerosol loading would have that effect on the temperature curve." As you know, we are now picking up again. The final area here is that we are also going through quite a deep solar minimum. So if you combine aerosols, deep solar minimum and the slowly varying ocean circulation, it is very easy to justify that short-term, decadal-time-scale, decline in the rate of rise of temperature.

John Hirst: It may be helpful to express something that I learned when I joined the Met Office about how the science has developed. The easiest example is a weather example. When we introduce new science for models, we go back to an event in history that we might not have got precisely right, reinitialise the model and run it through that event to see how much better we get it. That proves the quality of the science. That builds our confidence as we go forward that if that or similar events occur then we will get it right, or righter than we did in the past.

The same applies to the way we develop climate modelling. We will go back and initialise the model 20, 40, 50, 80 years ago and run it through and make sure that we are replicating the observed trends in the Earth's atmosphere. So it is not that we do not have any checking. Clearly, there is a difference between making a forecast for tomorrow when you experience tomorrow very quickly, but we are going back and modelling how the climate has evolved in history to make sure that our models replicate what actually happened. That, again, gives us the confidence that we

have the chemistry and physics right which will help us predict the future.

Q96 Stephen Metcalfe: Can I take you back to the supercomputing capacity? In the first session we heard an estimate of around £10 million to £20 million per year to provide the capacity. Is that a number that you recognise? Do you think it is more or less?

John Hirst: We always need to say what problems we are solving. There are short-term problems that we can get better at. There are longer term problems that we can better at. We need to balance the availability of science, the availability of infrastructure, including observations to verify and check how we are going, and the supercomputing capacity. It is not just about saying, "Here is a cheque for a supercomputer." It was quite rightly observed that we have science now waiting for application and a lot of scientific experimentation waiting for computing capacity, despite the fact that we run this pretty efficiently.

Having thought about this a bit, I think that if you take specific examples in the short term, getting weather events more precisely, you could allocate capacity and other bits of about £7 million a year to that in the next three to four years. Then if you take the monthly and seasonal forecasting that we do—I am trying to not call it seasonal; I am trying to call it the three-month rolling forecast—you would allocate some £7 million a year to the problems that we have ready. It comes to about £14 million over three to four years. During that period, you would constantly review what the next challenges are and what the next science availability is, so that you would refresh that as you go forward.

Q97 Stephen Metcalfe: That is quite a lot of money. There were suggestions about where that £14 million might come from in the earlier session. I am sure you have your own ideas and I do not want to get caught on that. Have you done a cost-benefit analysis on that additional spending and what the benefit is to the wider economy?

John Hirst: Yes we have. When we did our last procurement we had three A, B, C and D cases. The case we went to was not pushing the envelope as far as would have been ideal, because it was based on affordability—not that we were not grateful for it. At that stage, we had a return ratio of 10:1. That meant that every £1 invested got £10 return. That is not in the next week, but it builds progressively over months and years. We could have justified that same ratio with a computer three times bigger. That ratio still exists. Again, it joins with the earlier question of why we would not wait 9 years, but we are losing £2 billion a year in losses to the community, because of disruption due to non-preparedness for extreme events. You can save that money as you go and get the return.

Q98 Stephen Metcalfe: You said that it is 10:1, which happens to be a very round ratio. Can you justify that in any way? Can you give practical examples of where the additional computing capacity could lead to a better prediction, which could save x pounds?

John Hirst: Most of that 10:1, at the time, was built around preparedness for floods. It does not include the kind of benefits that we have explored with the Department for Transport for better preparedness for extremes in winter. There are many quotes on how much the disruption in winter last year cost. You can build that in. I am confident that we would not fall short of that 10:1. It is a rounded figure, because it would be spurious to say that it is 9.687:1. The estimates that you would have to make over several years are just not that accurate.

Stephen Metcalfe: But there is practical application behind that number, so it is justifiable.

Q99 Pamela Nash: I want to turn to the science strategy of the Met Office now. To what extent did you consult with external organisations and the meteorological community when you were forming the science strategy?

Professor Slingo: As Chief Scientist, it is my job to define the science strategy for the Met Office to ensure that it is fit for purpose in 10 years' time and to guide the science to deliver our operational requirements. I came, as you know, from the NERC community, where I led its climate modelling programme. There was consultation through the Met Office Scientific Advisory Committee, so it was involved in the development of the strategy. Colleagues were, of course, involved. As Sir Brian said, we have six academics sitting on the Science Advisory Committee who were engaged in those discussions. At the end of the day, our science strategy has to be one that I am confident is right for us as a business and as a public sector organisation that has to deliver our public task and one that I believe is achievable within our own resources—that does not mean that I do not welcome the consultation with the academic community; as we develop the implementation plan, that is very much in our minds. At the end of the day, it has to be my judgment that this is the science that we need to do to provide the highest-quality, most useful forecasts going forward, whether it is a few hours ahead, or out to a century ahead, in response to what I now know, or understand, as the cross-government needs.

It is clear—I see this very clearly having come from the academic community—that the Met Office research programme has to be very directed towards our public task, whereas in academia you follow the Haldane principle, which says that you do the best research for research's sake. The development of the strategy would be very different for me as Chief Scientist in the Met Office to the strategy that I was developing as head of the climate science programme in NERC at Reading University. I sit on NERC committees and I know what the big science challenges are. It is not surprising that the academic community would recognise the same challenges.

Q100 Pamela Nash: Did you feel that the level of consultation that took place was adequate?

Professor Slingo: It was absolutely appropriate for the job.

John Hirst: May I offer a thought as well? There are masses of exchanges of information that go on all the time in the Met Office. It is a structure and almost an

osmotic process. There is MOSAC and other advisory bodies. There are the bilateral arrangements that we have. There are hundreds of collaborations with scientists in academia in other institutions around the world that go on all the time. It is impossible for those not to help formulate the strategy. When the strategy has gone out, it is commented on all the time and will evolve progressively as people make comments about potential gaps or things that are emerging in science. We operationalise those contributions. There are both structured and natural flows of information, so consultation is almost unavoidable.

Q101 Pamela Nash: I appreciate that, but my question has arisen out of the memorandum that we received that said that the research councils would have appreciated a greater opportunity to have been consulted on when the science strategy was being developed. Why were the research councils not given a greater opportunity to contribute during the consultation?

Professor Slingo: I was rather surprised by that comment because the director of the National Centre for Atmospheric Science, who is the most obvious NERC representative, is on our Scientific Advisory Committee. The strategy was discussed with them. One of the things that is sometimes misunderstood is that a strategy is not an implementation plan. The NERC community tends to see strategies as implementation plans. NERC is mentioned throughout the strategy. Now that we are going into the implementation plan, as Professor Pyle talked about, the role of the Joint Weather and Climate Research Programme with NERC will be critical to the implementation of that strategy. It is at the implementation level that you really can work together. As Chief Scientist, it is my job to define the scientific direction of the Met Office so that it is fit for purpose in operational weather forecasting and climate prediction for policy decision making by Government.

John Hirst: We have already agreed that we will go back and ask what particular areas they might have been consulted on and what concerns they have because we want to draw in that information in a deep and thorough way.

Q102 Pamela Nash: On the implementation plan, I understand that the science strategy was published a year ago today, yet the implementation plan was only published last week. You said that those are two different things and it might have been misinterpreted. Why has there been that year of delay in producing an implementation plan?

Professor Slingo: Clearly, it takes time to develop an implementation plan. It does not mean that we have been doing nothing. We have actually implemented an awful lot of what is in that science strategy in terms of the science partnerships and the integration and restructuring of the science programme. Many of the recommendations have already been followed through, but we have to see the science implementation plan as part of the corporate plan. We have gone through a major refresh of our corporate plan in the last year. The science implementation plan has to be then put in the context of our business implementation plan and our implementation plans for Government services. There is a timetable to that and a year is what it has ended up being. We have implemented an awful lot of things during that time.

Q103 Pamela Nash: Would you not agree that a year is a long time? Has a level of uncertainty been fostered between Met Office scientists and external collaborators who are having to wait such a lengthy period of time?

John Hirst: No, it has not. I do not make my judgment about that on the basis of details within a science strategy, but, on having published that, the other met service in the world that is ranked in the top two or three, and which we respect very much, is the Japanese met service. It is on the MOSAC advisory committee and said, "This takes the strategic science strategies of all met services to a different level, and we will be following it." That is a kind of peer acknowledgment.

One of the things that we strive to do in being the best is attract first-class collaboration. We want the best scientists to want to collaborate with us, and there has been no let-up in that collaboration. People see what we are doing on a day-to-day basis, and want to come and work with us and share their expertise. The number of scientific papers that are published jointly with other institutions and leading scientists around the world are in the hundreds. I do not see any let-up or delay in that.

Q104 Pamela Nash: It has remained the same over the past year.

John Hirst: It has improved; it is increasing.

Q105 Stephen Mosley: In the previous session we heard that some people are saying that only a tiny fraction of the available historic weather information is accessible to the public without incurring large data charges. Do you recognise that as a widespread complaint?

John Hirst: I hear it. Some people complain about it quite a lot and persistently, and others don't complain about it at all. Every time we get a specific request or issue, we try and address it and ask, "What precisely do you want?" For example, I received a letter that was addressed to the Ministry of Defence about a year ago, grumbling about the lack of data. I went to the person and asked, "What is it you'd like?" I haven't received any response. Sometimes complaints are a general perception about history, and sometimes they are genuine things.

I am not diminishing the fact that there are data that people would like access to. Some of that stuff is still held in paper format in the archives, and it would cost money to put it all into digital form so that it can be readily accessed. We are constantly managing a tension between how much money should be spent to develop that and whether it would satisfy specific requirements more directly and more cost-effectively, or whether we need to make all those things accessible because there is a general demand. At the moment there is a general demand in some areas and, in consultation with the Royal Meteorological Society

and others, we are looking at how much data we need to put into that kind of category to make the information more readably available. We are testing demand in other areas to see whether it persists and would provide good value for money, or whether it should be done in a different way. It is pretty open, and we make what data we can available.

Q106 Stephen Mosley: You were talking about the different types of data—I guess you have raw data, previous forecasts, actual weather forecasts and the effective results of what actually happened. What are people actually interested in when they contact you?

John Hirst: It varies a lot from people who want to know what the weather was like on the day they were born—it starts with very small things—to people who are conducting research experiments in areas of preparedness for wind events or particular areas of science. There are people who are writing books about the development of the coal industry in south Wales and want to look at weather events. It ranges massively over a whole spectrum. The most consistent demand is from private sector weather providers, and we make data available as we can. It is worth noting that through our international relationships I help the UK private sector get access to data in other countries where there is not as much openness and flexibility as in this country.

Q107 Stephen Mosley: You are talking about private weather forecasters and the private sector. Do you think that if the information could be made more easily available and more cost-effective, it would help grow a more vibrant private sector?

John Hirst: To a certain extent, yes. Some private sector providers, I have to say, are concerned about the amount of data that we are providing free of charge. The 5,000 sites that are being made available in the Public Weather Service will cause some distress to some private sector providers, because that is the kind of thing they have been doing and charging customers for. There is a wide range of different kinds of providers. Clearly, some are much more sophisticated and some less so. There is not one answer that applies universally to all the private sector providers, but clearly, the data available are a key issue. We have a commitment to move up the volume and relevance of the data that we make available.

When you listed some of the things that you talked about, very few people want yesterday's forecast, to tell you the truth.

Q108 Stephen Mosley: I think Graham Stringer wanted 15 years ago.

John Hirst: The information is time-expired. We try and make available, as part of our mission, as much of the data as we possibly can behind the forecasts and behind the observations that we have, so that they can be used, checked, developed, enhanced and absorbed into other people's activity.

Q109 Stephen Mosley: Last week, on Thursday 27 October, the Government consultation on the public data corporation finished. Are you in favour of the Met Office forming part of the PDC, and what impact do you think that it will have?

John Hirst: You are asking me to comment on an area of public policy, which is not—I will respond to the Government's decisions on this.

The consultation, as I see it, is part of shaping what the PDC might be and how it might operate. We have been working with the teams in the Cabinet Office and in BIS to help them understand what we do already and what contribution we make. We can do some things collectively, but whether they are worth investment is for other people's judgment. We have a plan to develop partnerships with other environmental science organisations, which we have called the environment science to service partnership, and which works with colleagues in the NERC institutes to help bring them some of their science—fantastic, world-leading science—out into greater use, by developing applications and uses for that science across the boundaries between us. If we can make use of the PDC as a vehicle to do that kind of thing, it would be very beneficial.

Q110 Stephen Mosley: Surely you responded to the PDC consultation, did you not?

John Hirst: It is a public consultation, and I am in the process of writing a letter recommending some things that should be taken into account. However, as it is a public consultation and given that I am not a member of the public in this role, I have not responded to it. There is a different route.

Q111 Gavin Barwell: I want to explore collaboration, which I touched on with members of the previous panel, and I think you were all in the audience at that time.

First, a general question for all three of you: do you think that the widespread use of common modelling systems encourages collaboration, and if so, are there specific systems that you think the Met Office should be sharing more widely?

John Hirst: I will ask Julia to comment on some of these things in a second. One thing to make clear is that we recognise that it is impossible for us to do all the science that we need in order to deliver the best service possible ourselves. We cannot do it, so we reach out in a very structured way now to draw in the best science collaborations we possibly can, and to operationalise that for the best benefit of the UK and our customers. An underlying philosophy is that we collaborate. We have created a post; one of our very senior scientists is now head of partnerships. He works on developing the partnerships on the unified model and on developing collaborations internationally between us and scientific institutions. We are acting on that need to collaborate.

Julia, it is probably worth quoting some of the numbers from the collaborations that we do, and how much we rely on it.

Professor Slingo: As John said, as part of the science strategy, we highlighted the role of science partnerships in a much more formal way than hitherto, where it would have just been going on at a grass-roots level. We have a head of science partnerships who was in charge of our climate programmes and

who has now moved into this. He is a leading scientist.

We have started a process of quantifying the benefits that we accrue from such partnerships. Our statistics for last year show that we had 165 projects with an estimated value of £15 million, within year, so that is a third of our science budget within the Office.

Q112 Gavin Barwell: So that was 165 projects, with an estimated value of £15 million?

John Hirst: That is leveraging to value assigned to other people's efforts.

Professor Slingo: More than a third of that came through the Joint Weather and Climate Research Programme that we established with NERC, which John Pyle talked about. That is now developing very strongly. I, with the director of operations at NERC, chair the strategic programme board. Between us we have implemented what I think is a very good structure to allow the programme to take off.

About another third comes from our international partnerships, which is the leverage we get from the countries that use the unified model within their operational weather and climate predictions, where, again, we now have much more formal arrangements in place. It is more about partnership and ownership than licensing. To begin with we licensed the model, but now they have implemented the model in their forecasting systems and are beginning to do research and development on that model, we are coming to a much tighter partnership arrangement. We recognise that we are all in this together.

The benefits this year are £15 million. Within the past year we have also launched the academic partnership scheme with three major universities, which draws together about 1,000 scientists working in HEIs, rather than just in the research councils. That is a different leverage, a different way of stimulating science within the academic community, as well as translating that science into improved services. I imagine that, as the JWCRP gathers momentum, that £15 million will grow and grow over the next few years. We need to quantify that year by year, and we will.

Q113 Gavin Barwell: In their memorandum to the Committee, the Government strongly support the proposal for stronger partnerships in the science strategy, but they said that the proposed partnerships should include Government representation. Do you think that is appropriate? If so, how do you intend to facilitate that?

Professor Slingo: We need to be careful that, particularly with our academic partners, we don't conflict with the Haldane principle, which we need to recognise.

The science partnership programmes are presented at MOSAC, and we make it clear to the Hadley Centre Science Review Group that they are the collaborations that benefit the climate programme. I think that is appropriate at this stage. As the JWCRP gathers momentum, we could include somebody from the appropriate Government Department, probably BIS in this case, on the strategic programme board, alongside myself and Phil Newton from NERC.

John Hirst: Having also read that memorandum, I don't understand the thoughts behind it. We need to understand precisely what people want to do.

Q114 Gavin Barwell: It came as a surprise to you?

John Hirst: Yes. We need to understand a bit more about what people would like to achieve, and we will work hard to accommodate that.

Q115 Gavin Barwell: I want to give you the opportunity to answer the question I asked Sir Brian. In his written evidence, he said that the requirement on you to gain financial reward from your products could damage collaboration. You heard me put that point to him in the earlier evidence session. What would you like to say about that?

John Hirst: It is a tension that I think is quite healthy. At the extreme there is a risk. In the past there has been some confusion about what is the best way to develop this, but we have a clear view that the more we collaborate, and the more we develop our science, the more we will be able to bring in supportive revenues to our operations. It is not in the data; it is in the interpretation and contextualisation of that information, interpreting it for different users and understanding their requirements, where we really attract the right kind of revenues.

The benefit of having real customers who require real delivery and pay money for it is evident throughout the organisation. That keeps us focused on delivering and making sure that we are efficient and that we work in a businesslike manner. Although there is a risk that we must be aware of, it does not drive any inappropriate behaviours in the organisation—indeed, to a certain extent, it drives better behaviours than if we did not have customers.

Q116 Roger Williams: There is a perception that the Met Office's seasonal forecasts are unreliable. Is that because the forecasts are unreliable, because of how you communicate them to the public, or because the public do not understand probability and risk in such matters?

John Hirst: Long-range forecasting is an area of developing science and significant scientific challenge. But it also has massive potential benefit, because it addresses areas that businesses and responding communities are thinking about in preparing to make their activities more efficient.

In that whole area, the Met Office is one of a small number of leading institutions in the world. We are breaking down scientific barriers as we go. We prepare those forecasts principally for professional use, because they are quite complex at the moment.

As Brian Hoskins said, these are not the kind of forecasts that say, "You can take your deck chair to Weston-super-Mare beach on 15th of whenever." They are about general patterns, likelihoods and probabilities of general patterns emerging. They are useful in the UK for professional users, utilities companies and the civil contingencies secretariat. They are useful internationally for Governments—planting and developing crop plans in Kenya, for example, where we have examples of people

benefiting from our input as they help feed their population. So there are real benefits.

Long-range forecasting is a complex area of science to communicate. In refreshing our service to Government, we are saying, "Here are the limits and the extents of what you can decide." We are also working hard to find out how we can communicate that information to make it more simple to understand. I have said a number of times that I have been responsible in my past, when I was a group treasurer in a major international corporation, for buying and selling £14 billion or £15 billion worth of foreign currency a year. Even at this stage, given that it is based on physics and chemistry, some of the seasonal—long-range output—forecasting is more reliable than some of the economic forecasts I was using to make purchases.

Q117 Chair: Tell that to the Treasury.

John Hirst: They are not Treasury-given forecasts; they are commercially available. We have a lot of work to do in the area.

Q118 Roger Williams: Obviously, the work is to explain it to the public, but it is a bit like a chicken and egg situation isn't it? Is it your job to educate the public to have a better understanding of probability?

John Hirst: We cannot say, "Here is our information—it's up to you now." That would be derogation of duty. But we must understand what people do with our information and make it available in as digestible a form as we can to help them make the right decisions and understand the implications of what we are saying.

Q119 Roger Williams: I think it was Mr Baldwin who said that his group had suggested that that type of forecast should be made available not to the public but to particular groups.

John Hirst: We have clear rules that state that, if we are going to make information available to the Government, it must be made available publicly—it has to be put on websites. We have an obligation to ensure that the limits and uses of information are clear. We have tables that state what kinds of things to use a one-day, three-to-five-day, monthly, seasonal or decadal forecast for, so that people understand the context that we are operating in. But it will take a little while for people to get used to that kind of uncertainty and probability.

Q120 Roger Williams: You mention making greater use of your website. How will you give that information?

John Hirst: It will be available on our website. First, we have improved the context and amount of data in that forecast. It will be made available with explanations of the kind of things that are on there, what kind of use you could put them to and what the uncertainties do, and we will give a commentary around the data. That is what we are doing. That will now evolve over months as we develop the service.

Q121 Roger Williams: What should the Met Office be doing to communicate to the public the underpinning science of the forecasting you do? Can I just say that putting up maps and having symbols for the sun, rain and such things is rather dumbing down the science, not giving people better understanding?

John Hirst: May I challenge that? That is not the way of describing the science, to be fair. It is a way of communicating in a very short period what the general weather patterns will be. That is not the way we communicate the science. We have other plans to communicate the science. It is very helpful for people to understand a little more of this, and we co-operate with broadcasters—we have had two film crews in the office this week studying the science and how it can be communicated to build an understanding of what underlies it. Julia, would you comment on the science?

Professor Slingo: I came in as Chief Scientist and I have really pushed the need to be more open and transparent about the science we do and to get much more information on to our web pages. For example, we now have a research link on the front page that takes you into all our science areas and tells you what we do and who does what, so if you want to find out who a scientist working in a particular area is, you can.

We have just launched "Research news", where there are hot topics of the moment—one of which went up this week on declining Arctic sea ice—presented in language suitable for an interested member of the public. We have started looking at all sorts of other ways of communicating science, such as YouTube videos on topical issues, which get a lot of hits actually—an increasing number. We use Twitter and all sorts of media. We have just started a whole series of educational posters with accompanying videos, to explain the very basics of how the climate system works, for example, and therefore why one thing—carbon dioxide—changes everything.

The whole business of education is really important and it is really very difficult, but I think we have a clear aim within the science programme to put far more information out about where you are publishing and who is doing what. I hope that the "Research news" page will take off as somewhere to which interested members of the public will go and say, "I wonder what the Met Office has been doing this month. What's the latest stuff on the role of the sun?" The sun is another story on there at the moment.

Q122 Graham Stringer: Roger Harrabin at the BBC is setting you a test, comparing your forecast, both short and medium term, with private providers. How do you feel about that? Will you co-operate?

John Hirst: I would not say he was setting us a task. I think we are setting a task together to explore the area. We have had lots of conversations with Roger and the colleagues he has gathered around him helping to shape that study. To be fair, it is an area of verification and comparison that has been very challenging and has eluded a conclusive answer for the meteorological community for many decades. It is not a trivial exercise.

Q123 Graham Stringer: Can you expand on that a bit? Why isn't it trivial?

John Hirst: If you say, "We are forecasting showers", did the shower occur in your garden or someone else's? Therefore, in terms of showers in that area, was the forecast right or wrong? Forecasts for specific uses can vary. The information we would provide a fast-jet pilot on crosswinds on a runway he is going to use for take-off would not be appropriate for the person running the farm next door.

Ensuring you have the right context, purpose, time scales and degree of granularity is really important. Then you need to go over a sufficient period of time—to go back to what Brian Hoskins was talking about—to make sure that you're not checking just one event, but a whole series of events to see the aggregate performance.

Q124 Graham Stringer: Do I take it that you will co-operate?

John Hirst: We are co-operating.

Q125 Graham Stringer: You are in the process. You've said it is difficult. Do you have any assessment at the moment of how your medium-range forecasts compare with those of the private sector? To go back to the tabloids, the *Daily Mail* regularly says that Piers Corbyn—to name just one person—does it better than you do. Do you have any assessment?

John Hirst: Yes. We are collecting information on our and other people's forecasts in this domain, and we now have a growing database that shows that actually our forecasts are generally more reliable than most others. We look at that for two reasons. One is to make sure that we understand whether the claims made are right or wrong.

There's also an issue of sensible humility. If someone's getting it right more than us—if someone's doing better than us—we want to find out why and make sure that we take advantage of their understanding. There are a number of people—I don't know whether to talk about names—who claim these things but don't publish anything about their work and don't share information about the science, if there is any, behind what they do, so it is sometimes difficult to make comparisons that have underlying scientific sense. That creates a difficulty.

Professor Slingo: Particularly in the area of seasonal forecasting, which I think Roger mentioned, it's a probabilistic forecast, so you're not right or wrong and you need a whole history of forecasts to decide the level of skill and what we call the reliability of the forecast. As an international community, we have still to come together and work out how to do this in a way that makes sense.

Again, Roger's initiative is pushing us in that direction, so I welcome it, but we have to be careful, particularly when we're going to probabilistic forecasts, that we don't go into this in a naive way and try to approach verification in the way that we would for a deterministic forecast, which is what we've been doing for years, in terms of our performance measures.

For the things that Nick Baldwin talked about earlier, where we are set targets, we have had, with the World Meteorological Organisation, a long history of defining robust, verifiable targets or indices of forecast skill. We have now to go through that process for dealing with probabilistic forecasts and seasonal forecasts as an international community. We're beginning that process, but it will take some time.

Q126 Graham Stringer: I don't know whether my final question is answerable, but given the difficulties that you've just been through, is there anyone in the private sector or other national agencies who you feel is ahead of you in terms of their ability to do medium-range forecasting?

John Hirst: We are part of a consortium of leading met services working together under the auspices of the World Meteorological Organisation to develop these skills. Therefore we're already engaged with scientifically based people doing this kind of work. Although we always keep an open mind, I don't think there is an institution or a provider that gives a consistently and traceably reliable forecast better than the kind of work we're doing.

Chair: Thank you very much for a very informative session.

Wednesday 9 November 2011

Members present:

Andrew Miller (Chair)

Stephen Metcalfe
Stephen Mosley
Graham Stringer
Roger Williams

Examination of Witness

Witness: **Mr Edward Davey MP**, Minister for Employment Relations, Consumer and Postal Affairs, Department for Business, Innovation and Skills, gave evidence.

Q127 Chair: Good morning, Minister. Thank you very much for coming here today. We were expecting David Willetts—we meet him quite frequently and occasionally give him a hard time over various things—but we welcome you.
The Government's statement about the division of Met Office responsibilities states: "The Minister responsible for ownership of the Met Office is now Edward Davey MP; with the Rt Hon. David Willetts MP responsible for customer functions...and the customer for the Public Weather Service, receiving advice from the Public Weather Service Customer Group". Can you explain what that actually means? Where do the divisions actually lie?
Mr Davey: Of course I can, and thank you for inviting me to give evidence. I have only one brain, so I am sure you will be softer on me.
The division of responsibilities between Ministers reflects the fact that the Government are both owner and customer of the services provided by the Met Office. It is an important divide, and it does not always receive the necessary recognition and emphasis. We need to consider the assets and the governance of the Met Office as the provider of these services, but there is also the customer aspect. As you know, the Government purchase information for the Public Weather Service but also for the MOD, the Maritime and Coastguard Agency and so on. That divide is important. The Secretary of State and the Prime Minister both agree that that division of responsibilities should be reflected in our ministerial responsibilities. You have seen a lot of David, and we thought that you might want to see a little bit of me, especially as some of the issues that most concern your inquiry relate to the ownership function rather than the customer function. However, if you have any questions on the customer function I shall try my best to answer them.

Q128 Chair: On the question of ownership, have the Government now put to bed the idea of privatising the Met Office?
Mr Davey: We have no plans to privatise the Met Office. You will note that there has been a machinery change in Government; the Met Office has moved from the Ministry of Defence to the Department for Business, Innovation and Skills. It is now in a virtual holding company called the Public Data Corporation, sitting alongside Ordnance Survey, Her Majesty's Land Registry and Companies House. We will make more announcements on this, probably at the end of this month, but we believe that many of the efficiencies and synergies that we would like to see for the Met Office and the other assets held by the Public Data Corporation can be achieved through this move. While the PDC will create a vehicle for private involvement and investment, potentially, there are no plans for privatisation.

Q129 Chair: Can we be clear about it? Is having "no plans for privatisation" driven by the global scientific case for keeping it as a public facility, or is it a Treasury-driven commercial case?
Mr Davey: If one stands back and thinks about privatisation, there are many reasons why organisations have been privatised. If one is cynical, one might say that it is sometimes done to fill a hole in the Government's coffers. Although there is a rather big hole in the Government's coffers at the moment, it would be deeply irresponsible for a decision to privatise the Met Office to be taken on those grounds. The Met Office is a world beater, and we should be extremely proud of it and those who work for it. I therefore think that those sorts of reasons for privatising it would never be considered. There are other reasons why things get privatised, such as the need to drive efficiencies. However, the Met Office is pretty efficient and we have come up with other models to drive efficiency, so I hope that I have given you some reassurance on that.
On the international point, not only is the Met Office a world leader, but the way that it operates requires it to engage with the international community, not only in terms of meteorological sciences but with the intelligence services and through the information that it provides to the Ministry of Defence and our armed services. A number of areas are reserved, so when people considered privatising the Met Office they found it quite difficult to get over those hurdles. It is not widely recognised that the Met Office only owns 4% of its data. It represents the UK at the World Meteorological Organisation and, through that, it is able to exchange huge amounts of data internationally. Its work is dependent upon that data. Therefore, one has to take account of global opinion and those global relationships in how we manage and think about the future of the Met Office.

Q130 Chair: Is it that we simply would not be at the table, especially with the Americans, if it was entirely a private business?
Mr Davey: There would be challenges.

Q131 Chair: In terms of the changes, the MOD clearly still has an important need for the highest quality Met Office service. What structures are in place to ensure that it continues to get the support that it needs?

Mr Davey: There are quarterly meetings between officials from the Ministry of Defence and the Met Office to ensure that the customer service agreement is up to date and being met. It is a close relationship. There is obviously a historical relationship, and, although the change to BIS has broken it to some extent, it is still very close. We certainly would not want to put that relationship at risk. It is very important to this country.

Q132 Chair: One of the prized documents on display in the Met Office library is the weather chart for D-day. In any conflict situation, it is clearly mission-critical to maintain that accurate data. Are you confident that the mechanisms that you describe will continue to meet the needs of the MOD in the future? Putting it another way, if the MOD shouted for more help, can we be assured that it would be forthcoming?

Mr Davey: The MOD is a customer. It pays money to the Met Office for the services that it receives and the Met Office would like to have the Ministry of Defence's money.

Q133 Chair: In the case of conflict, I would see things slightly differently. I would expect a publicly or even a privately owned company to be responsive to the nation's need in those circumstances. Can we be assured about that?

Mr Davey: You can be totally reassured about that.

Q134 Roger Williams: The Met Office depends upon customer service agreements with various Departments for its funding. They are intra-government agreements and are not legally enforceable. Sir John Beddington said in his review that these arrangements do not give the stability required and are unlikely to provide stability in the future. Why is it that the defence customer service agreement—and, indeed, the Met Office Hadley Centre climate programme agreement—have not been agreed beyond the financial year 2011–12?

Mr Davey: I can understand why people have concerns about this and why the Met Office would like to see changes. If you go back in history, there have never been very long funding arrangements, so it is nothing new, but the current financial circumstances have made it more challenging. We need to consider whether these customer service agreements and the funding behind them can be put on a longer time scale, but that would be work in progress by the various parties. I cannot say that it will happen, or that it will happen by a certain date, but the point you make, Mr Williams, is very well made.

Q135 Roger Williams: The Hadley Centre climate change programme is now jointly managed by DECC and Defra, but that does not seem to have given it the required stability. Would it not be better if it was managed by only one Department?

Mr Davey: As I understand it, DECC and Defra are coming together to sign a memorandum of understanding—I shall be corrected if I am wrong—in order to give the Hadley Centre the reassurances that it seeks. That is important because it is doing some critical long-term research.

Q136 Roger Williams: You say that Departments are looking at how to provide more stability for funding. Would that include making these customer service agreements legally enforceable?

Mr Davey: I am not sure that the legally enforceable bit is the critical factor. While this purchaser-provider or owner-customer split is very important and very real, there are real negotiations about the contract. I sometimes think that people see it as a pretence, but it is very real. Because they are Government to Government and on a Crown to Crown basis, I am now absolutely clear that they are not legally enforceable.

Q137 Roger Williams: Under the Civil Contingencies Act 2004, the Met Office is the preferred supplier for advice and services to the Government. Does that give any more stability and certainty about future funding streams?

Mr Davey: One can be clear that these sorts of services are going to be needed into the future; they are not services that we can jettison or do without. In that rather profound way, there can be certainty. As for the exact levels of funding and so on, it is always difficult to say, but we have gone through the spending review and the big totals are there for all to see. I think that should give some comfort.

Q138 Stephen Metcalfe: As well as having the Government as a customer, the Met Office earns about 15% or 16% of its income from additional commercial activity. Do you think that that proportion—the physical amount—should be increased, and, if so, what are the pros and cons of doing so?

Mr Davey: We have no target figure to work toward, but there would be attractions to having one if the Met Office were to develop its commercial arm. It would need to do so carefully, but now that it is within BIS, under the Shareholder Executive for which I am Minister, and under PDC, there will be extra support for those activities, and extra advice and guidance, given the skills in the Shareholder Executive.

One of the reasons for developing PDC was to attract private investment. It may well be that joint ventures that might be needed to develop these commercial activities could be a lot easier to arrange than in the past. There was a joint venture five or six years ago, but it was not as successful as people had hoped. Perhaps under the new model we will see more examination of those options to provide the sorts of things you are talking about. But we should be clear that the services that the Met Office provides to the public sector, the Ministry of Defence and so on are absolutely critical. While it would be possible to expand its commercial activities, we must not at any stage put those other services at risk.

Q139 Stephen Metcalfe: We would probably all agree with that, but do you see any advantages for the Met Office itself, and the science that it does, by increasing joint ventures and its amount of commercial activity?

Mr Davey: Potentially, it can bring more money and investment into the Met Office. That has the attraction of supporting the science, but all the best meteorological scientists are probably already in the Met Office. These are early days in the job for me, but I am not aware of a huge cadre of meteorological scientists sitting outside that it could then partner. The attractions of it are the ability to think through new ideas and provide new capital that might make things more accessible and more attractive. You are absolutely right that it is an area that should be explored—it has been explored in the past—and what we are doing will facilitate that.

Q140 Graham Stringer: The Met Office clearly believes that to stay at the forefront of global warming science and meteorological science it needs more supercomputing capacity. Do you think that it should have it?

Mr Davey: A very good case has been made for that. In BIS, we are building a business case for investing in supercomputers. That work has started, and it is happening with a degree of urgency. We want to press ahead with building a business case for the high levels of investment that will be needed. One has to remember that technology is changing so fast that we have to ensure that these investments are done in the right way. That is why we have to ensure that the business case stacks up. But the scientific case to which you allude in your question is clear and is accepted.

Q141 Graham Stringer: You say that a good case has been made. Will you tell us what it is?

Mr Davey: I am not a scientist, but I understand that, when you are trying to crunch the huge volume of data involved in forecasting, and especially in short-run forecasting, which has to be done incredibly quickly, you need very powerful computers. Equally, when you are doing long-term seasonal or decadal forecasting, you need computers that can handle even more data. I am not sure that I have explained that very well, but that is my understanding of why, as we try to be more ambitious in accuracy and in our longer-term forecasting, we need ever faster and cleverer computers. That may sound a bit basic.

Q142 Graham Stringer: It does, but you are not a scientist. Are you aware of Moore's law—twice a year?

Mr Davey: Twice a year, yes.

Q143 Graham Stringer: My back-of-the-envelope calculations say that, if you wait nine years, you will get 64 times the computing capacity at one sixty-fourth the cost. That is a big differential from buying now. Whatever the business case, would it not be better to wait nine years, or whatever? The longer you wait, the cheaper and better the computing capacity. Why now?

Mr Davey: If you use that approach, you would never buy anything, would you? There are other reasons for purchasing, given the output that is required. We want an output from the science, but we also need to consider affordability and so on, which is why we need to make a proper business case. I do not want to give you the impression that making a business case is trying to put hurdles in the way of investment. It is a proper thing that all Governments do.

Q144 Graham Stringer: I do not agree. It does not mean that you would not necessarily buy it. It means that you would not necessarily buy it now, as it would be a lot cheaper and better in a few years' time. What is the case for doing it now?

Mr Davey: With respect, Mr Stringer, that is why we are doing the business case. We have started work on it. You do not do a business case knowing what the answer will be before you start.

Q145 Graham Stringer: You said that you did not know about science, but the business case seems to be that the scientists want it. That is a bit of a circular argument. Have you read what was said at our last evidence session?

Mr Davey: No, I have not read that evidence.

Q146 Graham Stringer: You didn't. In the last evidence session, we asked the Met Office whether, when it was looking at its climate models, it had got the predictions right for the flattening out of the increase in temperature that has taken place over the last 10 years. It said that it had not—not quite in those terms, I admit—but that it understood why it hadn't. Further, it said that it was very good at "hand casting", which means correcting the models over that period. Does it not worry you that that is a different kind of science? It looks at computer models and then corrects them historically, but it does not get it right when they are predicting the future.

Mr Davey: I speak as an economist, and I know that when economists come together they are always trying to predict the economy, spending huge sums on their work. Often, but not invariably, they get it wrong. That is the problem with forecasting, whether of the weather or the economy. The question is whether it is a good idea to be able to forecast and predict the economy or the weather better than we do now. Yes, I do think it is a good idea, and, while you have to build a business case, it is sensible to invest in the scientists and the facilities needed to improve forecasting. I am trying to understand what you are driving at, Mr Stringer. Are you against better forecasting?

Q147 Graham Stringer: I am talking about the Met Office's global warming predictions. I am saying that there is no evidence so far in terms of the predictions of climate change that it is getting it right. When it has gone back, it has been able to correct the models so that, had it changed the starting position, it would have been right. That is the real point. I am doubting whether it is science as we know it, really. That is what I am asking, and I am trying to separate that aspect from weather forecasting. Forecasts over the

four or five-day period have clearly become more accurate over the last 15 or 20 years. That is verifiable, because you can go back to see what had been predicted and it has improved its performance. There is a difference, and I am asking whether you are worried about it.

Mr Davey: I would imagine that climate change science is at an earlier stage than weather forecasting because, obviously, they are different things, as I am sure you appreciate. The potential cost and damage to the planet of climate change, if people are correct, is such that investing in scientists and computers to assist in improving this relatively new science seems to me a sensible thing to do. I am sure that there will be challenges along the way. I am not a climate change scientist or an expert on the matter, but I know that the Committee has already looked at the question. However, from where I am standing, having just read things like the UN's Intergovernmental Panel on Climate Change, I know that the world's best scientists have come together, no doubt sharing the predictions of many different computer systems, and they think that we should be seriously worried about it. Given a United Nations panel of scientists of that calibre, I as a mere economist would not want to challenge it. I think that we should take their predictions seriously and try to develop the science.

Q148 Graham Stringer: It would have been helpful if you had read the evidence that we heard last week, because I asked a question along those lines and I would be interested in your answer. Given that 90% of scientists accept that global warming is taking place—it is not a 100% consensus, but 90% is acceptable—why do we need any more investment in that science anyway? We accept that there is a difference within scientific opinion about whether the world will have warmed by 2° or 4° over the next 40 or 50 years. If that is the scientific consensus, why do we need to invest millions and millions of pounds now, when we know that it is happening?

Mr Davey: First, we should remember that the investment in the computers we are talking about would be used for weather forecasting as well as for climate change science. They would be dual purpose, if you like. You could, therefore, justify the expenditure—when we examine the business case we will obviously be considering such matters—through the improvements that we will get in forecasting the weather. The fact that you can use that computer power also for the climate change science seems to be another win. If I was to forget—

Q149 Graham Stringer: Do you know that that is the case?

Mr Davey: Do I know that what is the case?

Graham Stringer: Do you know whether the improvements in weather forecasting require precisely the same increase in supercomputing capacity that you need for predicting climate change?

Mr Davey: I am told that the model that will be used will be used for both purposes.

Q150 Stephen Mosley: May I return to something that you said earlier about the Public Data Corporation? You seemed to be talking in the present tense about the Met Office being part of PDC. I thought that consultation on the matter finished only a couple of weeks ago, and that, although the intention is to move the Met Office to PDC, the decision has not yet been firmly or formally made. Has that decision been made yet?

Mr Davey: You are right to pick up on that. We announced our decision on PDC in January, and we are consulting on a range of matters such as licences, data release and so on. That consultation has only just finished, and we have not yet responded to it. However, it has always been our clear intention to set up PDC. It is like a virtual holding company, so saying that it has started and is now in being is a bit tricky. We are not trying to put these organisations together. There are three organisations, and it would be useful to correct the record and be clear about it. In the machinery of Government change, you have the Ordnance Survey, Her Majesty's Land Registry and the Met Office coming in to BIS. I am also the Minister responsible for Companies House, another big data user. As we envisage it, those three assets will come together in an organisation called PDC. The actual start button will not be determined by the consultation; the consultation is about other matters as well.

Q151 Stephen Mosley: Moving on to Met Office data, I know that the Committee on Climate Change has called on the Government to ensure that data already collected by the Met Office is made more readily available. It highlights and contrasts what happens in the UK with what happens in the United States, where, apparently, weather data is much more freely available. Are there lessons to be learned from the US? Could improved access to data help us to create a more vibrant private sector?

Mr Davey: Yes and yes. As I said, the Met Office is the world leader in this area in weather forecasting. It has already released huge amounts of data, but our ambition is that it should release more quality data than any of its counterparts. We certainly have huge ambitions for it. For example, we are already consulting with the relevant people in the community on releasing historical data, which is available more freely in the US. We will certainly have announcements to make on this in the coming weeks and months, as we finalise the PDC decision.

Q152 Stephen Mosley: One concern that we have heard from the Met Office is that it has massive amounts of raw data. It wants to make that data more available, but it will be difficult to do so unless it is provided in a useful format. Do you think this will have any impact? How useful will large amounts of data be when compared to the effort that would be necessary to put it in a useful format?

Mr Davey: Those are all the right questions that we are asking as part of the process of bringing PDC together and of considering the various assets in that way. The Government are committed to open data, and I am committed to ensuring that the models that we put forward will enable and facilitate that. One reason why we are building PDC as this virtual

holding company is to learn lessons from those Government assets in order to facilitate the release of that data. We will be looking at all those issues. You are right to say that some of the raw data will be quite difficult for people to interpret immediately, but we want it to be presented in a useful format. As I said earlier, we have the ambition to release more data than other equivalent services. The question is how it is to be done and not whether we will do it.

Q153 Chair: I struggled with one sentence in the Government memorandum. It states: "The proposal for stronger partnerships and collaboration is fully endorsed and will be a crucial element of the success of the Science Strategy, although we suggest that the proposed science partnerships should also include representation from government to provide additional context to proposed research programmes." What on earth does that mean?
Mr Davey: Well—it means that we believe in partnerships, Mr Miller, and we think that they can be developed to the benefit of all involved. The suggestion that the Government should be represented on the science partnerships was, frankly, to ensure the links between the Government and policy-relevant research and that any potential research overlap is minimised. That seems sensible.

Q154 Chair: We have heard the Government say that they believe in partnerships, marriage and so on, but does this not drive a coach and horses through the Haldane principle?
Mr Davey: Through what?
Chair: The Haldane principle.
Mr Davey: I do not believe it does.

Q155 Chair: What is the role of Governments in a science body? If they are seeking to steer things, it would run totally counter to what the Science Minister has told this Committee before. What is the role of Governments in such an organisation?
Mr Davey: As I said, it is to ensure that research overlap is minimised. I do not believe that it is to lead the research. Following Haldane, no Government would wish to be that interventionist. We strongly believe that research should be directed by the academic community, and not through Government policy.

Q156 Chair: The word is "government". It does not say the research councils or the Technology Strategy Board or Universities UK. It says "government".
Mr Davey: In this context—that is why we included it in the memorandum—the Met Office is not a pure science body. It does not get funding from the research councils as do other parts of the academic community. It is a delivery body that uses science. Ensuring that it is linked to the science community seems a sensible thing to do. We do not seek to direct the science community, but we want to ensure that those links are strong. My understanding is that the relationship between the science community, academia and the Met Office is stronger and better than in the past.

Q157 Chair: That I agree with, but the reason for my questioning is not simply because it is my view. In response to that statement, the Met Office's chief scientist told us, "We need to be careful that, particularly with our academic partners, we don't conflict with the Haldane principle, which we need to recognise." The Met Office's chief executive said, "Having also read that memorandum, I don't understand the thoughts behind it. We need to understand precisely what people want to do."
Mr Davey: I hope that what I have said will give them some reassurance. It was not our purpose in the memorandum to go across the Haldane principle. We want to keep to those principles. Let me make it absolutely clear for the record, thanks to your question, Mr Miller, that research should be directed by the academic community and not Government policy.

Q158 Chair: If there is any further clarity on that subsequently—
Mr Davey: I am sure that my right hon. Friend the Minister of State for Universities and Science would be happy to give clarity on that.

Q159 Chair: I am sure he will. To what extent do the Government exert pressure on other nations to maintain funding for shared resources such as weather satellites?
Mr Davey: You will appreciate that pressure can be applied in different ways. I am not sure whether it is a question of Ministers phoning their counterparts and having strong discussions; it is more a question of ensuring that strong collaboration and co-operation across the globe is maintained. We certainly recognise that various Governments are under many cost pressures. The best way to apply pressure is to work together through those cost pressures and to understand their longer-term implications. As I said earlier, the Met Office owns only 4% of its data; it is very reliant on data from other international bodies and other countries. Therefore, we need to be clear about what will happen to the collection and provision of such data in future. Were gaps to occur in the future, we would need to think through how to meet them. I am not sure if it was that sort of pressure that you were looking for, Mr Miller, but I believe that we should ensure that the relationship is a collaborative one and not a troubled one.

Q160 Chair: I understand that, but, clearly, some shared investments will have significant economic paybacks in protecting various stakeholders in society. I put it specifically in the context of the polar orbiting satellites that have been delayed because of changes in the US budgetary process. What discussions have the Government had with their US counterparts to make a case for the Met Office on this?
Mr Davey: I believe that there are discussions on how those cuts should be factored into future planning. We know that the delays in agreeing funding for the next generation of US polar orbiters have increased the risk of a US data gap. It is something that we have to take seriously. We know that the US is attempting to mitigate the problem and to see whether the lifetime

of the existing programme can be extended. We are aware of their efforts to mitigate that. John Hirst has been speaking to the Met Office's national equivalent in the US, and the matter is being raised at Government level. We take the matter seriously, and it is important that we find a way forward.

Q161 Chair: You started your response by saying "I believe" that there has been a dialogue.
Mr Davey: I am more certain now.

Q162 Chair: You are now more certain by the magic of inspiration that has sprung in front of you. That was at John Hirst's level, but has there been any ministerial dialogue?
Mr Davey: I believe that there has, and I will be even more certain in a moment. I am wrong: there has not.

Q163 Chair: Would it not be useful if the relevant Ministers started having this discussion? It is a very sensitive area and, as I said, it has a significant economic impact upon scientists.
Mr Davey: I will ensure that we talk to John Hirst and find out what extra support he feels is needed from Ministers.

Q164 Stephen Mosley: A couple of years ago, we were promised a barbeque summer, yet it seemed to do little more than rain.
Chair: You can blame the Labour Government for that.
Stephen Mosley: The perception is that the Met Office does not provide reliable seasonal forecasts. Is that a fair perception?
Mr Davey: My understanding is that it is the best forecast in the world if you look at it over time, but it is not always going to get it right. However, if you look at satisfaction ratings and other criteria to check its performance, it does well.

Q165 Stephen Mosley: To be fair, the National Oceanography Centre said that many of the problems were due to sensationalist media reporting and to shortcomings in how probability and risk are understood by non-experts. To what extent are probability and risk factored into the way that the Government use the seasonal forecasts?
Mr Davey: For the Government usage of them, the probability and risk issues will be central to how they are considered. For example, if the Ministry of Defence was using Met Office forecasts for its planning, it would obviously be asking it what certainty there was. It would be very clear about that. I imagine that military planners would base their assessments on that advice. For those who really understand probability and are reliant on the data, it will be fundamental to their thinking because they will have to plan more than one scenario if weather dependency is important.

Q166 Stephen Mosley: When it comes to communicating this information to the general public, people tend to read the newspapers and watch the 30-second weather forecasts on the BBC. That level of risk and probability is not put across all that well in this country, unlike in the US. When the hurricane was due to hit New York, I believe that 12 scenarios were broadcast, showing different routes for the hurricane and the different probabilities of each route occurring. Could communication of this detailed information be improved in the UK?
Mr Davey: I know that the Met Office is working with a number of people to consider how best to get over such risks and probabilities. We know that other countries use percentages to get the information across. Broadcasters, who are information providers, want to know how the information that they are communicating is perceived and taken on board. They want to ensure that they get it right. It is important that the Met Office does proper research to analyse it. The Met Office is beginning to use a lot of probability data on its website, including fan charts and so forth. This is the direction of travel, but if we are to move away from, "It is likely to rain", or, "It is very likely to be foggy" or whatever phrase we hear or see now on our TV screens, it needs to ensure that we end up with something with which the British public feel happy.
You are right to raise the question. The Met Office is considering the matter, but I do not pretend to know what the final answer will be. As Minister, I want to ensure that it is done properly so that the general public get the right messages and are able to use them in their daily lives.

Q167 Stephen Metcalfe: Would you clarify what the Government use seasonal forecasts for? It is all very amusing to talk about barbeque summers, but why do the Government need that sort of information, and what do they do with it?
Mr Davey: I can imagine a number of things that they would do with it. The Government do a lot of contingency planning in a whole range of areas. As you can imagine, the contingency planning community will want this data for everything from emergency planning to gritting the roads in the winter. There is a whole range of different things for which you might want seasonal planning as that would change your purchasing decisions and planning.

Q168 Stephen Metcalfe: How do the Government factor in these probabilities? I understand that it is all about probabilities. Indeed, I believe that the barbeque summer was a 60% probability, which of course meant that there was a 40% probability that it would not happen. Who deals with that data, and how are decisions taken on what we should do to prepare for the coming winter, if it is all done on probability?
Mr Davey: Let's remember that it is on probability because that is inherently the case. We do not have perfect foresight. Therefore, it is not a fault of Government that people have to make these judgments.
You have to look at planning as a series of decisions. There are longer-term decisions. Seasonal planning might be a three-month scenario, and you might be thinking about what you need to do to prepare in case a particular scenario happens, but you will be reviewing those decisions the nearer you get to the point. Ultimately, of course, you will be looking at the

next day forecast. If you are one of those clever people in the contingency planning community, you will be thinking about these probabilities over time; your actions will be changing over time, and I should have thought that you will try to avoid spending money until the last possible moment. However, if it is going to be difficult to get resources such as salt at the last minute, you will want to ensure that stocks are ready if the probability of a really bad, severe winter is very high. I am not coming to you as an expert in this, and I am sure that my colleagues in the Department for Transport are much more on top of that usage of seasonal forecasting, but I give that as an example of something that touches on people's lives, and we need to get it right.

Chair: Minister, we are extremely grateful for your time. It has been a fascinating session. Two brains or not, several brains sitting behind you proved incredibly useful. Thank you very much for your attendance.

Written evidence

Written evidence submitted by the Met Office (MO 00)

1. Introduction

1.1 The aim of the Met Office is to provide the UK and its citizens with the best weather and climate service in the world, measured by the usefulness and quality of its products and services and the value for money it delivers. The quality of its services has a direct impact on public safety and national security and resilience.

1.2 International benchmarking of global weather forecasting skill is supported through the UN World Meteorological Organization (WMO). A range of metrics are used which all show that the Met Office is consistently within the top three centres globally. This position has been achieved through sustained investment in research, observations and supercomputing.

1.3 Underpinning this reputation is the delivery of outstanding science and the reliability and continuous improvement of Met Office products and services. This reputation is essential to building UK and international partnerships; which deliver significant cost benefits and enable the Met Office to achieve far more for its customers than it could on its own.

1.4 Weather and climate science is used by Government, emergency responders, commercial companies and the public to inform decisions. It is used as military intelligence to support strategic and tactical operations and by others to manage and mitigate the impacts of natural disasters, at home and abroad. It provides the scientific evidence base for Government policymaking on climate mitigation and adaptation, and informs major national infrastructure projects. Increasingly, it is seen as vital for helping society to be better prepared and become more resilient in a world becoming more exposed and vulnerable to weather and climate extremes.

1.5 Commercial companies depend on weather and climate information to inform a growing range of business and operating decisions—ensuring aircraft have enough fuel to fly safely, informing risk assessments by insurance companies, and supporting energy demand calculations by utility companies.

1.6 The Met Office is unique, globally, in providing both weather and climate advice from a single organisation using the same computer model and drawing from the same scientific, technical and delivery infrastructure. Other countries express a wish to emulate this approach.

1.7 The weather and climate services the Government and public rely on, sit at the cutting edge of the science. The delay between scientific advance and the help it offers, through improved services or policy advice, is very short indeed. The Met Office science programme is therefore very directed and has a high pull through of science into services. In 2010–11, 80% of weather research is estimated to have been used in forecasting with 50% having significant and positive impacts on weather forecast scores.

1.8 The quality of and advances in Met Office science and services depends critically on reliable observations and continuing access to significant supercomputing resources that are robust and available 24/7.

1.9 The impact of weather and climate on public safety,[1] national security[2] and the global economy[3] makes it essential that the Met Office remains at the cutting edge of understanding, modelling and predicting the atmosphere, oceans and full climate system. The Met Office Science Strategy is designed to maintain that position.

1.10 A 2007 assessment[4] of the Public Weather Service's (PWS) contribution to the UK economy concluded that:

(a) PWS delivers an exceptional return on investment—as a conservative estimate it delivers value of £7.40 for every £1 invested;

(b) PWS saves lives—hundreds of lives are saved each year[5] as a result of the services provided;

(c) PWS output is world class—the international meteorological community endorses this quality with numerous other meteorological services licensing the Met Office forecast model; and

(d) greater benefit could be achieved with even more accuracy; the more accurate weather forecasts are, the more likely people are to take action.

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1 For example the floods of summer 2007 resulted in 13 deaths, 7,000 people to be rescued by emergency services and flooding in 55,000 properties.

2 The National Security Strategy describes a major accident of natural hazard which requires a national response as a Tier 1 risk and states that the effects of climate change are likely to become increasingly significant as a risk multiplier, exacerbating existing tensions around the world.

3 For example, it is estimated that severe winter weather in 2010–11 reduced the UK's GDP by 5%, with travel disruption alone costing the UK economy £280 million per day

4 The Public weather Service's contribution to the UK economy: http://www.metoffice.gov.uk/about-us/what/pws/value

5 For example due to initiation of safety policies in industry, improvement of road, flight and marine safety and through the preparation and practice of contingency procedures for national emergencies

1.11 In 2010 the GCSA led a review of Government needs for climate science services over the next decade, and how these can be met.[6] Initial consideration of this was presented in Sir John Lawton's 2009 review.[7] Both reports concluded "*the Met Office Hadley Centre provides essential and world-leading climate modelling services to Government, and that it is uniquely placed to do so. It represents a critical national capability, with a central role of meeting the Government's requirements for climate evidence and advice.*" Both reviews recognise the synergy and efficiency achieved through shared research, infrastructure and capability within the Met Office. In 2009 this was estimated to be worth more than £12 million per annum.

1.12 Sustained investment in research and infrastructure delivers improvements in forecast accuracy, reliability and utility at all lead times and enables even greater economic value to be realised. The Met Office Science Strategy is designed to deliver those improvements and to support and enhance the full range of services the Met Office provides, including the PWS.

1.13 The Met Office believes there is an opportunity to deliver greater economic benefit from the UK's investment in environmental science. Partnership and collaboration with others actively undertaking research in related branches of environmental science will stimulate innovation, enabling improved and more efficient ways of delivering existing services. More importantly it enables the creation of new services designed to address a much broader range of natural hazards, and help the private sector exploit environmental information to advantage. Achieving this goal requires multi-disciplinary research, with scientific experts working with public and private sector partners to co-develop products and services.

2 *How effectively is the Met Office fulfilling its PWS remit?*

What is the Public Weather Service?

2.1 The Public Weather Service accounted for 48% of Met Office revenue in 2010–11[8]. It buys:

- (a) the support, maintenance and operation of the UK's observational network;
- (b) scientific research and development to deliver improved accuracy, longer lead time and more relevant free at point of use weather forecasts and warnings for the public and civil contingency community;
- (c) the real time 24/7 human analysis, interpretation and communication of observations and computer model outputs to generate weather forecasts;
- (d) the support, maintenance and operation of the supercomputer and underpinning IT infrastructure required to produce and disseminate the PWS forecasts for the public;
- (e) international commitments; and
- (f) the National Meteorological Library and Archive.

2.2 The Public Weather Service Customer Group (PWSCG) acts as customer for the PWS on behalf of government (including the devolved administrations and local government) and the UK public. It defines the outputs of the PWS, monitors the delivery of the PWS and where necessary challenges the Met Office and calls it to account. The PWSCG provides an independent and impartial body to balance the tension of public and responders' requirements, the funding available and current Met Office capability. The independent Chair of the Group is appointed by, and reports to, the Minister responsible for overseeing the customer function of the Met Office (Rt Hon David Willetts MP). Each year the PWSCG provides an Annual Report outlining how the Met Office has fulfilled its remit.[9]

2.3 Warnings of hazardous or disruptive weather are provided to the public and Category 1 and 2 emergency responders through the National Severe Weather Warning Service (NSWWS). Further support is provided to local resilience fora, the Scottish Government Resilience Room (SGoRR), COBR and NSC (THRC)[10] through a regional network of Public Weather Service Advisors. The Advisors work with responders to anticipate and mitigate the impacts of severe weather. In other emergency situations, at home or abroad, where weather intensifies the impacts, hamper the emergency response or slow recovery, the Advisors work with the teams involved. In the last year the Met Office has advised on:

(a) Grimsvötn volcanic eruption.

(b) Fukushima nuclear disaster.

(c) Winter weather (Nov-Feb).

(d) Libyan crisis.

(e) August riots.

[6] http://www.bis.gov.uk/assets/bispartners/goscience/docs/r/10–1290-review-of-climate-science-advice.pdf

[7] http://www.bis.gov.uk/assets/bispartners/goscience/docs/s/2009-sir-john-lawton-review-report.pdf

[8] For reference in 2010/11 the Met Office turnover was £196.1 million of which 47.7% was for the PWS, 17.5% from services to MoD, 18.2% for other services to Government—primarily climate science for DECC and Defra and 16.4% was for commercial services. (Met Office Annual Report and Accounts 2010/11 http://www.metoffice.gov.uk/learning/library/publications/corporate)

[9] 2010–11 report: http://www.metoffice.gov.uk/media/pdf/m/5/PWSCG_Annual_Report.pdf
2009–10 report: http://www.metoffice.gov.uk/media/pdf/1/c/PWSCG_Annual_Report_2009–10.pdf

[10] National Security Council (Threats, Hazards, Resilience and Contingency)

(f) Royal wedding.

(g) Pope's visit.

2.4 Warnings and forecasts are communicated through the Met Office website, its iPhone app, Weather Widget and through television and radio broadcasts.

(a) During the cold weather of December 2010 the Met Office website received 40 million visits (12.9 million unique visitors) with 3.6 million visits on just one day.

(b) Since its launch in January 2010, the Met Office iPhone app has been downloaded more than 1.8 million times, and is regularly the top free weather application.

(c) The Met Office Weather Widget is currently embedded in over 2000 other websites.

2.5 Information on the UK's climate is also made available on the Met Office website[11] including written summaries, maps of monthly average temperatures and rainfall, anomalies from long term averages, values for specific locations and records relating to extremes of weather for the UK, England, Wales, Scotland and Northern Ireland.

2.6 Paper based records of the nation's climate are held in the National Meteorological Library and Archive which is open to the public and maintains a comprehensive library collection for general, historical and academic use. The Library and Archive acts as a registered Place of Deposit (under the public records act) for paper-based meteorological records and physical artefacts related to meteorology. There are archives located in Exeter (for England and Wales), Edinburgh and Belfast.

Public awareness and satisfaction

2.7 The PWSCG routinely undertakes public perception surveys to assess satisfaction with the forecast and warnings service. These results are summarised in the PWSCG Annual Report and published on the Met Office website[12]:

(a) the November 2010 survey indicated that nine out of ten people found weather forecasts useful and just over three quarters found them accurate;

(b) warnings of snow and gales are generally considered more useful than warnings of heavy rain;

(c) averaged over the eight surveys conducted following severe weather events in 2010–11, 77% of respondents had seen or heard the warning and of these 89% of respondents found the warnings very or fairly useful;

(d) three surveys were carried out related to warnings for snow in Nov-Dec 2010 (27 Nov, 1 Dec, 13 Dec). In all three cases more than 90% of respondents found the warnings "very" or "fairly" useful.

2.8 Surveys of emergency responders are conducted routinely to assess their satisfaction with the PWS and warnings service. The Feb-March 2011 survey indicated:

(a) satisfaction with the PWS was extremely high with 97% of responders saying they are satisfied and almost three quarters (73%) saying they are "very satisfied". This has increased markedly since 2008 when only 58% of responders were "very satisfied";

(b) 62% of responders were "very satisfied" with the last weather warning received compared to 56% in 2008; and

(c) 90% of responders who have had contact with a PWS Advisor were "very satisfied" with the service provided, compared to 86% in 2008.

Continuous improvement

2.9 The accuracy of Met Office forecasts are evaluated against observations on a daily basis. The PWSCG specify accuracy targets for forecasts of maximum and minimum temperatures, rain, sun, wind speed and wind direction. In 2010–11 all targets were met. As of August 2011, on average (over a 36-month period) the percentage of forecasts accurate to within ±2°C is:

(a) 87.6% of maximum temperature forecasts on the day the forecast is issued (target for 2011–12 85%) and 78.5% of minimum temperature forecasts (target 76.5%);

(b) 81.1% of maximum temperature forecasts on the second day of the forecast (target 79.5%) and 71.7% of minimum temperature forecasts (target 69.0%).

2.10 Improvements are possible by making forecasts more local. In 2010–11 PWSCG tasked the Met Office with increasing the number of UK locations for which it provides forecast from approx. 350 to approx. 5,000 updated hourly. This gives people local weather forecasts to help plan their activities.

2.11 Following the launch of 5,000 sites Mark Smith, Director of Bournemouth Tourism stated that "*These new forecasts from the Met Office communicate weather forecast information in clearer, more appropriate and user friendly ways that allow tourists and tourism operators to better plan activities. As weather is a key driver for tourists, I am sure that this improved communication will have a positive economic impact on our*

[11] http://www.metoffice.gov.uk/weather/uk/climate.html

[12] www.metoffice.gov.uk/about-us/who/accuracy/your-say

industry and will improve the overall quality of life for British residents through more productive use of their leisure time."

2.12 Public consultation also indicated scope to improve how the National Severe Weather Warning Service is communicated, and the service was upgraded in March 2011. The main improvements are:

(a) impact-based alerts and warnings are now based on both the expected weather conditions and the potential impact they may have, recognising that the same weather can have a different impact in different parts of the UK, at different times of the year and depending on preceding conditions;

(b) improved website display—making it easier for the public to find information relevant to them, assess the risk and the option to drill down to more detail; and

(c) easier to understand—warnings have been made simpler and clearer using less technical language and the categories of warnings have been simplified.

2.13 Increasingly, advice is based upon the outputs from multiple forecasts (ensemble modelling)[13] which enable customers and stakeholders to make properly informed decisions based on probabilities and levels of risk. From September 2011 the 5,000 site forecasts will include the probability of rain and in 2012 the Met Office will introduce an ensemble of short range forecasts using the very high resolution UK version of the forecasting system to support the Olympics.

3 *Is the Met Office's Science Strategy 2010–15 robust and achievable and how will the strategy help to deliver a better service?*

3.1 The Science Strategy drives improved capabilities and efficiencies through scientific and technical advancements, by delivering a highly coordinated programme of research and development across weather, climate and marine science. It sets the agenda to meet the challenge of maintaining the Met Office, and indeed the UK, as a world-leader in weather and climate prediction. It drives ongoing development and improvements to its range of services, to deliver more robust advice to end-users.

3.2 The Science Strategy builds on the strong scientific reputation of the Met Office. Its R&D programme has always been, and continues to be strongly directed to improving the quality of its weather forecasts and climate predictions to deliver greater benefits to the UK. This focus is regarded as a major factor in the success of the Met Office and in the world-leading status of the UK in weather and climate prediction.

3.3 The Science Strategy:

(a) develops and exploits the significant synergies that exist in the science[14] and operational infrastructure[15] that underpin all Met Office services;

(b) enables the Met Office to respond to the increasing demand for seamless prediction systems to support planning and adaptation decisions across all timescales from hours to decades;

(c) breaks down the traditional barriers between weather and climate, which are widely recognised as hampering progress;[16]

(d) enables the Met Office to respond to, anticipate and shape the changing requirements of current and future stakeholders and customers; and

(e) recognises and incorporates the excellence of atmospheric and climate science within UK academia and NERC, and in leading international institutions and forecasting agencies.

3.4 The Science Strategy focuses Met Office research around four major cross-cutting science challenges which are designed to drive significant improvements in capability:

(a) longer lead time and more accurate local forecasts and warnings of severe weather, including extreme rainfall and flooding, enabling Government, emergency responders and other organisations to be better prepared and more resilient;

(b) significant improvements in assessments of future changes in weather patterns, especially the intensity and frequency of severe weather events, to enable more robust planning and decision-making around infrastructure investments to adapt to climate change;

(c) more confident regional predictions of changes in the global water cycle to underpin assessments of future challenges to water availability and global food security;

[13] Ensemble forecasting involves running multiple forecasts with slightly different initial conditions or modelling parameters to provide a probabilistic assessment of possible outcomes and risk

[14] The GCSA's report states "The case for the Hadley Centre's continued integration in the Met Office is compelling, given the strong synergies with the public weather service and modelling, and the shared infrastructure and common capabilities which link to this. Significant efficiencies arise from this relationship. It will be important to recognise this synergy and how it can be continued in any discussions about business models for the Met Office as a whole." Whilst the Lawton report states that "The Met Office Hadley Centre estimates that climate model development may benefit from the Met Office's research and development programme to the tune of more than £12 million per annum".

[15] Including 24x7 supercomputing, observations, modelling and forecasting capabilities

[16] Eg Hurrell et al (2009), A Unified Modeling Approach to Climate System Prediction, published in Bulletin American Meteorological Society, doi: 10.1175/2009BAMS2752.1 http://journals.ametsoc.org/doi/abs/10.1175/2009BAMS2752.1

(d) delivery of a comprehensive monthly to decadal forecasting service to enable improved operational planning across all sectors that are vulnerable to variations in weather and climate, especially in the developing world;

(e) ensuring that Government receives the best possible scientific evidence on potential risks of dangerous climate change by maintaining a strong base in climate change detection and attribution, and by developing a world-leading Earth system model; and

(f) underpinning Government policies on climate change mitigation with robust scientific assessment of their impacts at both the global and regional level.

3.5 Two independent groups review the integrity of Met Office science ensuring it is fit for purpose:

(a) The Met Office Scientific Advisory Council (MOSAC) reviews PWS funded science. It is chaired by Professor Sir Brian Hoskins FRS, who is also a Non-Executive Director on the Met Office Board. It comprises leading scientists from UK academia and research heads from leading National Meteorological Services. The Committee meets annually to review progress, ensure research plans address future customer requirements and monitor the effectiveness of collaborations. The Chief Scientist is required to respond to the Chairman's report which is presented both to the PWSCG and the Board.

(b) Climate research is reviewed by the Hadley Centre Scientific Review Group (SRG), jointly owned DECC and Defra and comprising UK and international climate science experts. Membership of the Group is determined by DECC and the current Chair is Professor John Pyle FRS. The Chair of the SRG also sits on MOSAC to ensure cohesion across the entirety of the Met Office scientific research. The Group meets annually and operates in a similar manner to MOSAC.

3.6 In 2009 MOSAC reviewed the Science Strategy. The Chair's report stated "The Met Office is in a unique position to react to the move towards considering the seamless nature of the weather-climate prediction problem and produce a range of services based on predictions for time-periods from hours to a century..... the guiding principle of seamless prediction was very strongly supported. The benefits to the Met Office in terms of both its unity and the mobility around it of its scientists are also significant."

3.7 A year later the 2010 MOSAC Chair's report stated "It is important to keep in mind the full range of challenging and important prediction problems included in the new seamless science perspective: from kilometre scale weather forecasting on hourly time-scales, through the weeks to decades time-scales, and on to century time-scale Earth System/climate projection. The range of talks presented and the discussions stimulated by them showed that the approach to R&D based on the seamless nature of the weather-climate prediction problem is already well embedded and the advantages are starting to be realised."

3.8 The Science Strategy Implementation Plan has since been developed and sets out the target vision, timeline and actions required to deliver the Strategy. Considerable progress has already been made by the Met Office, and partners, in implementing the Strategy and maintaining and building its scientific quality and reputation across its weather and climate science. In 2010, MOSAC "considered that remarkable progress had been made in developing and implementing the new organisational structure" and "recognised the high quality of the science presented to it, the relevance of this science to customer requirements, and the enthusiasm of all those who presented and discussed it".

3.9 Met Office research is now communicated to a general audience through the Met Office website,[17] which describes the science and profiles Met Office scientists.

3.10 At the core of the Science Strategy is the development of much stronger science partnerships. The Met Office recognises that the increasing breadth and depth of the science means that partnering with the best scientists in the UK and abroad will be essential for delivering the range of weather and climate services that will be required in the future. With its expertise in bringing science to market the Met Office has a key role to play in integrating and facilitating research.

3.11 In 2010–11 the Met Office engaged in 165 collaborative science projects, estimated to be worth over £15 million in additional resource, equivalent to a third of the Government-funded Met Office science budget. Formal structures are being established to bring partners' knowledge and expertise through into improved science and services. A new programme on Science Partnerships as outlined in the Science Strategy has been established to coordinate and develop a range of directed collaborative activities, which include:

(a) realising the benefits of the shared dependence on the performance of the Met Office Unified Model (UM) with our international partners in National Met Services[18]. For example, a shared operational seasonal forecasting capability has been agreed with South Korea, which will enable the Met Office to employ a model resolution and ensemble size that would not be possible with UK supercomputing resources alone;

(b) developing the Met Office/NERC Joint Weather and Climate Research Programme (JWCRP) to ensure that the UK's national capability in weather and climate science is sustained. This includes joint research strategies (eg UK Earth System Modelling Strategy) and the development and

[17] http://www.metoffice.gov.uk/research

[18] Current partners are Norway, Australia, South Korea, South Africa, India, New Zealand and the US Air Force.

maintenance of major investments in joint research facilities (eg BAe146 research aircraft). A jointly funded programme, the first of its kind, has been established on the Development of Next Generation Computer Codes. The shared supercomputing service (MONSooN)[19] to support JWCRP collaborative projects has proved highly successful, currently supporting 15 projects involving more than150 scientists. Utilisation is running at 93%;

(c) launching the Met Office Academic Partnership in 2010 to create a cluster of research excellence with the universities of Exeter, Leeds and Reading. Joint Chairs have been funded at each university and joint research plans are in development. In 2010–11 the partnership covered 41 projects worth £1.8 million in additional gearing;

(d) supporting 72 industrial PhD studentships across 15 UK universities.

Further development of the Science Partnerships programme is expected to deliver increasing levels of gearing from national and international collaborations.

3.12 The Science Strategy also addresses the challenges of maintaining and developing the research infrastructure, along with a world-class scientific work-force, required to deliver a world-class service.

3.13 Supercomputing is critical to delivering the Science Strategy and a range of options are actively being pursued. This includes exploring international opportunities (eg in the USA and China) and engaging at a high level in European discussions around future supercomputing initiatives. With NERC, a major project has just been approved which will enable cutting edge research on high resolution climate modelling and scalability of computer codes to address future supercomputer architectures.

3.14 The 2010 GCSA review of Government's needs for Climate Science Service recommended that a step-change increase in supercomputing capacity would be required to most effectively meet the Government's key evidence and advice needs. More recently, the House of Commons Transport Select Committee stated that benefits would be realised if funding was made available for additional supercomputing resources. This would enable the latest scientific capability to be used to deliver scenarios of hazardous weather in the next 20–30 years to inform infrastructure investment decisions, and provide more robust monthly and seasonal forecasts.

3.15 The improvement in service quality delivered through achieving the Met Office Science Strategy will continue to be dictated by how effectively scientific advances are translated into operational capability and improved advice to stakeholders and customers. In 2009–10, 81% of weather research is estimated to have been used in forecasting improvements, with 49% having significant and positive impacts on the weather forecast. In 2010–11 these figures were 80% and 50% respectively.

4 *What are the roles of the Met Office's Chief Scientific Advisor and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?*

4.1 The Met Office does not have a Chief Scientific Advisor in the sense of Government Department Advisors. It has an Executive-level Chief Scientist who reports to the Met Office Chief Executive and Met Office Board. This is a 2* Senior Civil Service appointment.

4.2 The Met Office Chief Scientist has responsibility for leading and delivering the Met Office Science programme, consisting of 490 scientists and a budget of £44.6 million. The Chief Scientist is responsible for setting the strategy, ensuring that the Met Office science programme drives improvements in the quality and reach of the full range of Met Office services, and that the scientific integrity of those services is of the highest standard.

4.3 As outlined in the Science Strategy, in 2010 the Chief Scientist brought together all Met Office science into a coherent programme, establishing a senior management structure and a single administration function. The Senior Management Team is constituted from the Deputy Directors of Foundation, Weather and Climate Science, along with the Heads of Science Administration and Science Partnerships. This has delivered a more flexible structure that enables the Met Office to respond more effectively to emerging issues and Government needs, and to re-prioritise its science and resources accordingly.

4.4 The Chief Scientist is Head of the Science Profession and oversees career development and teaching and learning opportunities. In September 2011 a formal programme of Continuing Professional Development opportunities was established.

4.5 The Chief Scientist and the senior staff ensure the Met Office delivers high quality and timely scientific advice by engaging pro-actively with government departments, industry and the public through a range of channels. Internal structures are in place to ensure that Government requests for advice are dealt with swiftly and that the appropriate scientists are engaged in the process. A senior-level Knowledge Integration post has been established to support DECC and Defra's needs for climate science advice. During hazardous weather, scientists work with PWS Advisors to ensure the advice provided is robust and scientifically sound.

4.6 The Chief Scientist works closely with the GCSA,[20] providing advice and information across the range of Met Office science and services. She ensures that key expert scientists across the Met Office are engaged to

[19] MONSooN provides a supercomputing platform for collaboration with NERC http://www.metoffice.gov.uk/research/collaboration/jwcrp/monsoon-hpc

[20] 8 1:1s with Government Chief Scientific Adviser in 2010–11, plus 26 other meetings and events

support the Scientific Advisory Group for Emergencies (SAGE). Recent examples include representation at the SAGE during the Eyjafjallajökull eruption in 2010 and the Fukushima nuclear incident in 2011. The Met Office provided written and oral briefings to GCSA and Secretary of State for Transport during winter 2010 and the Grimsvötn 2011 eruption.

4.7 The Chief Scientist regularly engages with a range of Chief Scientific Advisors[21] and hosts an increasing number of visits to the Met Office to promote in-depth discussions on specific policy needs. She fulfils high-profile public speaking engagements on weather and climate science, natural hazards and computational modelling. In December 2010, she gave the keynote Frontiers of Geophysics lecture at the American Geophysics Union.

4.8 The Chief Scientist is also instrumental in fostering new collaborations and ensuring effective alignment of research plans with our partners, particularly NERC, ECMWF, UM Partners and WCRP.[22] In 2010 she initiated a partnership with the US NOAA Space Weather Prediction Centre which has resulted in the delivery of operational space weather services in the UK.

4.9 The Chief Scientist and senior staff ensure that high quality, comprehensive and up-to-date advice is provided by maintaining a cutting-edge science base across all key areas, and working effectively with partners to deliver integrated knowledge and services. As part of this process, Met Office scientists engage in international programmes and publish in the top journals:

(a) In 2010, Met Office scientists served on over 180 key national and international committees. These committees set research agendas, influence investment decisions and define the delivery of science to services.

(b) In 2010, Met Office scientists authored 263 papers, 80% of which were co-authored with external partners. These scientists came from 441 different institutions across 44 different countries.

(c) In November 2009, a survey published in The Times Higher Educational Supplement ranked the Met Office Hadley Centre as the world's leading geophysical institution, ahead of Harvard and Princeton, in terms of the influence of its peer reviewed publications. According to ISI Web of Knowledge, the Met Office impact factor ("h-index") of 123 for papers published since 1991 is higher than any other equivalent weather or climate research institute in Europe. A landmark was recently reached when the first Met Office-led paper exceeded 1,000 citations.

(d) The Met Office is providing eight lead author or co-lead authors for the forthcoming IPCC 5th Assessment Report, which will draw heavily on Met Office climate research for its evidence.

5 *How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?*

Weather and climate models

5.1 The Met Office uses fundamentally the same model (Unified Model) across all timescales from daily weather forecasting to centennial climate change predictions, and for all space scales from the local to the global. For forecast lead times of a month or longer the Unified Model (UM) also includes a global ocean model; and for climate change projections, Earth system processes, such as an interactive carbon cycle and atmospheric composition, are included. This is a unique capability that no other National Meteorological Service or research institution possesses and it delivers significant scientific and operational efficiencies and benefits.[23]

5.2 The bedrock of all Met Office modelling and prediction is the weather forecast version of the UM. Its performance is evaluated against observations on a daily basis in weather forecasting mode and its performance monitored and benchmarked against other world-leading models.

5.3 To deliver much finer scale forecasts over the UK, the Met Office uses a system of nested models. In 2009 it introduced a 1.5km resolution model over the UK providing a step change in capability. This made it possible to issue warnings of the 2009 Cumbrian floods 48 hours in advance, enabling much greater preparedness than would previously have been possible. The utility of this model in providing local information on the potential impacts of climate change is being explored.

5.4 Whilst accuracy is clearly important, an operational weather forecast model also has to be robust, run on secure, resilient infrastructure and able to generate outputs fast enough for them to be useful. Typically the delay between the latest observation used in the model and a customer receiving a global forecast has to be less than eighty minutes for it to be useful. This places costs upon an operational centre such as the Met Office and constraints on the formulation of its weather forecast model.

[21] 16 1:1s in 2010–11, 25 external visitors to Exeter including three Secretaries of State and six Chief Scientific Advisors

[22] The Chief Scientist is a member of the NERC Council (Natural Environment Research Council), the ECMWF Science Advisory Council (European Centre for Medium-range Weather Forecasting), and the Joint Scientific Committee for WCRP (WMO/UNESCO/IOC/ICSU World Climate Research Programme)

[23] In 2009 it was estimated that combining weather and climate prediction in the Met Office saved approximately £12 million per annum.

5.5 The skill of Met Office global weather forecast model has improved systematically (Figure 1), with a rate of increase in skill of one day per decade. This means that a three-day forecast today is as skilful as a one-day forecast was 20 years ago. This increase in skill is attributed to more sophisticated atmospheric physics, higher model resolution and more comprehensive observations, especially from meteorological satellites.

5.6 International benchmarking of the performance of global numerical weather prediction systems is supported through the WMO. A range of metrics are used and all show that the Met Office is consistently within the top 3 centres internationally—an example is shown in Figure 2.

5.7 Similar metrics are not yet available for longer range forecasts. This is partly because these forecasts are probabilistic in nature and appropriate methodologies do not yet exist, and partly because verification statistics are much more limited due to the short length of the observational base, especially in the ocean. The quality of its performance against other centres is assured by including the UM in all model comparisons and in the European Seasonal to Inter-annual Prediction (EUROSIP) ensemble of models, and reinforced by its use in other countries (eg Australia and South Korea) as the basis for their own seasonal forecasting systems. The Met Office is one of twelve centres which have been designated by WMO as Global Producing Centres of long-range forecasts.

5.8 The Met Office also participates in objective comparisons of climate model performance, which have been integral to the international community since the first climate models were built. A 2008 paper[24] assessed the realism of such models in simulating the mean current climate using data from the Coupled Model Intercomparison Projects (CMIP) which underpin the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports. It indicates that the skill of all climate models increase notably with time and that the state of the art climate version of the UM was ranked in the top two models for all three CMIP projects.[25]

5.9 The robustness and skill of the UM-based forecasting system is evidenced by the increasing uptake by other National Met Services. The Met Office licences the UM to other National Met Services for operational use; the licence fee is waived if research effort is provided in kind to help improve the model. Current operational users are: Norway, Australia, South Korea, South Africa, India, New Zealand and the US Air Force. This international UM partnership is becoming increasingly important as the operational expertise of the participating members grows, and the model is tested against weather conditions across the world.

Dispersion modelling

5.10 During volcanic eruptions, pollution events and other scenarios when potentially hazardous material is emitted into the atmosphere, the Met Office uses its NAME[26] model to predict how material will be dispersed in the atmosphere and deposited on the ground. NAME uses the weather forecast data generated by the UM, together with estimates of the amount of material emitted, the height to which it is emitted and the size of the particles to estimate the distribution of material. Examples of events in which NAME has been used include:

(a) Pollution resulting from the Kuwaiti oil fires (First Gulf War).

(b) 2005 Buncefield oil storage depot incident.

(c) 2001 and 2007 Foot and Mouth disease outbreaks.

(d) 2008 Bluetongue outbreak over Europe.[27]

(e) 2010 and 2011 volcanic eruptions (Eyjafjallajökull, Grimsvötn, Chile, Eritrea).

(f) 2011 Fukushima nuclear incident.

5.11 It is much harder to verify the accuracy of a dispersion model, because dispersion events occur infrequently and it can be difficult to obtain reliable, quantifiable observations of the distribution and concentration of material. Confidence in the Met Office NAME dispersion model has therefore been established over time based upon subjective comparison of predicted spread of material and observations of the extent of the spread and engagement in intercomparison exercises. These, combined with the knowledge that the input meteorological forecast data are amongst the best in the world, have helped to generate confidence in the model and in the forecasts it provides.

5.12 The 2010 eruption of Eyjafjallajökull sparked considerable interest in and scrutiny of NAME. Since this event a number of papers have been published in the peer reviewed literature that demonstrate the capability of NAME and the potential for further improvements. The Civil Aviation Authority also asked Professor David Fowler FRS to conduct an independent review of the model which concluded that *"the NAME model represents a state of the art dispersion model...The presence of a globally leading UK-based team dedicated to the development and application of a state of the art dispersion model and its application using a state of the art*

[24] Reichler and Kim (2008) How well do coupled models simulate today's climate? Bulletin of American Meteorology Society, 89, 303–311—CMIP 1 (1995) and CMIP 2 (1997) were used in the 3rd IPCC assessment and the UM was ranked first for both intercomparisons, and CMIP-3 (2004) in which the UM was ranked 2nd was used in the 4th IPCC assessment.

[25] The current generation of climate models will form CMIP-5, to be reported in the forthcoming IPCC 5th Assessment.

[26] Numerical Atmospheric-dispersion Modelling Environment model (NAME)

[27] A report by DTZ http://www.iah.ac.uk/ecosoc/docs/Blue-Tongue-case-study.pdf estimated that by preventing a major Bluetongue outbreak from affecting the UK's agricultural sector, the Institute for Animal Health and its partners (which include the Met Office) contribute to protect British farmers from a potential £485 million loss in their annual income as well as to protect 10,000 jobs throughout the UK's economy that would otherwise be lost.

NWP model is considered a high strategic priority for both the development of the science and its practical application to a wide range of scientific issues".

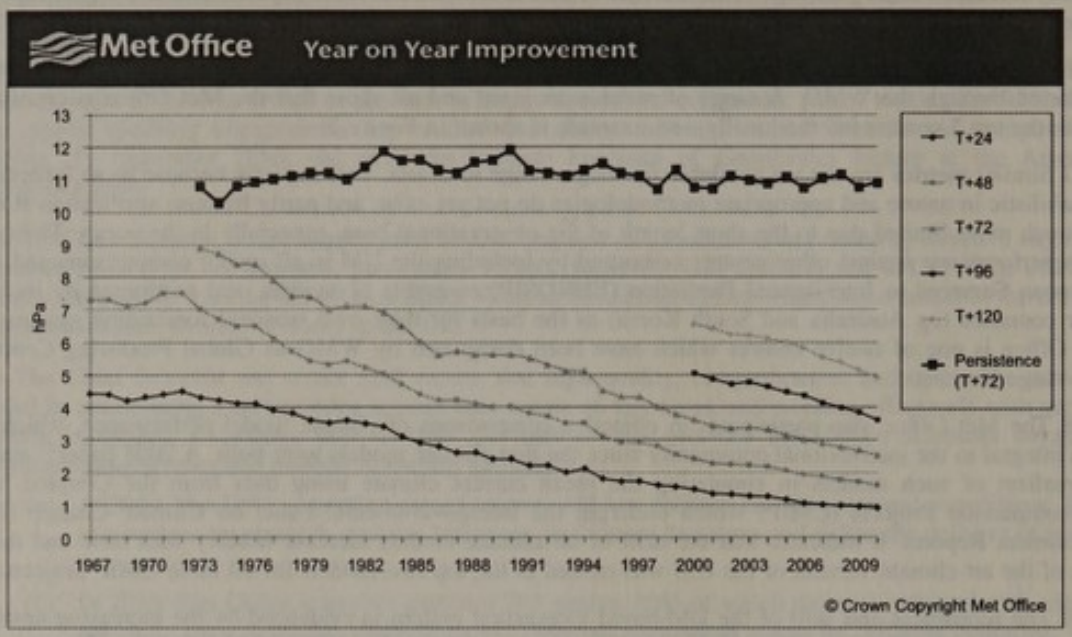


***Figure 1**: 40 year timeseries of Met Office weather forecast skill for surface pressure across the North Atlantic region for forecast lead times of one day (T+24hrs) up to five days (T+12hrs0), and compared with persistence—forecasting the weather will be the same tomorrow as it is today.*

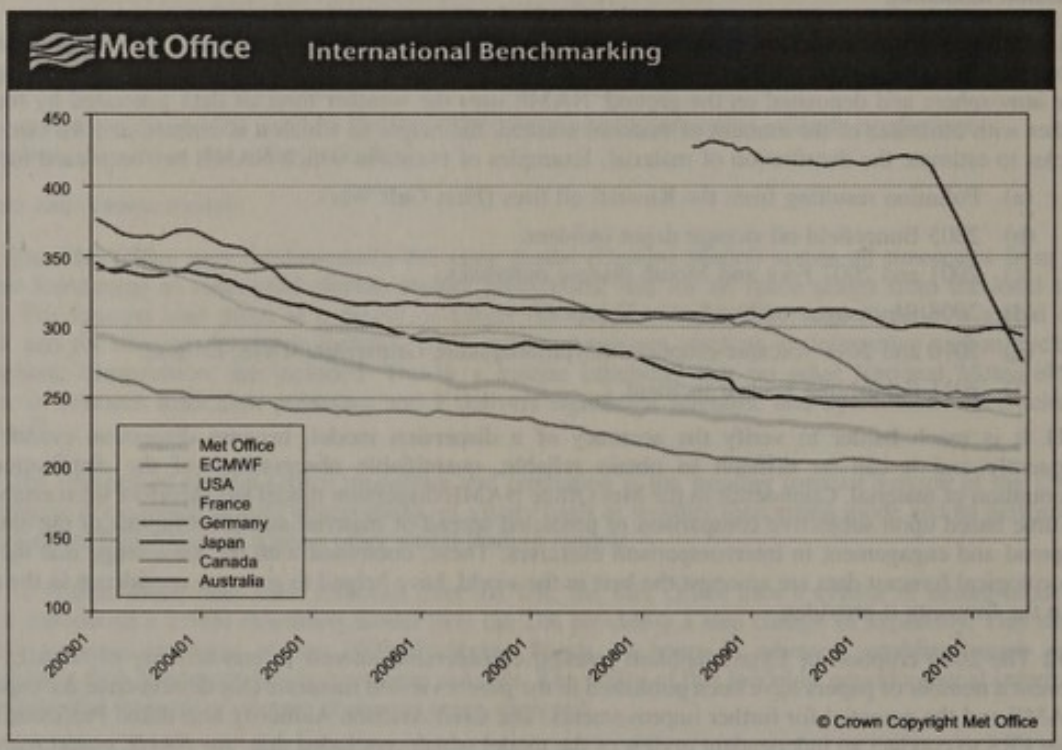


***Figure 2**: 12-month running mean root mean square error of three-day forecast of Northern Hemisphere Mean Sea Level Pressure in Pascals. The lower the statistic, the better the forecast. ECMWF has the lowest error throughout. However, this is offset by the additional time available to ECMWF to produce the forecast. Met Office forecasts are in second place throughout, and have converged on the ECMWF accuracy in the past year or so. The dramatic improvement in the Australian scores over the past year reflects the implementation of the Met Office Unified Model (the gradual improvement is due to the use of a 12-month running mean score).*

6 How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

6.1 As a Trading Fund the Met Office needs to constantly prove the value of its services to customers in both the public and private sector. There is therefore a permanent, constructive tension that encourages understanding of need, realisation of benefit and continuous improvement and innovation. Moreover, given that the Met Office and its services are always in the public eye there is active scrutiny.

6.2 The Director of Government Business is responsible for ensuring Met Office delivers products and services contracted by Government departments and NPDBs, including the PWS and for seeking opportunities to help Government meet its policy objectives through effective use of Met Office science and services. All customers have service level agreements with negotiated delivery schedules.

Coordination of activities with the research base

6.3 The Science Strategy recognises the importance of collaboration and partnerships. Activities with the UK and international research base are coordinated through the Science Partnerships Programme, overseen by the Chief Scientist and Head of Science Partnerships.

6.4 In 2010, Met Office scientists served on 39 committees related to the UK research base. The inclusion of representatives from the UK research community on MOSAC and the Met Office Hadley Centre SRG, along with Met Office Chief Scientist's membership of NERC Council, all help to ensure alignment of scientific strategy.

6.5 Met Office scientists serve on several steering groups for major NERC Research Programmes and increasingly act as key partners within those programmes. The JWCRP has been established to improve coordination and pull-through of NERC and Met Office science. There is also engagement with the EPSRC (eg flood protection) and BBSRC (eg animal health), and more recently with the MRC and the Wellcome Trust on weather, climate and health.

6.6 The Met Office engages strongly with EU Framework Programmes, in several instances providing leadership and management[28]. In 2010–11 the Met Office was involved in 22 FP7 projects with a value of £2.3 million.

Coordinating international activities

6.7 The Head of International is responsible for coordinating activities with international counterparts. The effectiveness of these collaborations is assessed by targets set by the PWSCG for the achievement of international objectives. In 2010–11 the Met Office achieved all of its agreed international objectives.

6.8 International collaboration is essential to provide the observations on which the Met Office depends. Observations are exchanged in real time between the 189 states and territories who are members of the WMO. As a major node on the WMO Global Telecommunications Network the Met Office outputs 6,000,000 messages a day, equivalent to 70 messages a second.

6.9 Within Europe, collaboration also exists through the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) to fund and operate the constellation of meteorological satellites required to provide weather and climate-related satellite data, images and products—24 hours a day, 365 days a year. Intergovernmental arrangements exist between Europe and other countries, including the US, for the real time exchange of weather and climate related satellite data.

6.10 In total the UK generates and owns less than 4% of the observational data on which it relies to deliver the PWS, less than 1% if satellite data are included.

6.11 As part of delivering the Public Weather Service the Met Office represents the UK at WMO, the European Centre for Medium Range Weather Forecasting (ECMWF) and EUMETSAT, with the aim of gaining best value for money from the UK's financial contributions. Membership also places obligations on the Met Office through the convention or treaty of the organisation including payment of the UK's financial contribution.

6.12 The views of the broader UK meteorological community are incorporated into the UK briefings for WMO Congress through a consultation meeting with the Met Office arranged through the Royal Meteorological Society. The UK Space Agency is invited to provide input to UK briefings ahead of EUMETSAT meetings.

6.13 The Met Office plays an active role in WMO and at the 2011 Congress meeting its Chief Executive was re-elected as a member of the Executive Council. He is Chair of the WMO Audit Committee and the Task Group on Continuous Improvement of Processes and Practices, which aims to reduce bureaucracy, improve efficiency, deliver better alignment to regional priorities, and seek partnership with other international organisations so that more money can be focussed on delivery of strategic initiatives and in particular capacity building in developing countries.

[28] For example, ENSEMBLES was a 5-year EU-funded integrated research project coordinated by the Met Office Hadley Centre to produce probabilistic projections of climate for Europe to help inform researchers, decision makers, business and the public.

6.14 The Met Office also participates in a number of the WMO Commissions and Working Groups. It is currently vice chair of the Commission for Aeronautical Meteorology which aims to further the application of meteorology to aviation and works closely with ICAO and IATA. The Chief Scientist is a member of the Joint Scientific Committee which provides scientific guidance for the World Climate Research Programme (WCRP) and consists of 18 scientists selected by mutual agreement between the three sponsoring organisations. The Met Office also chairs the Working Group on Numerical Experimentation (WGNE) which links weather and climate forecasting. Participation in these groups enables alignment of research plans, global collaboration between scientists and intercomparison of approaches and techniques, thus allowing best practice to be shared and improvements made in weather and climate prediction globally.

6.15 ECMWF and the Met Office work closely together in scientific research and model development to maintain their positions as leading global numerical weather prediction centres in the world. Each organisation is represented on the corresponding scientific review committees. For the last three years the Met Office has provided the Chair of the Technical Advisory Committee. The complementary remits of ECMWF and the Met Office are mutually beneficial, and can be shown to help drive excellence in Met Office science.

Coordination of activities with Government and NDPBs

6.16 The Flood Forecasting Centre (FFC), which has been operational since April 2009, co-locates meteorological and hydrological forecasters from the Met Office and Environment Agency in the Met Office 24/7 Operations Centre at Exeter.[29] The FFC was established in response to Sir Michael Pitt's independent review of the 2007 summer floods and has quickly become a key part of flood risk management in England and Wales through improved communication and consistency of weather and flood warnings.

6.17 The establishment of the FFC was an important first step in Government agencies working together to provide joined up scientific advice to Government and emergency responders. However, the Met Office recognises that the response to many other natural hazards requires a joined up approach from a range of Government agencies.

6.18 With this in mind the Met Office has been leading the creation of a Natural Hazards Partnership,[30] with the support of the Cabinet Office Civil Contingency Secretariat. The Partnership is working to deliver cross-partner joined up services making use of shared data, skills and other assets with the aim of improving the communications, preparedness and response capabilities of the UK civil contingency community. The Met Office has also established a 24/7 Hazard Centre with underpinning infrastructure, systems and functionality for Met Office staff and partners to better manage major natural hazard related incidents and their impacts.

6.19 The DFID—Met Office Climate Science Research Partnership was established to work in consultation with African stakeholders to advance the scientific understanding of climate variability and change in Africa, to build capacity in Africa in climate science, and to bring new science into use.

Delivering greater benefit from the UK's investment in science

6.20 There are also significant opportunities for Met Office science to be used to support the global needs of the aid, disaster reduction and insurance communities. The Met Office is leading a consortium, comprising IBM, Imperial College and the Grantham Institute for Climate Change to establish a sustainable business model for the provision of value-added services, standards-compliant data, applications and models through an internet cloud hosted platform, known as the Open Platform. Funding for the initial 15 month project to prove the concept has been provided by the Technology Strategy Board.

6.21 A recent series of Open Platform workshops in the US received a very enthusiastic response. There is considerable interest from the World Bank whose primary objective is to ensure their funding decisions are based upon the best and most current projections of the climate. The Open Platform will facilitate this by providing easy access to both free and premium climate and environmental information via a self-sustaining marketplace which allows users to rate the quality of the data, products, applications and models.

6.22 The Met Office believes there is an opportunity to deliver greater economic benefit from the UK's investment in environmental science. Partnership and collaboration with others actively undertaking research in related branches of environmental science will stimulate innovation, enabling improved and more efficient ways of delivering existing services. More importantly it enables the creation of new services designed to address a much broader range of natural hazards, and help the private sector exploit environmental information to advantage. Achieving this goal requires multi-disciplinary research, with scientific experts working with public and private sector partners to co-develop products and services.

6.23 Most importantly this research needs to be pulled through to routinely deliver products and services. The Met Office has been working to establish an Environmental Science to Service Partnership with other government departments and agencies[31] to help realise this vision. The partnership is very much in its infancy,

[29] The FFC relocated from London to Exeter in 2011.

[30] Partners currently include: British Geological Survey (BGS), Centre for Ecology and Hydrology (CEH), Environment Agency (EA), Government Office for Science, Health Protection Agency, Met Office, National Centre for Atmospheric Science, National Oceanography Centre, Ordnance Survey and the UK Space Agency.

[31] Partners include: Met Office, Defra, EA, NERC—represented by CEH and BGS and Ordnance Survey.

but if given support and encouragement, has the potential to deliver significant benefits, helping to support UK economic growth and continued excellence in environmental science.

The Met Office

The Prime Minister announced on 18 July 2011 that responsibility for the Met Office would pass from the Ministry of Defence to the Department for Business, Innovation and Skills. The Met Office is a Trading Fund, operating independently of either Government Department. The Minister responsible for sponsorship of the Met Office is now Edward Davey MP; with the Rt Hon David Willetts MP responsible for the customer functions, including the customer for the Public Weather Service, receiving advice from the Public Weather Service Customer Group (PWSCG). The PWSCG commissions weather services on behalf of government and the UK public.

Although the Met Office has no statutory responsibility it is identified as the preferred supplier of meteorological information and services under the Civil Contingencies Act.

The Met Office

September 2011

Supplementary written evidence submitted by the Met Office (MO 00a)

Met Office Funding

Met Office Funding Structure

1. The Met Office is a Trading Fund within the department for Business Innovation and Skills. This means the Met Office:

(a) Has no vote funding;

(b) Must cover costs from revenue earned from customers, both government and commercial;

(c) Has a multi-year Return on Capital Employed (ROCE) target from HM Treasury;

(d) Returns profits to owner as dividends.

2. Under the Trading Fund Model the Met Office returns approximately £10 million per annum in dividend. The Met Office commercial business turns over ~£32 million and is profitable and absorbs a share of fixed infrastructure costs which could not be significantly reduced in the absence of commercial business.

Met Office Revenue

3. As the Met Office has no vote funding all of its revenues are secured and managed contractually. These contracts vary in type and length but fall into three broad categories:

(a) Government Customer Service Agreements (CSAs).These are multi-year agreements in place to cover primary Met Office services:

- Public Weather Service (PWS), funded by BIS, the Civil Aviation Authority (CAA) and the Maritime and Coastguard Agency (MCA);
- Defence Service, funded by MOD;
- Hadley Centre Climate Programme (HCCP) funded by DECC and Defra.

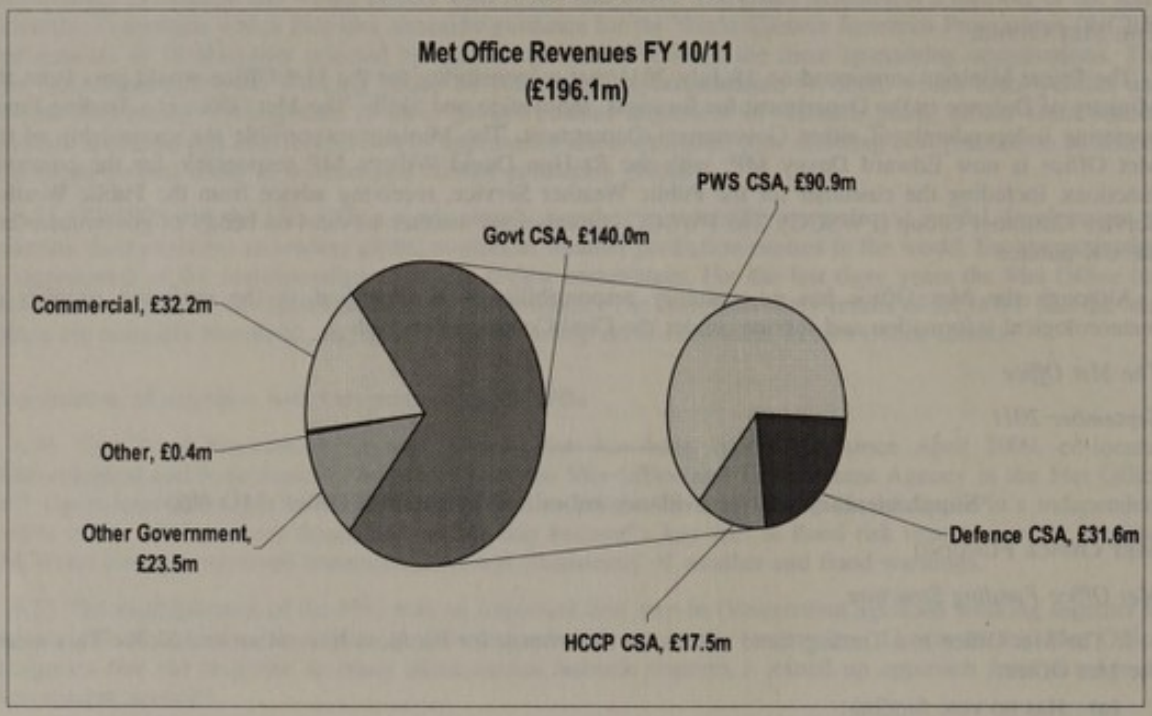
(b) Other Government contracts—numerous contracts to provide specific weather related services and products to government departments, can be competed with other private weather service providers.

(c) Commercial contracts—a diverse range of value added products and services delivered across a number of market sectors with open competition. Services are priced on a value basis.

Figure 1 provides a breakdown of the revenues across the categories.

Figure 1

MET OFFICE REVENUES 2010–11



Met Office Costs

4. The Met Office has a largely static fixed cost base focussed on a few key categories:

(a) Staff Costs—many of the skills required by the Met Office are unique, particularly weather and climate science, weather forecasting and observing. This results in a large number of staff being trained and developed within the Met Office who then remain with the organisation for the whole of their careers. These unique skills and knowledge are not readily available in the UK job market and are difficult to replace.

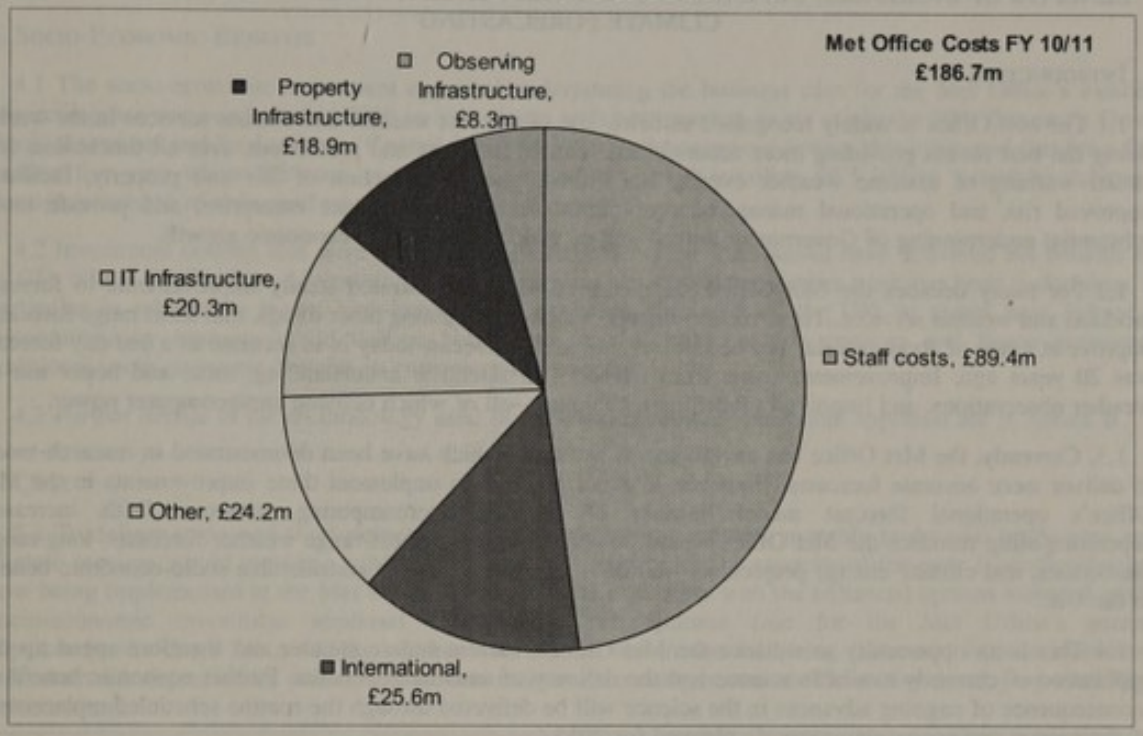
(b) International obligations—the Met Office is the UK representative on a number of international treaties (primarily, EUMETSAT, WMO and ECMWF) and has commitments to satellite programmes of 20+ years. This secures UK access to global observational data and knowledge necessary for it to provide the Government CSA services.

(c) Infrastructure—primarily property, observing infrastructure and IT infrastructure and particularly supercomputing. There are large long-term contracts in place to provide this infrastructure.

These costs are summarised in Figure 2.

Figure 2

MET OFFICE COST BASE 2010–11



Issues

5. The Met Office and the customer departments have secured the Government CSA revenues as far as possible by putting in place multi-year Customer Supplier Agreements which describe the outputs which will be delivered and allow for efficiencies to the benefit of both the customer and the Met Office. The key benefit this provides the Met Office is greater security on its revenues to match the long-term commitment of its resources, infrastructure and cost base. The CSAs are priced in accordance with HMT Fees & Charges guidance (cost plus a 3.5% ROCE mark-up).

6. The CSAs are Intra government agreements and are not legally enforceable. Departments can withdraw the requirement for services and the associated revenue. A recent example of this was on the Defence Research programme which withdrew £4.5 million of funding for the HCCP with only three months notice.

7. Following the withdrawal of MOD funding for the HCCP, Sir John Beddington led a review of UK Climate science needs in 2010, which looked at requirements, funding and governance. The report states "*A key conclusion, and indeed the prompt for the review, is that the existing arrangements have not provided the stability required, and seem unlikely to do so in the future. There are strong arguments for placing resourcing and governance for what is a key national capability on a more sustainable footing, including to facilitate strategic planning and investments. The risk of a continued situation in which the Centre*[32] *lurches from one funding crisis to the next as individual departments, with distributed responsibility, seek to make savings that may not recognise wider Government interests*". Following the Beddington review, DECC and Defra agreed joint management of the HCCP, on behalf of Government.

8. Despite the intention that CSAs should be multi-year agreements, currently only the PWS CSA is agreed beyond FY 11/12 and the security of long term funding for all services other than the PWS remains an ongoing issue.

October 2011

[32] The Met Office Hadley Centre

Further supplementary written evidence submitted by the Met Office (MO 00b)

BENEFITS OF INCREASED SUPERCOMPUTING RESOURCE FOR MET OFFICE WEATHER AND CLIMATE FORECASTING

1. Introduction

1.1 The Met Office is widely recognised as being one of the best weather and climate services in the world. Being the best means providing more accurate and reliable forecasts and predictions over all timescales, and earlier warning of extreme weather events. Both allow greater protection of life and property, facilitate improved risk and operational management of public services and private enterprise, and provide more substantial underpinning of Government policy—all of which contribute to economic growth.

1.2 For many decades the Met Office has measured and demonstrated steady improvements to forecast products and weather services. These measurements demonstrate, among other things, that short range forecasts improve at a rate of about one day per decade, so a three day forecast today is as accurate as a one day forecast was 20 years ago. Improvements come from advances in scientific understanding, more and better use of weather observations, and improved modelling techniques—all of which demand supercomputer power.

1.3. Currently, the Met Office has developments available which have been demonstrated in research-mode to deliver more accurate forecasts. However, it is not possible to implement these improvements in the Met Office's operational forecast model because of limited supercomputing resource. With increased supercomputing resource the Met Office would be able to improve short-range weather forecasts, long-range predictions, and climate change projections—all of which would deliver considerable socio-economic benefit to the UK.

1.4 This is an opportunity to enhance the Met Office's current supercomputer and therefore speed up the application of currently available science and the delivery of associated benefits. Further economic benefit as a consequence of ongoing advances in the science will be delivered through the routine scheduled replacement of the current supercomputer currently planned for 2015.

2. Improved Short-Range Weather Forecasts

2.1 At short range, the following enhancements (in priority order) could be provided with additional supercomputing resource and would enable much more accurate forecasts and warnings to be provided to government and commercial customers and to the public:

- 2.1.1 new capability to run ensemble[33] forecasts at 1.5km resolution, thus better-forecasting areas of embedded convection which result in the highest and most damaging rainfall rates;
- 2.1.2 implementation of more-sophisticated techniques for assimilating the latest observations into the high resolution model (current resources will only allow this to be tested over South East England for the Olympics); and
- 2.1.3 new capability for use during rapidly evolving situations, to introduce hourly forecast updates for very short range customer products issued by the joint Met Office /Environment Agency Flood Forecasting Centre (currently it is only affordable to issue updates every six hours).

2.2 Examples of where these enhancements would deliver improved advice to users, and impact their response, are included in the case studies at Annex A.

3. Improved Operational Monthly to Decadal Predictions and Climate Services

3.1 At longer timescales, increased supercomputing resource would enable models to be run at higher resolution (equivalent to the resolution used for one to five day global forecasting 10 years ago). Increasing the resolution of long range models would yield enhanced forecasts through improved simulation of the important drivers of mid-latitude weather, for example through better representation of sea surface temperatures and more realistic representation of phenomena such as El Nino. Improved advice on conditions over monthly to decadal timescales, including improved information on the likelihood and impact of severe weather events such as snow, heat waves and flooding, would provide more detailed and robust support to contingency planners and, in turn, enable better-informed investment and planning decisions across the public and private sectors, including those relating to resilience investments.

3.2 These opportunities are consistent with the 2010 *Beddington Review*[34] which recommended further investment in supercomputing and associated hardware to meet cross-government needs for climate services.

[33] An ensemble forecasting system samples the uncertainty inherent in weather prediction to provide more information about possible future weather conditions. Rather than producing a single forecast, multiple forecasts (members) are produced by making small alterations to the starting conditions for the forecast. The ensemble forecast system is designed so that each member should be equally likely, so that the ensemble can be used to forecast the probabilities of different possible outcomes. Where all the members in an ensemble are similar the Met Office can be more confident in the forecast; where they differ more account must be taken of uncertainty.

[34] http://www.bis.gov.uk/go-science/science-in-government/global-issues/climate-change

It is also consistent with the case for additional Met Office supercomputing resource submitted to DfT following the Transport Select Committee's Report *Keeping the UK Moving*.[35]

4. Socio-Economic Benefits

4.1 The socio-economic investment appraisal underpinning the business case for the Met Office's existing supercomputer was conducted in 2008 in accordance with best practice as set out in the HM Treasury's Green Book: Appraisal and Evaluation in Central Government. For the approved option, this estimated that for a £50 million five year whole-life cost, net UK socio-economic benefit totalling £0.5 billion would be delivered through provision of enhanced weather and climate services.

4.2 Investment options that were considered unaffordable at the time would have delivered net benefits up to £0.6 billion–£0.7 billion. Moreover, since the appraisal was completed further work has been undertaken, in particular in relation to recent high-impact weather events that affected the UK, to assess how enhanced supercomputing resource could deliver better, more-useful products and services and hence associated additional socio-economic benefits to customers and society.

4.3 Further details of the methodology used in the socio-economic investment appraisal are at Annex B.

5. Cost

5.1 To deliver improved short-range weather forecasts and operational monthly to decadal predictions and climate services would require a supercomputer with at least twice the capacity of the near 1 petaflop facility now being implemented at the Met Office. This would be consistent with the enhanced options included in the socio-economic investment appraisal underpinning the business case for the Met Office's current supercomputer. Costs for a facility of this size are set out in the following table and include associated infrastructure, depreciation, power, service and maintenance charges, and staff costs for developing modelling infrastructure.

Service	*2012–13* £m	*2013–14* £m	*2014–15* £m	*Total* £m
Improved short range weather forecasts	7	7	7	21
Monthly and seasonal forecasts and climate services	7	7	7	21
Total	**14**	**14**	**14**	**42**

6. Supercomputer Architecture Requirements for Operational Weather and Climate Forecasting

6.1 Operational weather forecasting requires direct access to 24/7, resilient supercomputing, with sufficient capacity to deliver forecasts within specific timeframes. For a number of reasons (outlined below) alternative remote supercomputing options, such as third party facilities, grid computing and cloud computing, are not suitable at the current time.

6.2 The time constraints on forecast delivery require model codes to be highly optimised. This benefits both weather and climate operations and research and ensures optimal use of available computing resource—the current mix of operational and research activities leads to very high Met Office supercomputer usage (>95%) delivering real value for money in terms of capital and ongoing energy costs.

6.3 The numerical algorithms which form the basis of weather and climate models place specific demands on supercomputing architectures which differ from those of other sciences.[36] Larger memory per processor, and very fast interconnects between processors, are essential requirements for efficient computation.

6.4 Weather and climate models also produce exceptionally large volumes of data, providing further challenges for machine architecture over and above compute power. Rapid data output transfers are essential to avoid machine latency and the full facility requires direct access to major data archive storage capabilities.

6.5 A separate segment on the Met Office supercomputer[37] provides supercomputing capacity to support joint Met Office / NERC collaborative research work undertaken through the Met Office / NERC Joint Weather and Climate Research Programme (JWCRP). This shared service is proving highly successful for research purposes—currently supporting 15 projects involving more than 150 scientists, with utilisation running at 93%—not least because it provides the weather and climate research community with technology specifically designed to suit its computing problems. This facility will be enhanced as part of the current mid-life upgrade to the existing supercomputer and the Met Office will continue to work closely with NERC to ensure a supercomputing platform for weather and climate collaborative purposes continues to be provided in the most-effective manner.

[35] http://www.publications.parliament.uk/pa/cm201012/cmselect/cmtran/794/79402.htm

[36] This is due to the nature of atmospheric (and ocean) flows and the requirement to draw together information from surrounding grid points in order to solve the physical equations.

[37] Termed "MONSooN" (Met Office and NERC Supercomputing Nodes)

Annex A

CASE STUDIES ILLUSTRATING POTENTIAL IMPROVEMENTS IN SHORT-RANGE FORECASTING OF HIGH-IMPACT WEATHER EVENTS

Case Study 1: Localised Rain and Hail in Ottery St Mary, 30 October 2008

In the early hours of 30 October 2008, an exceptional localised storm produced at least 160mm, and probably over 200mm of precipitation in a 3 hour period, affecting an area of some 10 sq km around Ottery St Mary, Devon. Flooding of up to 1.5m occurred and over 100 people were evacuated from their homes. The longer term impacts and clean-up operation costs were estimated to be about £1 million.

Forecast guidance noted the risk of heavy rainfall in Devon during the six hours prior to the event. However, the amount was in the vicinity of 40mm in 3 hours, much less than that observed. Moreover, the precise development changed from run to run so that without a proper ensemble system it was impossible to judge what level of uncertainty should be associated with these forecasts. Warnings were issued when the storm was identified on radar imagery.

A simulation of the forecast that would have been provided by the 1.5km model 12 hours before the event captured the main elements of the storm, but with a maximum precipitation of about 60mm and a positional error of about 20km. Although more accurate than the 4km operational result, it is unlikely that this additional information, on its own, would have made it possible to issue useful warnings.

An ensemble of simulations using the 1.5km model has revealed that the position of the extreme rainfall was indeed quite uncertain at 12 hours ahead. The ensemble would have given confidence in the level of uncertainty—ie that the southern coastal strip of East Devon was at risk, and that therefore a small group of towns were at risk—from Exmouth to Lyme Regis and inland to Honiton. Later updates would have narrowed this area. A flood risk forecast could have been issued 6 hours ahead and the area most at risk would probably have been narrowed to one or two settlements by 2 hours ahead. Earlier, more precisely targeted flood risk warnings would have enabled at-risk households to have taken precautionary actions, thus preserving property and would have allowed earlier mobilisation of Environment Agency staff to check for blocked watercourses.

Figure

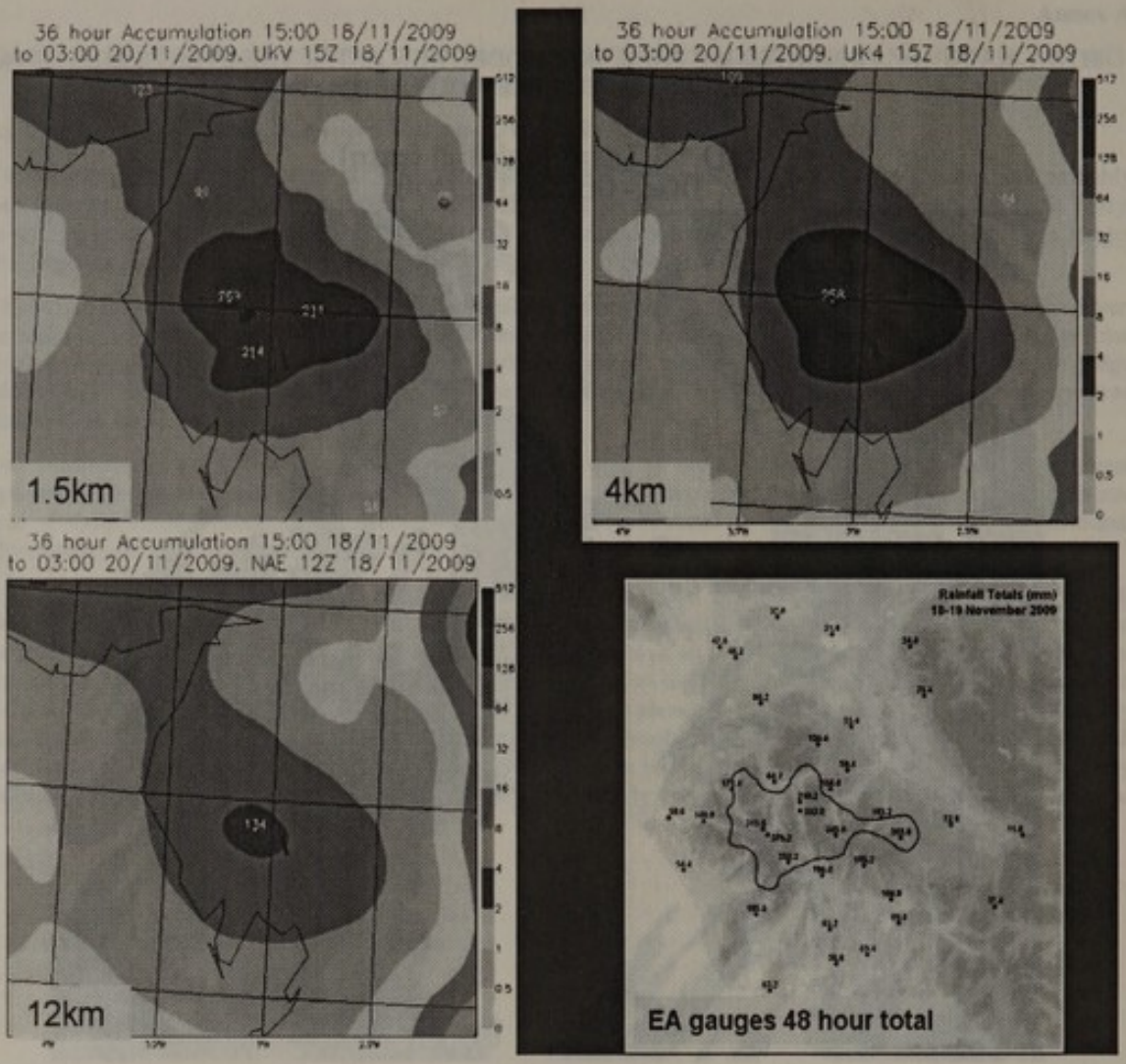
TOTAL RAINFALL PREDICTED BY THE 1.5KM MODEL RUN AFTER THE EVENT FROM DATA AVAILABLE AT 3PM THE PREVIOUS AFTERNOON

CASE STUDY 2: CUMBRIAN FLOODS, NOVEMBER 2009

Extreme rainfall amounts, breaking previous records, fell over Cumbria on 18–20 November 2009 as a result of a depression bringing very warm, moist tropical air north-eastwards across the UK. Rainfall amounts were very strongly enhanced by uplift over high ground resulting in totals of more than 300mm recorded at locations in the Lake District.

General forecasts for this event were very good with an extreme weather warning issued through the Met Office National Severe Weather Warning Service more than 24 hours ahead of the event.

The 1.5km model was available in trial mode at this time, and the results are shown below. While the difference from the 4km model on the left appears modest (10mm in the maximum), the detail in the shape of the 128mm precipitation contour is crucial for determining which rivers will flood and by how much. At this stage, however, the uncertainty in the detail of the distribution is unknown. An ensemble capability and frequent updates of the 1.5km model, coupled to a river flow model, would enable proper risk assessments to be made for the rivers and the potential impacts on communities, enabling confident early warnings to be issued to emergency services and the public.



Case study 3: Snowstorms, February 2009

The main snowfalls occurred in the period 2–6 February. On 2 February, initial falls of 10cm in central London and up to 30cm in the suburbs seriously affected transport into the capital. Later falls of snow caused major disruption in many parts of the country. The final fall on 6 February produced localised accumulations in Devon that resulted in many motorists being stranded overnight on the A38/A380 south of Exeter.

The initial snowfall in London and the South East was very well forecast, and an extreme weather warning issued (one of only two in 2009—the other being for the Cumbria floods). The subsequent snow falls were also well forecast in general. However, the localised nature of the event west of Exeter was too small to be adequately captured by the forecast models available at the time.

While the overall performance was good, assessment of the risk in the early stages was limited to county-scale information because of the resolution limitations of the medium range forecasts two to three days ahead of the event. With higher resolution ensembles at these ranges, the features of the Downs and the urban areas would have been better resolved and could have permitted more focussed warnings. The Exeter case has not been simulated with the 1.5km model, but performance in other case studies indicates that the better resolution of the steep orography to the west of Exeter would have led to better forecasts of the local conditions.

Case study 4: Heavy Rain in Dorset, 18 August 2011

Intense, short-duration and localised downpours affected parts of Dorset on 18 August 2011. A number of localised incidents of surface water flooding were reported, resulting in the Fire Service dealing with over 100 incidents in a 2 hour period.

While the deterministic 1.5km resolution UK forecast model output provided some indication of heavy rain to occur over parts of southern England up to two days in advance, significant differences from forecast run to run lead to considerable uncertainty in the location of the heaviest rain. A low confidence "Extreme Rainfall Alert" was issued on the morning of 18 August, indicating a 20% risk of 50mm rainfall across parts of Dorset over a 6 hour period. The short lead-time warning and low confidence is very likely to have contributed to limited preparedness.

Investment in enhanced supercomputing power would have enabled a number of high resolution ensemble forecasts to be run. Running multiple forecast scenarios for this event would have provided forecasters with improved indications of the probability of severe rainfall across southern England, by sampling the uncertainty in the initial conditions and reflecting the chaotic nature of convective weather systems. This would probably have allowed more confident warnings, better indications of possible peak rainfall intensities, and longer lead time information on the potential risk, to be issued.

Annex B

SOCIO-ECONOMIC VALUE OF THE CURRENT MET OFFICE SUPERCOMPUTER

1. Government policy setting out how the costs of public sector investments must be justified in terms of their likely socio-economic benefits is set out in HM Treasury's *Green Book*. The appraisal in the Met Office's 2008 supercomputer Business Case complied with this policy and was approved by MoD's Chief Economic Adviser.

2. Since the primary beneficiary of the improved products and services underpinned by the supercomputer is UK society (albeit that climate information has global benefit), the investment appraisal captured benefits to UK society rather than benefits to the Met Office or benefits to MoD.[38] More-powerful supercomputing capability enables both enhanced Public Weather Service (PWS) and climate science products. Socio-economic benefits attributable to each service sector were quantified separately.

3. The PWS methodology estimated the benefits that would accrue through higher quality and more-timely *actionable* information for decision-makers[39] made possible with improved supercomputing capability. A five-year NPV[40] was calculated for several supercomputing options (varying in price) over a baseline of maintaining current functionality. The methodology followed these steps:

(a) A single benefits sector, flood damage mitigation, where it is possible to quantitatively estimate the economic benefit of extended lead times of high impact weather warnings, was selected;

(b) The supercomputer upgrade enables an enhanced suite of Numerical Weather Prediction (NWP) models to be run and therefore allows the Met Office to issue actionable warnings at longer lead times. Lead times were estimated for each supercomputer upgrade option and converted to an economic benefit for the flooding example;

(c) The total socio-economic value to the UK and the associated uncertainty in this value was then estimated using Monte Carlo analysis,[41] varying the following assumptions within reasonable bounds:

  (i) the economic benefit of each supercomputer upgrade option;

  (ii) the percentage attribution of the economic benefit to the Met Office;

  (iii) the percentage of the Met Office's economic contribution attributable to supercomputing;

  (iv) the number of additional sectors which may benefit to the same degree as the flooding sector—while it is possible to name many,[42] the total number of benefit sectors including flooding was assumed, prudently, to be in the range 1 to 3, with an expected number of 2.

4. The Monte Carlo approach described above gave an estimated mean NPV benefit of £341 million for a TCO[43] of £25 million, a ratio of 13:1.

5. The climate science methodology was developed by Dr Chris Hope,[44] a contributor to the *Stern Review on the Economics of Climate Change*[45] and uses Monte Carlo analysis to assess the benefits of reducing uncertainty in the future climate sooner rather than later. Hope allowed a number of parameters (such as climate sensitivity to CO_2 rises and impact costs of adapting to climate change) in his analysis to vary across a range of values and re-ran his model thousands of times whilst randomly varying these parameters within plausible probability distribution functions. The result was a probability distribution of likely economic benefits of reducing uncertainty earlier. The analysis estimated NPV benefits of £165 million for a TCO of £26 million, a ratio of 6:1.

6. The aggregate benefit ratio was 10:1 (£506 million benefit for £51 million TCO), calculated by combining the PWS (13:1) and climate science (6:1) ratios.

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[38] The Met Office's Owner in 2008.

[39] including the public, emergency responders and politicians.

[40] Net Present Value

[41] *Green Book* page 87: "Monte Carlo analysis allows an assessment of the consequences of simultaneous uncertainty about key inputs, and can take account of correlations between these inputs. It involves replacing single entries with probability distributions of possible values for key inputs. Typically, the choice of probabilistic inputs will be based on prior sensitivity testing. The calculation is then repeated a large number of times randomly (using a computer program) to combine different input values selected from the probability distributions specified. The results consist of a set of probability distributions showing how uncertainties in key inputs might impact on key outcomes".

[42] Eg chemical, biological, radiological, nuclear (CBRN) incidents, outbreaks of foot and mouth and blue tongue disease, aviation safety and efficiency, wind-storm damage, road and rail transport, maritime safety, utility company operations.

[43] Total Cost of Ownership ie annual depreciation and running costs.

[44] http://www.jbs.cam.ac.uk/research/faculty/hopec.html

[45] http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/sternreview_index.htm

7. The appraisal also showed that more-expensive supercomputer upgrade options (unaffordable at the time) would have delivered additional socio-economic benefits.

November 2011

Written evidence submitted by Professor John Pyle (MO 03)

DECLARATION OF INTEREST

I am the 1920 Professor of Physical Chemistry at the University of Cambridge and a Co-Director of NERC's National Centre for Atmospheric Science (NCAS). I chair the Met Office Hadley Centre Scientific Review Group and am a member of the Met Office Scientific Advisory Committee. I was a member the committee chaired by Sir John Lawton which recently reported on the Hadley Centre.

I have a long-standing, successful collaboration with scientists at the Met Office to develop and exploit atmospheric chemistry schemes within the Met Office climate model. The nature of research is such that I am also in competition with scientists from the Met Office.

The views I express are my own. I will confine my comments mainly to the area of climate research.

OVERVIEW

1. The Met Office Hadley Centre (MOHC) is a world-leading climate research centre—one of very few—with a justifiably outstanding reputation. Its research has been prominent in the various reports of the Intergovernmental Panel on Climate Change (IPCC); scientists from the MOHC have played leading roles in all the IPCC reports. The MOHC Scientific Review Group, which I now chair, has consistently been impressed by the wide range of world class climate science being performed and considers it "fit for purpose" to support UK Government policy needs in the climate agenda. The MOHC is excellently placed to continue to develop its world class climate capability.

Is the Science strategy robust and achievable?

2. The scientific foci in the science strategy address important and developing themes in the global weather/climate research agenda. There is a clear policy/societal need to understand climate change and variability at small spatial scales and on times scales from years, through decades to centuries. Delivering this understanding is a central part of the strategy. The emphasis in the strategy on Earth system processes is also a necessary advance on previous work; understanding how the climate system could change involves more than an understanding of meteorology and physical oceanography. Chemical, biological and cryosphere process are also key.

3. The MOHC rightly recognise that collaboration, eg in Earth system modelling, is essential. They are unlikely ever to have in-house, world class expertise in all these science areas so that developing appropriate collaborations is crucial (see 8).

4. A key part of the strategy is the restructuring of Met Office R&D. There seem to have been various attempts at reorganisation in recent years. This looks to be a good model but only time will tell. I particularly welcome the establishment of a Foundation Science directorate. This looks to be an excellent development and one that could ease some of the tensions in developing a single Unified Model, which is used for both weather forecasting and climate research.

5. The strategy draws attention to the need for substantially increased computing power. The MOHC Scientific Review Group has expressed concern that the Met Office have slipped down the league table in terms of its computing resource; the funding to maintain a higher rank has not been obtained. It is impossible to deliver world class weather and climate science without access to adequate computing capacity. The levels of funding for high performance computing will be a concern in the future.

SENIOR SCIENTISTS

6. I have found a very positive attitude from senior scientists at the Met Office to the development of an optimal relationship with academic scientists (see 8–9). They have also been extremely responsive to comments, suggestions and any criticism from the MOHC Scientific Review Group.

THE MODELS

7. The Met Office modelling strategy revolves around the use of the Unified Model, in principle a flexible modelling system that can be used to do modelling from very short spatial scales—local weather—through regional weather forecasting to global climate predictions. In all these areas the Met Office model is very highly regarded and in many is world leading.

Collaboration

8. The Met Office and NERC, representing mainly the academic community, have recently entered into a collaboration agreement via the Joint Weather and Climate Research Programme (JWCRP). This aims to build joint research activity in a number of areas, including climate. Earth System modelling is an area where the Met Office needs these collaborations in order to maximise its scientific impact. The intentions of JWCRP are excellent but it would be foolish to underestimate some of the practical difficulties, for both parties. Collaboration will likely entail some loss of sovereignty; effective management of joint programmes will be a challenge. While collaboration between individuals is a longstanding feature, this more institutional collaboration is to be welcomed and encouraged.

9. Among the practical issues being addressed through the JWCRP, there are a number which relate to modelling. The MONSooN project allows Met Office and NERC scientists to work on the same computer codes by sharing a machine hosted in Exeter. This is a major advance allowing much more effective collaborations. Previously (partly due to security issues) work had to be carried out on different computers, using, inevitably, slightly different codes. This made, for example, joint model development a very slow, frustrating and cumbersome affair. I welcome MONSooN enthusiastically; I would like to see it expanded.

10. The Unified Model architecture is often difficult to negotiate and many UK academic meteorologists employ other, easier-to-use numerical models for specific research projects (eg mesoscale modelling). The Met Office needs to consider this seriously. I believe the intellectual exchange with the academic community will be increasingly important for the Met Office; if instead, UK academics use other, rival models, this will certainly be to the detriment of the Met Office, and UK science, in the medium and longer term. More thought needs to be given to making their models "user friendly".

Other

11. World-wide there is a momentum towards "climate services". Definitions vary but this would include the provision of a wide range of climate information to a number of different customers. There are still many major challenges in climate science, which the Met Office strategy properly recognises. I am concerned that a premature commercialisation of climate science could distract the Met Office from its core activity, as detailed in the strategy. There is, of course, increasing pressure on the Met Office to attract non-government funding. There needs to be continued scrutiny to ensure that the balance is correct and does not detract from delivery of the Met Office's public service function.

Professor John Pyle

September 2011

Written evidence submitted by the European Centre for Medium-Range Weather Forecasts (MO 04)

European Centre for Medium-Range Weather Forecasts

1. The European Centre for Medium-Range Weather Forecasts (ECMWF) is an international intergovernmental organisation supported by 34 States, including the UK, based in Reading UK where it employs about 240 staff and houses a state-of-the art supercomputer and data storage facility.

2. ECMWF was established in 1975 in recognition of the need to pool the scientific and technical resources of Europe's meteorological services and institutions for the production of medium-range weather forecasts and of the associated economic and societal benefits. Medium-range refers to time periods of three to 10 days ahead; however, increasingly, extended forecasts are being produced for monthly to seasonal time-scales.

3. ECMWF's annual budget of about £40 million is funded almost entirely from annual contributions from the Member and Co-operating States according to a scale based on their gross national income. The UK contributes around 16% of the ECMWF budget.

4. ECMWF is the acknowledged world-leader in global medium-range numerical weather prediction, the advanced computer observation-analysis modelling technique used to predict the weather. It has a wide-ranging programme of research and development as well as an operational capability that produces weather forecasts every day that are sent to Member State national meteorological services (in the UK, the Met Office) for their use.

5. ECMWF provides specialist training for scientists, forecasters and technicians including those from the Met Office. It also provides employment opportunities including for UK meteorologists, computer technicians and administrative staff.

6. The Director-General of ECMWF is Professor Alan Thorpe who took up his role on 1 July 2011 after previously being Chief Executive of the UK's Natural Environment Research Council and the Chairman of the Executive Group of Research Councils UK.

ECMWF Submission to the Inquiry

How effectively is the Met Office fulfilling its Public Weather Service remit?

7. ECMWF provides the Met Office with medium-range weather forecasts from which its forecasters can produce forecast products for their customers including the public. As ECMWF is the recognised world-leader in medium-range prediction, this assists the Met Office in delivering the best possible forecasting information to its users. All global weather prediction models are routinely evaluated by the World Meteorological Organisation using independent and objective measures of skill; the ECMWF and the Met Office models are in the world-leading category.

Is the Met Office's Science Strategy 2010–15 robust and achievable and how will the strategy help to deliver a better service?

8. The Met Office has a justified worldwide reputation for the scientific quality of its research and development in meteorology, climate change and weather forecasting. It has many well-respected scientists who publish their research in the international peer-reviewed literature. The new Science Strategy reflects well the key areas of development needed to maintain the Met Office's position within Europe and worldwide as a leading national meteorological service.

9. There is a fundamental need for national and international partnerships to achieve the scientific advances required to improve weather forecasts; no national meteorological service can deliver what is needed on their own. The Met Office Science Strategy recognises this need.

10. Met Office scientists collaborate extensively both nationally with the NERC-funded academic research community and internationally both in Europe (such as with ECMWF) and worldwide. This is an extremely effective way in which the required science can be drawn into the Met Office to improve their models and services. An example is the four-dimensional variational data assimilation method developed at ECMWF, which has since been used by the Met Office.

11. In particular, the Met Office and ECMWF collaborate very effectively together on the science of weather prediction with many joint projects, exchange of staff and participation in training and workshops.

What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?

12. One role of the Met Office Chief Scientific Adviser, Professor Julia Slingo, is as a current member of the ECMWF Science Advisory Committee (SAC). Other senior scientists from the Met Office have also in the past been members of the SAC as well as other ECMWF advisory bodies. The SAC brings together Europe's leading scientists to discuss the science of weather prediction and to advise ECMWF on its draft programme of scientific activities including new lines of enquiry to take and on research developments.

How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?

13. There are extensive objective international comparisons carried out continuously regarding the skill of global numerical weather prediction models from the Met Office and the other major international forecast centres, including ECMWF. The ECMWF and the Met Office models are in the world-leading category. Over the last thirty years the skill of such weather forecast models has improved very significantly, including over recent years.

14. Regarding climate change, the Hadley Centre is acknowledged as the world leader on climate change modelling, projections and attribution. ECMWF is involved in climate monitoring using re-analysis techniques but otherwise it is not involved in climate change activities.

15. The Met Office has its own regional modelling capability that is used for forecasting fine-scale detail of UK weather over the period up to two days ahead. This capability is recognised internationally as being at the cutting-edge of short-range weather prediction. (Note: this is outside of the scope of the European coordination on global medium-range forecasts associated with ECMWF.)

How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

16. The UK, via the Met Office, is a Member State of ECMWF, which is a key component of what is known as the "European Meteorological Infrastructure". This infrastructure coordinates meteorological activities in Europe for the benefit of the national meteorological services by increasing effectiveness and efficiency. The Met Office is a member of all the ECMWF advisory committees and of its Council.

17. The Met Office has helped ECMWF and EUMETSAT (that provides the coordinated European weather satellite network) to become European success stories. This in turn has helped the Met Office to excel at what it does.

18. The existence of ECMWF and its operational medium-range weather forecasts, which are provided to the national meteorological services of its Member States, means that these services can focus on activities related to tailored products and services for their customers. This contributes to the effectiveness and efficiency of national meteorological services within Europe, including of the Met Office.

European Centre for Medium-Range Weather Forecasts

September 2011

Written evidence submitted by Professor Sir Brian Hoskins CBE, FRS (MO 06)

BACKGROUND

Professor Sir Brian Hoskins CBE, FRS.

Director of the Grantham Institute for Climate Change, Imperial College, London.

Professor of Meteorology, University of Reading.

I have performed meteorological research over a period of more than 40 years and have had extensive national and international research and research organisation experience.

I am a Fellow/Member of the National Science Academies of the UK, USA and China.

I am also on the UK Climate Change Committee.

DECLARATION OF INTERESTS

I have been on Met Office science review/advisory committees for more than 25 years. I am now a Non-Executive Director of the Met Office and have chaired its Science Advisory Committee (MOSAC) since its inception 15 years ago.

EVIDENCE

1. Despite my significant and increasing involvement with the Met Office over a 30-year period, I continue to maintain my independence from it. Based on my general experience, as well as my knowledge of Met Office science and its application, I would be happy to answer any questions if asked by the Committee. Here, rather than direct my comments to the specific matters raised in the ToR, I will make a few quite general comments which I hope will be helpful to the Committee in its deliberations and indicate which of the matters they are relevant to.

2. The Met Office would be in the top two or three in the world of almost anyone's lists for weather forecasting and for climate change projection. An important enabling component for this achievement has been its performance of a body of high quality research in both areas and, more recently, its collaboration with others, particularly the academic community in the UK. *(Relevant to #1, 2, 4, 5)*

3. To provide the weather and climate services required by the Public and the Government, and to achieve the financial targets set for the Met Office, it is essential that it maintain its programme of high quality scientific research and collaboration. The 2010–15 Science Strategy of the Met Office aims to ensure this. *(Relevant to #1, 2, 4, 5)*

4. For a number of years some of us have been promoting the benefits of considering the Seamless Weather-Climate problem: prediction on time-scales from hours up to a century and space-scales from kilometres to global. The Met Office is uniquely well-placed in the world to realise this approach because it has both weather and climate in its remit and because it has developed an overall modelling system that it can apply to all time scales. I welcome the fact that this aspect has a central role in its Science Strategy. *(Relevant to #1, 2, 4)*

5. Given the public, user and financial pressures on the Met Office, it is important that in both its long-term strategy and shorter term response to demands, the Met Office does not indicate or promise an actual or potential predictive capability that is beyond what is suggested by current scientific understanding. An important aspect of this is the need to articulate the uncertainty that is inherent in predictions made on all time-scales, and to encourage its "customers" to accept this and to fully exploit the available information. *(Relevant to #1, 2, 4, 5)*

6. In recent years there has been a great improvement in the Met Office's R&D collaboration, both nationally and internationally. In the UK a unique Met Service-Academia/NERC partnership is developing. The international use of the Met Office global weather forecast and regional climate models is also an important new development. The requirement on the Met Office to gain financial reward from its products could be damaging to collaboration, an aspect that needs to be carefully watched and handled. *(Relevant to #2, 5)*

7. The Met office Scientific Committee (MOSAC) was set up 15 years ago when the then Chief Scientist sought independent advice, following the change to Trading Fund status and the demise of the previous research overview process. The reporting of its findings by MOSAC has evolved over the years. The procedure now is

that a Report from me as the Chair is agreed by the Committee and is presented by me to the Met Office Board and discussed by it. A written response from the Chief Scientist is sent out to the Committee following this Board meeting. *(Relevant to #1, 2, 4, 5)*

8. Throughout its existence, MOSAC has been notable in a number of ways. Its membership comprises top atmospheric science academics in the UK and the equivalent of chief scientists from a number of Met Services around the world. Its discussions have been very open on both sides, and the discussion by MOSAC has been probing but supportive. Recommendations made by MOSAC appear to have always been considered carefully by the then Chief Scientist and the majority have been acted upon by the Met Office. *(Relevant to #1, 2, 4, 5)*

9. As the atmospheric scientist on the Met Office Board, I act on behalf of it to agree with the Met Office the technique the application of it for setting its annual weather forecast targets. I then advise the Board on the acceptability of the proposed targets. This process has led to significant modification of those targets in some years. *(Relevant to #1)*

Professor Sir Brian Hoskins CBE, FRS

September 2011

Written evidence submitted by the National Oceanography Centre (MO 09)

1.0 About Us

The National Oceanography Centre www.noc.ac.uk was formed on 1 April 2010 by bringing together into a single institution the Natural Environment Research Council's activity at the National Oceanography Centre, Southampton (NOCS) and the Proudman Oceanographic Laboratory (POL) in Liverpool. The NOC works in close partnership with the wider marine science community to create an integrated research capability. Research priorities include the oceans' role in climate change, sea level change and the future of the Arctic Ocean.

2.0 Declaration of Interests

The National Oceanography Centre (NOC) and our parent body, the Natural Environment Research Council (NERC), have a long-standing close scientific collaboration with the Met Office including secondment of staff, research contracts, shared ocean and atmospheric modelling activity and joint location of facilities, for example the Met Office ocean scientific moorings team and specialist facility is based at the National Oceanography Centre in Southampton. This team is responsible for a network of marine observing equipment, including nine moored buoys which provide early warning of severe weather conditions, and technical support for drifting buoys and Argo float deployments. The team have collaborated with NOC scientists participating in the Rapid Climate Change and Porcupine Abyssal Plain observatory programmes. In addition, Professor Julia Slingo is a member of the NOC Advisory Council, and NOC director Professor Ed Hill had a reciprocal role at the Met Office Hadley Centre.

3.0 Responses to questions raised by the Committee

3.1 *How effectively is the Met Office fulfilling its Public Weather Service remit?*

3.1.1 The Met Office is certainly able to produce short-range weather forecasts of sufficient accuracy for "the UK public to make informed decisions about day-to-day activities". It is able to warn people and organisations about extreme weather with adequate warning to protect life, property and infrastructure. It is only able to do this through continued access to high quality staff, computing infrastructure, and observations from a wide array of platforms and sensors located in space, the atmosphere, the sea surface and below the sea surface (ie the "Argo" network). Many of these platforms are expensive to buy and operate, but the value of the lives and infrastructure that they protect—a single example would be by providing warning of storm surges for London—vastly exceeds the cost of acquiring data. See for example:

http://www.nerc.ac.uk/using/casestudies/documents/storm-surge-report.pdf

3.1.2 Improved fine-scale modelling and understanding of fundamental processes should lead to enhanced accuracy and robustness of regional forecasts. This should benefit the insurance and re-insurance industries who need probabilities of extreme events for their insured losses on timescales of one to two years ahead. There is a common public perception, however, that the Met Office does not provide reliable *seasonal* forecasts, largely due to sensationalist media reporting and shortcomings in how "probability" and "risk" are understood by non-experts. However in contrast to this public perception, significant spending decisions are made based on seasonal forecasts, ranging from a farmer's choice of crop to major construction projects. Private weather forecasting companies are now often called upon to make these seasonal predictions, suggesting that this is an aspect of the Public Weather Service remit where the Met Office service could be improved. The accuracy of forecasts by these private companies needs to be carefully evaluated on a long-term basis. On individual occasions it is quite likely that a private forecaster may outperform the Met Office. Also, the accuracy of the Met Office forecasts should be compared with other national weather agencies. There is also the problem of communicating the forecast. Most of the public perception is via TV broadcasts but the time available for the

information to be presented has been shortened. However, more detailed information is available than used to be the case, so the forecasters and weather presenters have difficult choices to make about what to concentrate on.

3.1.3 The Met Office is demonstrating steady improvement in weather and climate predictions through research. For example the improved understanding of the location and duration of slow-moving heavy precipitation events, or intense rainfall from convective rainstorms such as Boscastle, is a result of improved modelling skill, the use of ensemble short-term predictive systems, and investment in supercomputing infrastructure.

3.1.4 Access to historical weather information is good, with straightforward access via the web portal. The Met Office website also provides a large amount of useful information on daily weather with the ability to select specific regions of the UK. Attempts should be made to widen its use among the general public; it contains much more information than the BBC.

3.2 *Is the Met Office's Science Strategy 2010–15 robust and achievable and how will the strategy help to deliver a better service?*

3.2.1 The Met Office Science Strategy 2010–2015 is a comprehensive, robust and achievable strategy that is welcomed by the science community at the National Oceanography Centre. The proposed four main priorities of Forecasting Hazardous Weather from Hours to Decades; Water Cycle and Quantitative Precipitation Forecasting; Monthly to Decadal Prediction in a Changing Climate; and Sensitivity of the Earth system to Human Activities provide a wide spectrum of research expertise to meet the challenges faced by the UK and the rest of the world through the 21st Century.

3.2.2 The Strategy recognises that the separation between weather and climate research is no longer required and that there is a need for a seamless approach to modelling and prediction. The proposed new structure for delivering Met Office research and development will encourage joined-up working across all weather/climate scales and should foster a closer research partnership with the very capable UK and international research community that is located outside the Met Office, bringing all-round benefit.

3.2.3 The Strategy is underpinned by the emergent Met Office-NERC strategy on Earth System Modelling which is being delivered through the Joint Weather and Climate Research Programme (JWCRP). This is a strategic partnership which is fostering much closer working relationships between NERC and Met Office scientists in building improved models to focus on climate change predictions on timescales of up to centuries. Similar links exist through the NCOF (National Centre for Ocean Forecasting) partnership (also part of JWCRP) which focuses on improved ocean forecasts on timescales upwards of a few days. By strengthening links with the NERC community in these ways, the robustness and achievability of the Met Office strategy is enhanced, as are the resulting services from their forecasting systems.

3.2.4 Access to core scientific expertise will be necessary across organisational boundaries and the Strategy advocates expanding the successful partnership with NERC on the Joint Weather and Climate Research Programme and sees the Met Office playing a key role within the Living With Environmental Change programme. The proposed three Directorates (Climate Science, Foundation Science and Weather Science) lend themselves well to cross-organisational working and collaboration. It is further noted that even though Climate Science and Weather Science are separate Directorates, they are working towards an integrated approach through their adoption of the seamless modelling strategy, in which a traceable hierarchy of related modelling systems will span all relevant time and space scales.

3.2.5 NOC welcomes the proposals to:

- Bring together a more structured approach to partnerships with Unified Model users.
- Strengthen and extend the Joint Weather and Climate Research Programme with NERC.
- Develop a more effective relationship with the Research Councils and the LWEC programme.

3.2.6 We particularly welcome the establishment of a Met Office Academic Partnership Scheme and the establishment of Met Office Industrial Fellowships.

3.2.7 Under section 6 of the Strategy the proposals to encourage retention and development of scientists by allowing more opportunities for advancement, creativity and innovation are very positive.

3.2.8 The "Expert Scientist" and "Research Fellow" roles will provide excellent opportunities for collaboration with the wider research community, though suitable financial arrangements will need to be set up to allow the interaction to take place. University and Research Council scientists are already heavily committed and assigned to costed research programmes so formal partnerships and collaborations with the Met Office will have to be paid for somehow.

3.2.9 The recommendation to provide more opportunities for Continued Professional Development is important.

3.2.10 We agree with the need to develop a much stronger capability in computational science and software development. The multi-core, massively parallel petascale computers require a very large investment in resources to achieve their full potential. NERC centres are well placed to work with the Met Office to help address this resource requirement.

3.2.11 Supercomputing is a fundamental requirement for understanding ocean and atmospheric processes and will require continued funding, collaboration and "joined-up" working to maximise potential.

3.2.12 Observations are critical for advancing and testing the models and theoretical understanding the ocean-earth-cryosphere-atmosphere system. The marine science community relies upon in-situ observations from above, afloat and below the sea surface, and this requires platforms such as satellites, aircraft, ships, buoys and autonomous floats such as the "Argo" profilers. The Strategy recognises these needs.

3.2.13 Space borne Earth Observation is tremendously important to marine scientists to "fill-in the gaps" in observations of the sea surface and increasingly to enable the full range of air-sea surface interactions to be measured. We look forward to working more closely with the Met Office, including through the Global Monitoring for Environmental Security (GMES) programme, to see investment in new instrumentation and platforms, and to ensuring delivery of an operational product through calibration and validation. NERC and the Met Office worked together in successful advocacy for UK participation in the Jason-2 and -3 altimetric satellite missions.

3.2.14 The Met Office has an important role to play in International leadership, including continued support of the IPCC, WWRP and WCRP. The National Oceanography Centre will welcome a strong lead from the Met Office in the relevant international fora.

3.2.15 Communicating science enables policy makers and the public to act upon the knowledge gained by scientists and address the challenges that face the UK and the world in a century that promises to show the impacts of climate change, reduced fresh water availability, growing human population, changes to land use and many other parameters that require active management, stewardship and adaptation. These are highly political issues. Communicating the underpinning science, with its associate uncertainties, to policymakers and the general public requires particular approaches and skills that have not historically been part of the scientist's toolkit.

The Met Office Strategy recognises that staff will need training to become better communicators and that there must be openness and transparency on research, methods and data.

3.3 *What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?*

The main roles of the Met Office Chief Scientist and other senior scientists are to take a strategic overview of, and to coordinate and rationalise, the scientific activity of the Met Office. The Chief Scientist has a deep and extensive knowledge of both the Met Office and external UK research capabilities and systems, and is widely acknowledged as an international expert in her scientific fields. Other senior scientists are similarly highly regarded in their fields, and have an extensive knowledge of Met Office capabilities, and a growing appreciation of the skill base in the external UK community (eg through interaction with NERC in the JWCRP programme and in the delivery of NERC's strategy through the development of Thematic Action Plans). They are therefore in a strong position to provide robust and sound advice to HMG, UK and international scientific institutions, and the IPCC assessment process.

3.4 *How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?*

Historically, the Met Office have been viewed as somewhat insular. However, the situation is now much improved through the adoption of common modelling systems and approaches, shared with the external (RC, UK Academic, and European) research community. Specifically, NERC and the Met Office now share a common computational platform, MONSooN, which is greatly aiding collaboration with the external community, and pull through of research from the external community to the Met Office. Furthermore, the Met Office and NERC have adopted a common ocean modelling system, NEMO, and have formed a strategic partnership to develop and utilise this model within the JWCRP framework. A common UK configuration of NEMO has been adopted by NERC and the Met Office, implemented on MONSooN, jointly analysed by the two groups, and now forms the backbone ocean model in use in the Met Office systems today. The work programme is overseen by a joint management committee. In addition, both the Met Office and NERC are partners in the international NEMO consortium for the wider development of the NEMO ocean model. Through such increased and effective collaboration with the external community, the robustness of the Met Office ocean modelling systems is now excellent, with NEMO providing a world-leading system.

3.5 *How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?*

3.5.1 Within the marine research community the Met Office is represented by a senior scientist on the government's Marine Science Co-ordination Committee and participates in work packages such as science alignment and the co-ordination of long-term marine observations. The Met Office contributes to the work of the Environmental Research Funder's Forum, and the Ocean Processes Evidence Group.

3.5.2 The Met Office is represented by a senior scientist as part of the UK delegation to the Intergovernmental Oceanographic Commission of UNESCO, and has contributed substantial technical expertise to component

programmes such as GOOS (the Global Ocean Observing System), JCOMM (the Joint IOC/WMO Commission on Oceanography and Marine Meteorology) and tsunami warning systems. The possibility that a tsunami warning system capability might be incorporated into the Joint Flood Forecasting Centre operated by the Met Office and the Environment Agency is being explored.

3.5.3 The Met Office has a close working relationship with the Natural Environment Research Council through the Joint Weather and Climate Research Programme (as already indicated in 3.4 for ocean modelling) and is increasingly playing a key role in the cross-Government, cross-Research Council programme on "Living with Environmental Change" (LWEC). In addition the Met Office works closely with the UK marine research community in many other areas, including the National Centre for Ocean Forecasting, national capability in deep water moorings, technology development, the training of PhD students and seminar programmes. However we would welcome a more joined-up collaboration with the Met Office in the area of future sea-level rise research.

3.5.4 There is frequent interaction and exchange of staff between the Met Office and the Research Council and University research sectors, with scientists passing between employers and transferring ideas and skills. Under the proposed Met Office science strategy these links will be strengthened, and Met Office scientists afforded the opportunity to enjoy university-style freedom to undertake curiosity-driven research for up to 20% of their time. This will very much strengthen the science base of the Met Office and make it a much more attractive employer to the brightest Post-doctoral researchers. However, it seems doubtful that this opportunity could be afforded to all Met Office scientists.

3.5.5 In general some parts of the Met Office such as the Hadley Centre work much more closely with the outside world than the core part of the Met Office, which partly explains the international recognition accorded to the Hadley Centre. Under the proposed science strategy the alignment of weather and climate research should enable the Met Office to become more outward-focussed and better able to interact with a wider community.

3.5.6 Since its inception in 2000, the UK contribution to the Argo profiling float programme has been managed by the Met Office with strong support from NOC (Southampton and Liverpool). This function has been carried out successfully against a background of perpetual funding uncertainties. The Met Office has also been active in the international coordination of Argo.

3.5.7 The move of the Met Office into BIS, home of the Research Councils, should also facilitate an enhanced interaction with a wider community.

This submission on behalf of the National Oceanography Centre prepared by Stephen Hall with input from: Adrian New, Andrew Willmott, Kevin Horsborough, Jacky Wood and Trevor Guymer
National Oceanography Centre

September 2011

Written evidence submitted by the Royal Meteorological Society (MO 11)

How effectively is the Met Office fulfilling its Public Weather Service remit?

1. The Public Weather Service (PWS) is, in our view, a world class service, providing important warnings for the protection of life and property from hazardous weather events. The value of the PWS is demonstrated many times over each year through the impact it has in helping civil contingencies and raising public awareness in events such as the London Bombings, the Buncefield fire, the 2009 floods, and the wider global impacts for the UK, UK citizens overseas and UK international development initiatives, such as volcanic ash advisory services and the radioactive atmospheric dispersion issues from the Fukushima power plant melt-down.

2. The role of the Public Weather Service Customer Group is key to providing an independent review of the Met Office's effectiveness in fulfilling the PWS remit. The Customer Group ensures that Government is obtaining best value for money, setting and measuring performance against focused targets and ensuring that the public are afforded the protection provided by the latest scientific knowledge and understanding.

3. In our view the PWS Customer Group would benefit from widening its reach, not necessarily in terms of its membership, but in terms of those it consults to ensure that it is meeting the wider public need.

4. Further, it is important that there is a clearly defined boundary between the Public Weather Service provided free-at-the-point-of-use and those paid-for services which are provided through a competitive market place by organisations such as the Met Office and the private sector weather provider community. In our view a review of this boundary would be valuable and timely. This review should consider, amongst other things, the different models adopted in different countries and, with economists and meteorologists working together, consider whether other models that make more public data and information freely available would help to grow the UK's private sector weather provider community and return greater economic value to the UK.

Is the Met Office's Science Strategy 2010–15 robust and achievable and how will the strategy help to deliver a better service?

5. It is important to begin by noting that the Met Office exposes its Science Strategy to regular scrutiny and reviewed by an expert committee of national and international scientists.

6. We are aware that there are others from across our scientific community membership that are providing a detailed contribution to this inquiry on the content of the Met Office's Science Strategy, therefore our comments focus on four more general issues.

7. Firstly, we believe that the Strategy does reflect well the key challenges and priority areas for achieving the greatest return on the investment in the science and the research programme. In our view, the areas of focus are well chosen in terms of delivering maximum value to improvements in both weather and climate services.

8. Secondly, there is no more challenging problem in computational science than that of simulating the Earth's climate, and availability of computing resources continues to be a significant factor in limiting the skill and reliability of weather and climate forecasts. Whilst we recognise the financial challenges the UK faces, we do believe that a further significant investment in computing resources is required, over and about the current commitments. This problem may only be solved by pooling resources with our international partners to provide top tier supercomputing resources dedicated to the climate problem.

9. Thirdly, strong partnerships with the wider science community, both in the UK and internationally, is essential in ensuring that the UK gains the maximum leverage from its investment in the Met Office.

10. Fourthly, across each of these science areas, it is important that the Met Office looks to exploit the value of probabilistic forecasting methodologies. These methodologies allow uncertainties in the forecast, arising from imperfect starting conditions and imperfect models, to be quantified. The reliability of weather-sensitive decision-making will be improved enormously if flow-dependent predictive uncertainties can be properly quantified. The Met Office has taken a lead in the production of probability forecasts for climate, through the latest UK Climate Projections (UKCP09) project and its input into DEFRA's Climate Change Risk Assessment. However, for climate prediction and its application to Climate Change Risk Assessment (CCRA), there remains a fundamental unsolved question of whether the estimated UKCP09 probabilities are actually reliable (for example, does an estimated 90% probability of an event mean the event is somehow very likely to happen?). In the coming years, future CCRAs should ideally explicitly take into account predictions from a range of models worldwide, not just the Met Office's Hadley Centre Model. More generally, and looking further into the future, representing uncertainties in weather and climate modelling is a critical area of cutting-edge research, and new stochastic methods are emerging from the academic and other operational centres (for example the European Centre for Medium Range Weather Forecasting, ECMWF) from which the Met Office should be able to benefit.

11. For day-to-day weather prediction the Met Office has much further to go in providing estimates of forecast uncertainty to the public. If the Met Office was able to provide more information about uncertainty in its forecasts, it may be less subject to the criticism it has seen from time-to-time from public and media alike. Here, working with the BBC (who have editorial control of the broadcast weather forecasts) is crucial, to develop and broadcast graphical techniques for representing uncertainty. There may be some useful parallels from other areas of public information, for example with the Bank of England's methods to represent uncertainty in its forecasts of inflation rate and gross domestic product.

What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?

12. The Met Office is a science-based organisation and the work of the Met Office Chief Scientist, supported by other senior scientists, is in our view essential in order to ensure world class scientific leadership; that is:

- — there is an organisational framework that promotes and fosters innovation and scientific excellence;
- — the programmes of work remain connected to and focused on the key science issues;
- — there is scientific integrity in the work of the organisation;
- — the Met Office continues its work in developing effective national and international scientific partnerships; and
- — those working in scientific programmes have the necessary competencies, training and professional development.

13. The Met Office Chief Scientist and the senior scientific team remain actively engaged with the wider work of the national and international science community. There are many examples of this, including the Met Office's continued commitment to ensuring that its early career scientists participate with the work of our Society's student conference, the establishment, with the Research Councils, of the UK's Joint Weather and Climate Research Programme, the introduction of the new academic partnership programme and the international collaboration on numerical weather prediction, both with the European Centre for Medium Range Weather Forecasting (ECMWF) and through the Met Office's own partnership with Australia, New Zealand, Norway, and South Africa (to recognise just some of the notable international partners).

How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?

14. In our view the Met Office is widely and independently recognised as a world-leader in weather and climate modelling and prediction.

15. The whole suit of Met Office models are exposed to a rigorous testing, validation and verification programme which is open to wider national and international scrutiny. In particular performance against targets, defined both internally and externally, is widely publicised. Further, the models are regularly verified again observations and other models and this process is used to help in continually targeting areas for greater improvement.

16. Having said that, simulations of climate are still far from perfect, and for many variables, the biases of the climate simulations against observations can be as large as the climate change signal which the models try to predict. There are a number of reasons for this, which evolve around the basic notion that climate is an enormously complex multi-scale physical, chemical and biological system—as mentioned above, there is no more computationally complex problem in science. In recent years, climate institutes have begun to develop their climate models to reflect this so-called Earth-System complexity, but the institutes, including the Met Office, are constrained both by limited human resources, and computing resources (as highlighted above). In the light of these constraints, there is an urgent need to review whether the best way forward is continue with largely institutional-based modelling effort (for example the Met Office Hadley Centre model, the Max Planck Institute model, the Meteo-France model, the EC-Earth model etc), or to try to pool human and computing resources, for example within Europe, thus taking advantage of economies of scale. The establishment of the Airbus consortium provides just one an analogy for such a development.

How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

17. The Met Office has only recently moved its owning department from the Ministry of Defence to the Department for Business, Innovation and Skills. It is difficult to comment on whether this new governance framework is working effectively.

18. Aside from this, the Met Office has a range of mechanisms through which it co-ordinates its activities with its stakeholders, several of which have already been mentioned in this submission. A common theme in these is the openness to external scrutiny and review.

19. In addition the Met Office represents the UK's interests in a range of international groupings such as the European Centre for Medium Range Weather Forecasting (ECMWF), the European Meteorological Satellite Agency (EUMETSAT) and the World Meteorological Organization (WMO). The UK benefits significantly through this sharing of responsibilities, funding and coordinated planning with the Met Office's international counterparts and partners. Without these partnerships in place it would simply not be possible to deliver the range of services provided by the Met Office for the UK.

Declaration of Interest, Details and Contacts:

20. The Royal Meteorological Society is the UK's Professional and Learned Society for Weather and Climate. The Society is a registered charity, based in Reading, UK, and works to advance the understanding of weather and climate, the science and its applications, for the benefit of all. The Society supports those with an interest in weather and climate in the UK and around the world. Society members include scientists, students, practitioners and amateur enthusiasts and the Met Office is a Corporate Member of the Society.

21. The current President of the Society is Professor Tim Palmer FRS. More details about the Society can be found on our website at "www.rmets.org".

Royal Meteorological Society

September 2011

Written evidence submitted by the Government (MO 14)

The Prime Minister announced on 18 July 2011 that responsibility for the Met Office would pass from the Ministry of Defence to the Department for Business, Innovation and Skills. The Met Office is a trading fund, operating as a self-contained commercial entity within BIS. The Minister responsible for ownership of the Met Office is now Edward Davey MP; with the Rt Hon David Willetts MP responsible for the customer functions, including its wider scientific role, and the customer for the Public Weather Service, receiving advice from the Public Weather Service Customer Group (PWSCG). The PWSCG commissions weather services on behalf of government and the UK public.

This memorandum draws on advice from the Public Weather Service Customer Group, chaired by Nick Baldwin and from the Government Departments which work with the Met Office or use its outputs. The Met Office will be submitting a separate memorandum to the Committee.

The Met Office is a major national asset. It is widely recognised as one of the leading weather and climate forecasting centres in the world and has provided weather forecasting and related services for the UK for over 150 years.

The Public Weather Service (PWS) provides free-at-the-point-of-use weather information and severe weather warnings for the UK public, including the general public and the resilience community who act on their behalf to allow them to make informed decisions to plan day-to-day and longer-term activities. The PWS also provides research and development activities to deliver required improvements to PWS forecast and warning services; it meets international commitments on behalf of UK Government and it provides underpinning data for stakeholders.

Funding for the PWS comes from four sources:

(a) Through BIS (formerly MoD) on behalf of Government;

(b) Civil Aviation Authority on behalf of the civil aviation community;

(c) Maritime and Coastguard Agency on behalf of the marine community; and

(d) From other funding providers such as EU and NERC for specific projects and activities.

The price of the PWS to the PWSCG in FY11/12 (ie a. above) is £68.1 million. The additional lines of funding ((b)–(d)) increase this to £93.4 million. This accounts for approximately half of Met Office annual revenue.

In addition, based on the quality of its science and citations, the Met Office Hadley Centre (MOHC)—the centre within Met Office dedicated to climatology research—has been recognised as the leading geophysical institute in the world.[46] Recent reviews of the MOHC,[47,48] recognised its value to Government and affirmed that it *"provides essential and world-leading climate modelling services to Government, and that it is uniquely placed to do so. It represents a critical national capability, with a central role of meeting the Government's requirements for climate evidence and advice."* The Met Office and its Hadley Centre have delivered scientific credibility and influence for HMG in support of international negotiations and diplomacy. Met Office science is trusted, and the quality of its climate science evidence recognised across the world.

1. *How effectively is the Met Office fulfilling its Public Weather Service remit?*

1.1 The Public Weather Service (PWS) provides a range of weather information and warnings to enable the UK public to make informed decisions, to optimise or mitigate against the impact of the weather, and to contribute to the protection of life, property and basic infrastructure. The PWS also fulfils international commitments on behalf of the Government.

1.2 The PWSCG acts as the formal customer for the public weather service, on behalf of Government departments, and the general public, for free-at-point-of-use weather services, and ensures that these services are aligned to the operational needs of public sector users of PWS outputs. PWSCG is an independent body that also acts as funding body and guardian of the Met Office's underpinning operational capacity. Background on the PWSCG is attached at Annex A, with its terms of reference attached at Annex B.

1.3 The PWSCG provides independent advice to the Minister for Universities and Science, and as such, its evidence on "How effectively is the Met Office fulfilling its Public Weather Service remit?" is attached separately from 1.13 to 1.30.

1.4 The Met Office's Public Weather Service (PWS) provides a number of functions for the public (and public sector partners) related to both basic weather information and weather warnings, and also weather influenced events.

1.5 Legislation supporting the Civil Contingencies Act, 2004 requires Category 1 and 2 responders to have regard to the Met Office's duty to warn the public and provide information and advice, if an emergency is likely to occur or has taken place. The Met Office, in our opinion, provides a world class service for emergency planners and policy makers across national and local government, which is the envy of many other countries.

1.6 The Met Office provides the following services under their PWS remit:

— Monthly, 15 day, five day and daily forecasts.

— Site specific UK and global forecasts.

— A range of other forecasts available via the Met Office website.

— A range of specialist forecasts for interest groups (mountaineering, gardening etc).

— Seasonal Forecasts (three-monthly).

[46] *Analysis of geosciences institutes, worldwide.* Times Higher Education Supplement; November 2009 [available on-line at: http://www.timeshighereducation.co.uk/story.asp?sectioncode=26&storycode=409181&c=1]

[47] Lawton (2009) *The 2009 Sir John Lawton Review of the Met Office Hadley Centre* [available on-line at: http://www.bis.gov.uk/assets/bispartners/goscience/docs/s/2009-sir-john-lawton-review-report.pdf]

[48] Beddington (2010) *Review of climate science advice to Government and Met office Hadley Centre role, governance and resourcing* [available on-line at: http://www.bis.gov.uk/assets/bispartners/goscience/docs/r/10–1290-review-of-climate-science-advice.pdf]

— National Severe Weather Warning Service.
— UK and global response services.
— Public weather service advisers.
— Hazard manager—a web portal for emergency responders showing current and near future weather conditions.
— Forecasting guidance from the Met Office Operations Centre.
— General help and advice from the Met Office Customer Centre.
— National Meteorological library and Climatological Advice.
— Use of the Met Office plane.

1.7 Clearly this world class service is extremely wide, covering a wide range of products and customers. Part of the effectiveness of the Met Office is its willingness to go the extra mile for its customers to ensure they have the products they need and best understand. For example the severe weather warnings are now impact-based to assist the emergency planners to understand what 100mm of rain in a 3 hour period actually means. Public Weather Service Advisers officially work a 9–5 day, but during emergencies and at a wide range of weather related events their hours are considerably longer.

1.8 Under its PWS remit the Met Office produces a "suite" of forecasts to assist emergency planners and the public. The UK is one of only a few countries who ask its Met Office to provide a seasonal forecast, three months ahead of the event. In doing so there is a reputational risk for the Met Office. This is very challenging work, and the Met Office continues to work to improve the product.

1.9 The Met Office has one of the largest distribution lists across government and ensures that all weather warnings and information is delivered across the emergency planning community as part of its commitment under the Civil Contingencies Act.

1.10 The Met Office also developed the "traffic light" system of four colours which highlights the weather maps and advisories it sends out. This simple system alerts emergency planners and the public to the level of risk and certainty of the weather event. This system is now used across all early warnings distributed by the Met Office, Flood Forecasting Centre and Environment Agency.

1.11 VisitEngland—the country's national tourist board—represents the tourism industry. With the weather in Britain one of the most difficult regions in the world to forecast, VisitEngland acknowledge the Met Office as a world leader in weather forecasting that operates a highly complex service internationally.

1.12 However, a criticism VisitEngland hear from the tourism industry, is that, with the climate so highly variable, the presentation of forecasts in the media, especially television forecasts, should be more careful to explain the probability of future events. The key issue, VisitEngland recognise, is the way in which the media communicates this information. For example:

— The current model used by the BBC shows cloud cover predictions and precipitation over the British Isles in some detail—it is felt the level of detail can be misleading because it implies more certainty than there is about future weather events.
— It is felt that weather symbols on maps (TV and newspapers) are too large and do not account for local variations on the ground. They believe that more recognition should be given to the local factors that influence weather patterns and that blanket statements covering whole regions are best avoided, or qualified by a probability component.
— VisitEngland do not believe that televised weather forecasts should be used as a form of entertainment or jokes by either weather forecasters, or more often their link presenters (eg BBC Breakfast News). For example, unqualified comments about "the usual rain over the Bank Holiday," or other clichés regarding our climate, have a serious economic impact on the tourism industry—impacting on people's decision-making, especially about taking day trips.
— VisitEngland feel that the public relations aspect of weather forecasting should not be the role of the Met Office.

Evidence from the Public Weather Service Customer Group

Performance standards and measurement including independent surveys

1.13 The PWSCG drives continual improvement and sets challenging performance standards for the PWS by annually setting performance measures and development milestones. These are also negotiated and signed off as part of the annually agreed Customer Supplier Agreement.

1.14 The required standards are a mixture of Met Office measured (but independently audited) targets based on weather forecast and warning parameters (eg maximum and minimum temperature, wind speed and direction, rainfall and sunshine) and targets measured by independently undertaken surveys to assess public and responder reach and value.

1.15 *In FY 2010/11 the PWS achieved all its Key Performance Indicators.*

1.16 Between 2007 and 2010 the PWSCG has commissioned an independent annual survey to gauge public perception of the PWS. Approximately 2000 members of the pubic are surveyed each time. These surveys have found that:

- Nearly all respondents consider forecasts easy to understand.
- Nine out of 10 think weather forecasts are useful (very or fairly).
- Between seven and eight out of ten think that weather forecasts are accurate (very or fairly).
- Most look at or hear a forecast at least once a day.
- Most (83%) consider severe weather warnings to be very or fairly accurate and more (90%) think they are very or fairly useful.

The Public Perception results have remained stable year-to-year.

1.17 The PWSCG also commissions a biannual survey of the emergency responder community; in March 2011:

- Satisfaction with the PWS was found to be extremely high, with 73% saying that they are very satisfied with its services and 97% either satisfied or very satisfied. This represents an improvement from 2008 when 58% were very satisfied.
- Satisfaction with the last weather warning received is also high, with 62% of responders saying that they are very satisfied. This has strengthened since 2008 (56%).
- Satisfaction with the service provided by PWS Advisors remains very high (90% of those who have had contact with them are very satisfied), and has increased since 2008 (86% very satisfied).

The PWSCG has ensured that the PWS is transparent about how well it is performing against targets by requiring the Met Office to publish relevant statistics for temperature, rainfall and sunshine that are updated monthly, on the Met Office web site: http://www.metoffice.gov.uk/about-us/who/accuracy/forecasts.

PWSCG Consultation Activities

1.18 PWSCG undertakes a programme of consultation that enables the PWSCG to make decisions based on end-user benefits, and ensures that all PWS services are aligned to the operational needs of Public Sector users of PWS outputs. As a result of the consultation programme, the PWSCG challenge the Met Office PWS to deliver a set of development milestones. As a result of this the PWS has achieved some major and significant improvements over the past few years including:

- Review and introduction of an impacts based National Severe Weather Warning Service;
- Expansion of the number of site specific forecasts from ~350 to ~5,000;
- Increased "reach" of PWS products and services through the introduction of new channels including for example, an iPhone app, weather widget and mobile service. Information on reach published in the Met Office website shows an increasing trend across each of these platforms over the past 14 months;
- Introduction of "specialised" forecast services eg mountain weather forecasts; avalanche forecasts.

1.19 *In FY 20101/11 the PWS achieved all its Development Milestones.*

Obligations to other customers

1.20 The PWSCG acts as guardian on behalf of public sector users of the Met Office's underpinning operational capability. Thus, it supports Research and Development to ensure the Met Office is able to meet future requirements. In order to ensure continual challenge, the PWSCG annually set key milestones for the research areas of the Met Office. The PWSCG takes advice on the foundation weather science strategy and direction from the Met Office Science Advisory Council (MOSAC) who peer review the Met Office science plans.

1.21 *In FY2010/11 the PWS met 14 out of 18 of its research and development targets.*

1.22 Those targets that were missed were done so deliberately to de-risk delivery of higher priority strategic projects, following consultation and agreement between the Met Office PWS and PWSCG.

1.23 The PWSCG recognises its obligations to ensure the continued availability of research, forecast and observational (Baseline Data) data required by the Met Office in order to deliver services to other Public Sector customers, and to make the same data available to the Met Office's commercial arm and the private sector. It does this by setting annual targets of availability, timeliness and accuracy.

1.24 *In FY2010/11 the PWS met all 38 of its Baseline Data targets.*

1.25 The PWSCG also ensures that the Met Office provides data to the private sector through a Data Wholesaling Unit, in compliance with Competition Law, the Re-use of Public Sector Information Regulations and the HMSO's Information Fair Trader Scheme. This data is derived from the Baseline Data. The PWSCG requires that the Met Office review and update the catalogue of Wholesale Data annually.

International Obligations

1.26. The PWSCG requires the Met Office PWS to fulfil commitments on behalf of UK Government on three designated international bodies:

(i) EUMETSAT.

(ii) European Centre for Medium range Weather Forecasting (ECMWF).

(iii) World Meteorological Organisation (WMO).

International subscriptions to the World Meteorological Organisation (WMO), European Centre for Medium-Range Weather Forecasts (ECMWF) and EUMETSAT are funded through the PWS and overseen by the PWSCG. These subscriptions deliver benefits far beyond PWS—through Met Office services to MoD. BIS and others, and through other users of satellite and model data and observations, including academia, other Government Departments and the private sector.

1.27 The PWSCG set and monitor targets to ensure the PWS and wider users and stakeholders receive the best value for membership of the international bodies. The PWS is also required to report to the PWSCG on outcomes of international meetings. For example, it was recently informed on the outcomes of the UK delegation to the WMO Congress where John Hirst was successfully reappointed to the Executive Council and the newly appointed Director of ECMWF will be presenting his strategy and vision for the Centre at an upcoming PWSCG meeting.

1.28 *In FY2010/11 the PWS met all its International targets.*

Meteorological Library and Archive Service

1.29 The PWSCG require the Met Office to provide a meteorological library and archive service available to anyone with an interest in the weather or climate and an approved place of deposit for meteorological information under the public records Act (1958). This is to enable the general public to research the UK's weather and climatology and to access information that helps the public to understand the science and history of meteorology. There is also a legal requirement handed down to the Public Weather Service from the Lord Chancellor's office to archive meteorological data on behalf of the UK Public.

1.30 The PWSCG require the library and archive to report on activity each FY. In FY 10/11

— There were 187,270 pages viewed on the Library Catalogue.

— Over 99% of a total of 2904 library and archive enquiries were answered within five working days.

— Customer satisfaction with the enquiries service was high: 3.9/4 rated for speed, relevance of information, and whether customer is totally satisfied with the response.

2. *Is the Met Office's Science Strategy 2010–15 robust and achievable and how will the strategy help to deliver a better service?*

2.1 Services to government currently make up the majority of Met Office business. The Public Weather Service is the main component of this but other services provided to government include advice on climate science and climate change impacts, advice for informing more specific emergency activities (for example through the Flood Forecasting Centre), and operational advice to the armed forces.

2.2 The core function of the Met Office is weather forecasting. The accuracy of near term forecasting, up to ten days out, is now very high but there is greater uncertainty associated with predictions on longer timescales: monthly, seasonal, decadal and beyond; and particularly with respect to predictions at regional and local spatial scales. Reducing these uncertainties will enable more confident assessments of future weather patterns, including extreme events. More reliable future forecasting would be of great benefit to operational decision-making and resilience planning in a number of sectors, including with respect to our vital infrastructure and resources. HMG's priorities for climate science evidence and advice are well documented in the Government Chief Scientific Adviser (GCSA)'s 2010 review of climate science advice to government.[49]

2.3 The context of the Met Office Science Strategy is to develop a seamless approach to weather and climate forecasting. It appears geared towards meeting government needs for more reliable forecasting and assessment of impacts across the full range of time and spatial scales. Delivering improvements in forecast capability requires advances in scientific understanding of how some earth system processes influence our weather and climate, improved representation of these processes in models, and sufficient supporting infrastructure to enable this. We believe the Met Office science strategy provides a generally clear and targeted framework for addressing these issues.

2.4 We recognise that the underpinning observational and supercomputing infrastructure, and scientific knowledge is the same for forecasting across all timescales, from days to centuries, and that synergies and efficiencies can be delivered by co-locating weather and climate services. It is judicious that the Met Office strategy seeks to exploit these as far as possible through an integrated organisational structure and seamless prediction system.

[49] Beddington (2010) *op cit*

2.5 The need for increased model resolution is a thread which runs throughout the strategy. We understand that, just as the accuracy of weather forecasts is significantly improved by high resolution modelling, so can the regional and local specificity of longer-term climate forecasts be improved. A strong case for continued investment in supercomputing capacity to enable climate models to be run at greater resolution was made in the GCSA's review[50] of HMG's climate science advice needs. This review also recognised the significant near-term costs involved and the need for greater collaboration on supercomputing resources, including internationally, stressing that long term development of modelling capability would likely require a European solution. We welcome the Met Office plans to pursue this as part of their science strategy and we support them in this.

2.6 The challenges which the Met Office strategy identifies are global in nature. Collaboration, both nationally and internationally, and across disciplines, is fundamental to addressing these challenges, and advancing scientific understanding and new research, for example on climate and extreme event attribution. The proposal for stronger partnerships and collaboration is fully endorsed and will be a crucial element of the success of the Science Strategy, although we suggest that the proposed science partnerships should also include representation from government to provide additional context to proposed research programmes.

3. *What are the roles of the Met Office's Chief Scientific Adviser and its other senior scientists? How do they provide comprehensive and up-to-date scientific advice?*

3.1 The Met Office Chief Scientist (CSc) is part of the network of departmental Chief Scientific Advisers (CSAs) which, under the leadership of the Government Chief Scientific Adviser (GCSA), works collectively to ensure that robust, joined-up science and engineering evidence and advice is at the core of decisions within departments and across government.

3.2 As part of this network the Met Office CSc contributes to discussions on cross-cutting issues, bringing to bear specialist knowledge and also profiting from knowledge exchange with CSAs from other disciplines. Being part of this network helps to ensure the relevance of the science advice provided by the Met Office CSA to government.

3.3 The Met Office CSc also has regular one-to-one contact with the GCSA and departmental CSAs. Met Office scientists at all levels are also in regular—for some departments, daily—contact with departmental science and policy officials, providing high-quality up-to-date science advice to these departments. The Met Office Chief Executive, John Hirst, and his directors, also have good working relations with and are in regular, direct contact with, senior officials of customer departments.

3.4 The Science Strategy highlights that the role of the Met Office Science Advisory Committee (MOSAC) will be enhanced in the near future. In considering changes to the remit and terms of reference of MOSAC we would encourage the Met Office to reflect on the independence of the Committee and the Principles on Scientific Advice to Government, noting the revised Code of Practice for Science Advisory Committee (CoPSAC) to be published in the Autumn. This identifies best practice guidelines and provides practical advice on the operation of Science Advisory Committees.

4. *How robust are the models used by the Met Office for weather forecasting, climate predictions, atmospheric dispersion and other activities?*

4.1 Models are powerful tools to understand future states but all good modelling (climate or otherwise) produces a range of possible outcomes. Ensemble forecasting[51] methods used by the Met Office help provide a better assessment of the uncertainties associated with weather and climate predictions. The Met Office Science Strategy seeks to reduce modelling uncertainties through advancing our underlying scientific understanding and exploring options for increasing model resolution. This will improve the confidence we can have that the models reflect real climate trends and processes well, and provide the best possible input to inform climate adaptation decisions and investments that we need to make in the near term.

4.2 We understand that the formal "skill" of the Met Office global numerical weather prediction (NWP) model has improved consistently in the past decades and that, for example, the current three-day forecast is as skilful as the one-day forecast was 20 years ago, in line with other leading forecasting centres. We also understand that in international benchmarking of the performance of global NWP systems, supported through the World Meteorological Organisation (WMO) and using a range of metrics; that the Met Office is consistently in the top three, alongside the Japanese Meteorological Agency and the European Centre for Medium-range Weather Forecasts.

4.3 Met Office provides the large majority of climate, weather and ocean forecasting and related services required by government. For Defence and the Armed Forces Met Office numerical weather predictions (NWP) have significant use at all levels of military operational planning. At the strategic level, forecasts of seasonal variations allow long term planning, whilst at the operational and tactical levels the current NWP output is required to assess the impact of environmental factors on weapon systems and manpower. Detailed assessments

[50] Beddington (2010) *op cit*

[51] Ensemble forecasting involves multiple forecast runs with slightly different initial conditions for each, in order to provide a probabilistic assessment of possible outcomes

of this impact are required over a timeline of hours, days and weeks and must be updated regularly and, crucially, be within accuracy guidelines agreed between the MoD and the Met Office.

4.4 The MoD has worked in partnership with the Met Office for a significant period of time and has contributed to the development of a variety of meteorological and oceanographic models, used alongside the NWP, to support current and anticipated defence operations. The MoD funds specific nested high resolution models required to support military tasks worldwide, meteorological models to support ballistic and CBRN (Chemical, Biological, Radiological, and Nuclear) downwind messages and dispersion modelling products and their outputs, required for operational planning and evaluation. The MoD also has operational releases of all Met Office Tactical Decision Aids and environmental information in agreed formats to support Mission Planning Systems.

4.5 DECC and Defra co-fund the Met Office Hadley Centre and climate model development. Climate modelling directly informs government policies on climate change mitigation and adaptation, by providing assessments of the impacts of different levels of atmospheric greenhouse gas emissions nationally and globally to inform planning and policy decisions. The 2009 Lawton Review[52] highlighted a consistency of view across expert contributors to the review that MOHC was one of the leading groups of climate modellers in the world and that it "*worked at the cutting edge in many areas, for example in some areas of Earth Systems' modelling and in decadal prediction*". We understand that Met Office climate models have performed well in the first three international climate model intercomparison projects (CMIP-1 to CMIP-3)[53] coming 1st, 1st, and 2nd respectively and DECC and Defra are confident that the MOHC's latest earth system models (HadGEM family) will perform well in the current CMIP-5[54] which will be reported on in the IPCC Fifth Assessment Report.

4.6 The Met Office has long been developing a unified modelling system, wherein the same fundamental science and modelling are used across the whole range of forecasting timescales, from hours to centuries (so called "seamless science" and "seamless prediction").

4.7 A decade ago, the Met Office invested in the development of a ground-breaking, low-cost, PC-based regional climate model (PRECIS) for use locally, primarily in developing countries. PRECIS remains one of very few such systems and has received considerable approbation from users worldwide. PRECIS-2 is currently being developed with DFID funding.

4.8 Met Office is a designated Volcanic Ash Advisory Centre (VAAC), responsible for monitoring and forecasting the movement and dispersion of volcanic ash originating from volcanoes in the north-eastern part of the North Atlantic Ocean. The Met Office atmospheric dispersion model, NAME, underpins the advice provided by the Met Office in their capacity as a VAAC, and was used to support the work of the Scientific Advice Group for Emergencies (SAGE) in the Volcanic Ash incident in March 2010. Since that time enhancements have been made to NAME's operational functionality to improve the physical basis of ash concentration forecasts. The World Meteorological Organisation (WMO) has also led work to compare the modelling approaches of the nine VAACs[55,56] and this work has shown a high degree of alignment between the top tier models (including NAME) when run with the same source terms.[57] This continuing programme of model inter-comparisons will identify the strengths and weaknesses of different models and drive additional improvements in all models. NAME has also recently been independently reviewed at the request of the CAA.[58] That study, and the work by the WMO, has shown that NAME compares favourably with models used by other international meteorological organisations.

4.9 The Government recognises that the robustness of Met Office models is contingent on the accuracy and adequacy of supporting observational data. Observations directly input to models and to model development (through enhancing our scientific understanding) and are the only means of verifying model outputs.

4.10 A global climate observation system is fundamental to continued improvement in weather and climate forecasting and the 2010 GCSA review[59] confirmed the need for long term high quality observations of the climate system to underpin advances in forecast capability. Arguably, the Met Office is unique in the world in respect of its ability to link analysis of observations and climate modelling and this has been recognised by several independent reviews.[60] We are pleased that the Met Office Science Strategy includes a strategic aim to build appropriate collaborations on observations (for example, of essential climate variables) and we would welcome a clearer view of progress on this.

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[52] Lawton (2009) *op cit*

[53] CMIP-1 and CMIP-2 models were used the IPCC 3rd Assessment Report. CMIP-3 models were used in the IPCC 4th Assessment Report

[54] There was no CMIP-4. ***C4MIP*** was intercomparison for fully coupled models with an interactive carbon cycle—hence not relevant here

[55] C S Witham, *et al* (2007). *Comparison of VAAC atmospheric dispersion models using the 1 November 2004 Grimsvötn eruption*, Meteorological Applications, Vol 14 (1)

[56] Ash dispersal forecast and civil aviation 2010, UNIGE—Ash dispersal forecast and civil aviation 2010—Results

[57] It should be noted that the majority of studies have focussed on comparison between dispersion models, rather than comparisons of NAME coupled with different weather prediction models

[58] Review of the Met Office Trajectory and Dispersion Model NAME, Professor David Fowler Centre for Ecology and Hydrology Edinburgh, July 2011

[59] Beddington (2010) *op cit*

[60] E.g. Risk Solutions (2007) Hadley Centre Review 2006 Final Report, a report for MoD/Defra

4.11 Consideration of observational capability was also the primary concern of the recently established Volcanic Ash Observations Review Group, chaired by the GCSA at the request of the Secretary of State for Transport. This group considered the robustness of the Met Office NAME model for predicting the location of volcanic ash and concluded that understanding and improving our knowledge of the source term inputs into NAME was key to reducing the uncertainty in model outputs. This group also agreed that, given the recent independent reviews of NAME, a further review of the model itself was not necessary at this time.

5. How effectively does the Met Office coordinate its activities with government departments, non-departmental public bodies, the UK research base and its international counterparts?

Met Office has a strong relationship both with its sponsoring departments and other key customer departments. A number of examples, which are not exhaustive, are described below. (The Research Councils are providing a separate submission to the Inquiry, which will address how effectively the Met Office coordinates activities with the UK research base.)

5.1 Since its formation in 1990, the MOHC has delivered policy-relevant climate science evidence and advice to HM Government, primarily funded by DECC and Defra and their predecessors and by MoD until 2009. Since the current Climate Programme was set out in 2007, Met Office management has maintained an excellent supplier-customer relationship with DECC and Defra, acting flexibly to deliver research that closely meets departmental needs, as confirmed in the GCSA's review in 2010.[61] Met Office climate scientists at all levels are in daily contact with DECC and Defra officials, providing evidence and advice to inform policy. This interaction has been encouraged, facilitated and strongly supported by senior Met Office scientists and management and is seen by the departments concerned as a critical component of a successful directed research programme.

5.2 In 2009 Defra published the latest UK Climate Projections (UKCP09), based on Met Office world class science, breaking new ground in promoting climate risk assessment to support the UK's preparedness for climate impacts and ensuring climate resilience. The user interface and tools to exploit these sophisticated climate projections have been developed to ensure a close fit with evolving user needs and to stimulate risk assessment in the public sector (central and local), regulated industries and other businesses. Government's own climate change risk assessment (CCRA), to be published in early 2012, is built on UKCP09. This directly supports Defra's objective of building resilience to climate change. Keeping the advice in the UKCP products up to date is likely to be important for future CCRAs.

5.3 The Met Office Hadley Centre leads a consortium of UK research institutesto deliver the Avoiding Dangerous Climate Change (AVOID) programme. AVOID was set up in 2009 specifically to provide policy-relevant scientific and technical evidence to HM Government (DECC and Defra in particular) to inform national and international strategies on mitigation and adaptation. The findings of the programme have been used inform the UK positions ahead of recent UN Framework Convention on Climate Change (UNFCCC) Conferences of Parties and has contributed to international reports such as those by the EU[62] and UNEP[63] on the "emissions gap".

5.4 Promoting awareness of global climate impacts with other governments around the world is a key part of HMG's strategy to change political conditions in order to promote a global legally binding treaty on emissions reduction under the UN Framework Convention for Climate Change (UNFCCC). The Met Office provides support on accessing, understanding and interpreting the latest climate science which allows the FCO to talk with an authoritative voice on climate change from a sound scientific evidence base. The Met Office has also been able to provide unbiased scientific answers where there is disagreement on the basic issues of the science which have proved sticking points in discussion. Met Office climate scientists have accompanied FCO representatives on country visits, speaking at events organised by the FCO to raise awareness and engagement on climate change issues.

5.5 The Met Office has undertaken a range of studies for informing discussion, such as a report on the vulnerability of global energy infrastructure to climate change and a series of summaries of the impacts of climate change for key FCO priority countries. The Met Office communicates the often complex and uncertain science of climate change in a way that is most value to the FCO. This is to enable non-specialists to engage with the science and set a baseline of understanding of the impacts of climate change, from which UNFCCC negotiations can be undertaken. This work often communicates research done by the Met Office on the sensitivity of the climate to human activity, such as the "4 Degree Map"[64] which has been an extremely useful influencing tool worldwide.

5.6 FCO has a keen interest in Met Office studies conducted for other Government departments, such as the recently completed reports prepared for the Government Office for Science Foresight project on the International Dimensions of Climate Change. The project on climate impacts which the Met Office is implementing for DECC is a key part of HMG preparations for the UNFCCC Conference of Parties in Durban in November.

[61] Beddington (2010) *op cit*
[62] Fee *et al* (2010): Scientific Perspectives after Copenhagen: Information Reference Document. European Union.
[63] UNEP, "The Emissions Gap Report: Are the Copenhagen Accord pledges sufficient to limit global warming to 2°C or 1.5°C?".
[64] http://www.fco.gov.uk/en/global-issues/climate-change/priorities/science/

5.7 The Met Office has consistently provided high quality and responsive scientific advice and support to the GCSA-chaired Scientific Advice Group in Emergencies (SAGE), including provision of advice to the first Fukushima SAGE on the 13 March with only an hour's warning that a SAGE was being formed. During the Fukushima emergency a 24 hour emergency response mechanism was established which would not have been possible without the dedicated support provided by Met Office scientists. This mechanism enabled advice on the potential consequences of a release of material from the Fukushima plant to be provided to UK citizens in five Japanese cities within half an hour of release, based on pre-calculated dose rates and predicted weather conditions.

5.8 Both DECC and the energy industry found the Volcanic Ash Advisory Centre to be of great assistance in ensuring the safety of helicopter operations at offshore oil rigs during the Icelandic eruptions last year. The centre also provided good data quickly, to assist the department in assessing the potential risk to the UK energy network through volcanic ash accumulating on overhead lines.

5.9 The MoD has maintained a close working relationship with the Met Office through Defence Intelligence. The framework for this partnership is a Customer Supplier Agreement (CSA), supported by annual Service Definition Agreements (SDA) covering the provision of meteorological and oceanographic support to Defence. This is a detailed agreement specifying the support requirements for specific defence roles, exercises and overseas operations, training and the infrastructure required to deliver this support. MoD research requirements are progressed through the SDA framework after consultation within specific defence areas and where appropriate with NATO partners. The pull-through of this research is monitored by Defence Intelligence to ensure value for money is achieved.

5.10 The move of the Met Office from MoD to BIS in July creates a different working relationship between MoD and Met Office that will be governed by a new Service Level Agreement (SLA), however, it is anticipated that this move will not reduce the outputs and services already provided to MoD. In order to ensure a close liaison is maintained in the future, it is recommended that an RN OF5 (Meteorological Specialist) post is established within the Met Office in Exeter to firstly, balance the Met Office post currently funded by MoD within DI ICSP and secondly, to add continued support to the valued and extensive contribution the Met Office makes to Defence.

5.11 The Met Office already has very strong links with the climate and earth system science academic community in the UK and abroad. DECC and Defra have strongly encouraged MOHC to build links with NERC and other UK institutions over the past few years and are pleased to see these have delivered new, world class research and improved climate projections. For example, since April 2010, MOHC have published 165 peer-reviewed papers based on Climate Programme research (many in very high profile journals) and in 2009–10 approximately 80% of their papers were co-authored by non-Met Office staff. This proportion has been steadily increasing since the Climate Programme started.

5.12 The Met Office has also conducted research projects funded or partly funded by the FCO and DfID, to build capacity within countries, or to help further the dialogue on climate change issues within that country. Examples of this include: the Met Office PRECIS regional climate model given to countries to enable them to run their own climate change experiments; research in collaboration with counterparts in Brazil to understand more about regional climate change in that area; research in collaboration with Russian climate scientists to improve the representation of Russian climate within climate models; a project on climate change and security in the Sahel, jointly funded by the French Foreign Ministry and undertaken with OECD. The Met Office has an excellent reputation worldwide and has a strong network of contacts with counterparts overseas.

5.13 We understand that several other major bilateral collaborative links have now been forged by the Met Office, for example with Australia, New Zealand, Korea and Norway, among others, which are already delivering improved modelling systems. In 2010, the Australian Bureau of Meteorology implemented the Met Office's Unified Model to deliver its national weather forecasts and a dramatic performance improvement (as measured by skill metrics) has already been achieved. The Korean Meteorological Administration (KMA) also used the Unified Model for their national weather forecasting and the Met Office and KMA will implement a joint seasonal forecasting system in 2012. Further evidence of strong international collaboration, encouraged and supported by DECC and Defra, is MOHC's increasing work with UK, U.S. and other partners in the Attributing Climate Extremes (ACE) group which is building new and robust methods for attributing extreme weather and climate events.

5.14 The Defence Oceanographic programme significantly benefits from the Met Office's collaboration with national and international partners, most notably through the National Centre for Ocean Forecasting (NCOF), the MEMO consortia and European Commission research projects. The continued development of Global and nested higher resolution models has supported the strategic deployment of the nuclear deterrent, Mission Support and Planning (MSP), Mine Counter Measures (MCM) and Anti Submarine Warfare (ASW). Continued development of models will support Tactical Decision Aids and acoustic range prediction models as directed by MoD policy.

5.15 As Earth systems models improve there are new opportunities to increase engagement with academics in the impacts and biophysical modelling community. For example, understanding and reconciling differences between integrated Met Office models and other specific impacts from elsewhere will improve the science of both and increase consistency of advice for decision-makers. Some work is already underway in areas such as

water availability and crop modelling and is highly promising. There may also be particular benefits from working with more impacts specialists with expert local knowledge in particular regions around the world. Further increasing data availability and accessibility will support collaboration efforts. There could also be opportunities for developing new climate services by examining best practice in how forecasts and advice are delivered and used around the world.

5.16 The climate system has no national boundaries and we believe that continued collaborations will improve understanding of crucial phenomena such as ENSO (the El Nino Southern Oscillation), and eventually lead to significant benefit and added value to the UK. We continue to encourage and support the Met Office in building strong collaborations in the UK and internationally to deliver increased scientific capability and knowledge exchange.

5.17 Following the flooding in 2007 Sir Michael Pitt's Review recommended that the Met Office and Environment Agency worked much more closely together to ensure that future flooding events may be better predicted and avoided. The Met Office and the Environment Agency set up the Flooding Forecast Centre, (FFC), staffed by members of both organisations. They have over the past couple of years developed the centre in its premises in the Met Office at Exeter. Daily flood forecasts are produced and distributed and the two organisations work extremely closely and well together. The FFC have also taken responsibility for the Storm Tide Forecasting Service. Using Met Office forecasts of coastal water levels and weather forecasts the FFC alerts the EA and SEPA to the risk of coastal flooding.

5.18 Additionally, the Met Office has established the Natural Hazards Partnership, with support from the Cabinet Office and GO-Science. The Partnership brings together the leading public sector environmental agencies to share expertise and develop multi-hazard services to reduce the impact of natural hazards on the UK. Within a year of the Partnership being established, it has already piloted a multi-hazards warning service and the expertise is being integrated into the Cabinet Office National Risk Assessment process to ensure the best use of scientific evidence in planning and preparing for natural hazard events.

5.19 The Met Office has always worked very closely with a variety of other government departments. The Met Office has a role in forecasting the spread of airborne diseases such as foot and mouth and blue tongue for DEFRA. Numerical Atmospheric Modelling Environment (NAME) can be run using localised weather data, and using Geographic Information System (GIS) and Ordnance Survey mapping systems overlaid to show possible spread of the disease.

5.20 In collaboration with the Department of Health the Met Office have helped produce the Heatwave plan for England and Wales. This plan, based on 4 levels and a series of regional threshold temperatures ensures that hospitals and all medical practitioners receives information about potential hot weather and its potential to cause excess deaths. At Level 4 the nature and length of the heatwave would be such that a wide range of government departments would be affected. DH and the met Office are now working on a Cold Weather plan for the UK based on a similar set of principles and warning levels.

5.21 In the event of an incident caused by hazardous chemicals local fire or police services can contact the Met Office and request a CHEMET report. These chemical meteorology reports include plume modelling and weather forecast information. The development of this service has involved the Met Office working closely with the Fire Service and DCLG.

5.22 During the Buncefield fire and the emergency that followed, the service provided by the Met Office to other government departments was invaluable. As well as the CHEMETs provided, the Met Office plane flew through the plume to collect samples for analysis. As the plume moved towards the near continent the Met Office provided modelling of where the plume might travel so the UK could fulfil its international obligations to inform its partners of potential danger.

5.23 The Volcanic Ash Advisory Centre advises the Civil Aviation Authority about ash in the atmosphere, usually, but not exclusively, from Icelandic volcanoes. This work is carried out on behalf of the Department for Transport (DfT). In the recent Icelandic volcano eruptions the Met Office have worked very closely with DfT to provide ash plume monitoring. The Met Office contacts with the Icelandic Met Office have proved invaluable.

5.24 During major emergencies or incidents the Met Office has been called upon to provide staff to attend strategic command meetings both in COBR and the Scottish Government Emergency Room. For the first time during the Icelandic volcano emergencies, the Met Office embedded a member of staff at the Cabinet Office, and this was greatly appreciated, both by us and other government departments involved.

5.25. A member of the Met Office was also embedded in DfT during last winter's severe weather to ensure that DfT received the most up to date information to assist in modelling for salt supplies across the UK. This proved to be an important and valuable service.

5.26 The Met Office also works with DECC and DEFRA on the response to small scale nuclear incidents. This followed the Chernobyl incident in 1988. The Radioactive Incident Monitoring Network (RIMNET) enables any increase in radiation levels across the UK to be detected and automatic alerts generated.

5.27 VisitEngland have had discussions with Met Office about sharing research opportunities. For budget reasons this has not been possible, but they are open to future possibilities should the financial position change.

5.28 The Government's view is that the Met Office works very effectively with a wide range of departments and continues to seek to improve the service it provides to its customers.

Department for Business, Innovation and Skills

September 2011

Annex A

BACKGROUND ON THE PUBLIC WEATHER SERVICE CUSTOMER GROUP

PWSCG is responsible for setting the requirements and outputs of the PWS provided by the Met Office, supporting research and development to meet future requirements, and providing independent advice and recommendation to the Minister for Universities and Science (formerly the Under Secretary of State for Defence (Minister for Veterans)) to enable formal agreement of the PWS Customer-Supplier Agreement (CSA).

In addition to detailed definitions of the PWS outputs, the annually negotiated and agreed CSA specifies performance measures and standards, international commitments and the service price, including year-on-year efficiency savings.

Membership of the PWSCG consists of:

- Independent Chair—currently this position is held by Nick Baldwin.
- Cabinet Office Civil Contingencies representative.
- Association of Chief Police Officers representative.
- Chief Fire Officers Association representative.
- Local Government Association representative.
- Scottish Executive Government representative.
- Welsh Government representative.
- Environment Agency representative.
- Highways Agency representative.
- Independent member representing the UK public.

The PWSCG meets quarterly to provide strategic direction and challenge to the Public Weather Service. The group is supported by a secretariat which monitors and challenges PWS performance on a monthly basis and is currently advised on reach by the Editor of BBC Weather.

The PWSCG is responsible for defining the scope of the PWS remit (which defines the Met Office Public Task) which is to:

- produce weather forecasts which help the UK public make informed decisions about day-to-day activities;
- warn people of extreme weather to mitigate its impacts—contributing to the protection of life, property and infrastructure;
- improve weather and climate predictions through research;
- fulfil international commitments on behalf of the UK Government; and
- provide public access to historic weather information via our Library and Archive and climatological records.

The PWSCG undertakes a programme of consultation to ensure that any changes that are made to current or future PWS outputs are based on independent consultation and will withstand a robust degree of external challenge. In addition, the PWSCG ensures availability of research, forecast and observational data required by the Met Office in order to deliver services to other Public Sector customers, and to make the same data available to the Met Office's commercial arm and the private sector. Finally, the PWSCG requires the PWS to fulfil commitments on behalf of UK Government on three designated international bodies. Details on how well the PWS meets these requirements are provided from paragraphs 1.14 to 1.31 in this memorandum. Further detail can be found in the PWSCG Annual Report for financial year 2010–11: http://www.metoffice.gov.uk/media/pdf/m/5/PWSCG_Annual_Report.pdf.

Annex B

TERMS OF REFERENCE OF THE PUBLIC WEATHER SERVICE CUSTOMER GROUP (PWSCG)

Note: These terms of reference are in the process of being updated for formal adoption as part of the change of PWSCG ownership from MoD to BIS.

PURPOSE

The PWS provides a coherent range of weather information and weather-related warnings that enable the UK public to make informed decisions in their day-to-day activities, to optimise or mitigate against the impact of the weather, and to contribute to the protection of life, property and basic infrastructure.

The PWS also fulfils international commitments on behalf of UK Government, and provides research, and forecast and observational data which are essential inputs to a wide range of Met Office services.

The PWSCG acts as the customer on behalf of the public for free-at-point-of-use weather services and ensures that these services are aligned to the operational needs of Public Sector users of PWS outputs. It also acts as guardian on behalf of public sector users of the Met Office's underpinning operational capability. It is responsible for setting its requirement and specifying its outputs, supporting research and development to meet future requirements, and providing independent advice and recommendation to the Under Secretary of State for Defence (Minister for Veterans) to enable formal agreement of the PWS Customer-Supplier Agreement.

MEMBERS

- Independent Chair.
- Cabinet Office—Civil Contingencies.
- ACPO—Association of Chief Police Officers.
- CFOA—Chief Fire Officers Association.
- Local Government Association.
- Scottish Executive Government.
- Welsh Assembly Government.
- Environment Agency.
- Highways Agency.
- Independent Member.

ADVISORS

- Editorial Manager, BBC Weather Centre.
- Head of PWS CG Secretariat.
- PWS CG Secretariat Support Manager.

RESPONSIBILITIES

Specific responsibilities include:

- Setting the current and future requirement of the PWS and specifying its outputs.
- Ensuring appropriate inclusion of international commitments within the PWS.
- Conducting or commissioning appropriate consultation and market research to ensure:
  - representation of interests of professional partners and public users of the PWS; and
  - representation of interests of public sector customers for whom the Met Office provides direct services using a defined baseline of PWS capability and data.
- Conducting or commissioning appropriate financial or technical scrutiny to ensure:
  - delivery of value for money in relation to the quality of service required; and
  - efficiency.
- Setting performance indicators and associated targets.
- Robustly monitoring performance and delivery against specified outputs.
- Agreeing funding for services based on past performance and present requirements.
- Providing support for Met Office bids for additional funding from alternative sources, as appropriate, to enable further development of the Service.
- Considering and endorsing proposals for in-period changes within the PWS as required.
- Maintaining appropriate level of communication with the Met Office Executive and Chair Met Office Board.
- Maintaining appropriate level of communication with MoD DG Finance or his representative.

RELATIONSHIPS AND LINES OF COMMUNICATION

The Secretary of State for Defence is the Minister responsible for the Met Office and is accountable to Parliament for the Trading Fund's policy and operations. The Chief Executive of the Met Office is personally accountable to the Secretary of State for the effective and efficient management of the Trading Fund and for

achieving the Aims and Objectives set out in the Framework Document. He is also appointed the Accounting Officer for the Trading Fund.

The Under Secretary of State (Minister for Veterans) acts on behalf of the Defence Secretary as Owner, and is advised by the Met Office Owner's Council. It is the means through which the Trading Fund reports performance and seeks top level guidance from the Ministry. The Chairman of the PWSCG reports to the Secretary of State for Defence through MoD DG Finance or his representative.

PWSCG is responsible for proposing changes to these Terms of Reference to the Minister through MoD DG Finance or his representative.

Group Members

The Chairman will be a public appointment by MoD DG Finance on behalf of the Minister. Other Members will be drawn from the main Public Sector users of PWS outputs, together with public appointment(s) by the Chairman as appropriate to represent public users of the PWS. Head of the PWSCG Secretariat will act as advisor to the PWSCG and, as a representative of the funding Department will provide assurance to the budget holder regarding appropriate use of MoD funds. In addition, a representative from a nominated broadcaster (currently BBC) will be assigned to the Customer Group to advise on output specification and effective communication of the PWS message and inform the PWSCG on public perception of the PWS outputs, based on feedback from viewers and listeners.

The Chairman and public appointee(s) will be remunerated by MoD through the PWSCG Secretariat, contracted for a fixed term.

PWSCG Chairman

The Chairman has responsibilities additional to those of the group. He/she is the single point within the PWSCG accountable to the Secretary of State for Defence, and is responsible for:

- Chairing the PWSCG.
- Ensuring the proper execution of the PWSCG ToRs.
- Reviewing and, if appropriate, seeking amendment to the PWSCG ToRs.
- Establishing and maintaining the most appropriate funding mechanism to fulfil the PWSCG ToRs.
- Formal approval of the PWS Customer-Supplier Agreement (CSA).
- Negotiating funding from MoD through the STP process.
- Negotiating and agreeing the PWS price annually with the Met Office.
- Confirming to the Custodian of the PWS funds that invoices from the Met Office are consistent with the agreed output price.
- Ensuring that PWS funds are spent with due regard to economy, value for money and the Government's drive for efficiency.
- Establishing, maintaining and documenting the most appropriate PWSCG process to fulfil its ToRs.
- Building and maintaining links with appropriate user representatives to inform the development of future output definitions.
- Raising the profile of the PWS within government.
- Increasing the integration of the PWS within broader government initiatives.
- Increasing the impact of the PWS on beneficial outcomes for the UK.
- Identifying and supporting, as appropriate, bids to alternative funding sources.
- Providing reports to the Met Office Board and Departmental Owner.
- Providing a focal point for all PWSCG correspondence.

The Chairman will appoint a deputy to act on his/her behalf in his/her absence.

Secretariat

The PWSCG will be supported by a Secretariat staffed by officials provided by the MoD. The Secretariat will be a dedicated resource and strongly support the Chairman and PWSCG, in particular:

- Consulting widely with public and professional users of the PWS.
- Liaising with other government stakeholder interests in the PWS.
- Drafting output requirements for incorporation in the annual review of the PWSCG CSA and formally improving the Service Definition Annexes.
- Ensuring appropriate financial provision.
- Liaising with the Met Office and monitoring of performance against agreed KPIs and targets.

FORMAL MEETINGS

The PWSCG will normally meet at least twice a year to conduct its formal business. Other ad hoc meetings may be called by the Chairman as required. A formal meeting of the PWSCG will be considered quorate provided no more than two Members are absent. Where necessary, voting will be on a two thirds majority basis and the Chairman will have the casting vote.

DURATION

The PWSCG is established on an on-going basis until no longer required, when it will be dissolved on instruction from the Minister.

Supplementary written evidence submitted by the Government (MO 14a)

ANSWERS TO THE QUESTIONS POSED FOLLOWING ORAL EVIDENCE GIVEN BY EDWARD DAVEY, MINISTER FOR EMPLOYMENT RELATIONS, CONSUMER AND POSTAL AFFAIRS ON 9 NOVEMBER 2011

1. *The Minister mentioned that DECC and Defra would be signing a memorandum of understanding in relation to the Hadley Centre Climate Programme. Can you send us details of when this is happening and can we see a copy of the memorandum please?*

The current contract between DECC and Defra and the Met Office Hadley Centre for the Climate Programme runs from 2007 until 2012.

The Government Chief Scientific Adviser in his review of Climate Science Advice to Government and Met Office Hadley Centre Role, Governance and Resourcing recommended that ideally, a single sponsoring department should fund core science and modelling at the Hadley Centre.

The aim of this recommendation was to deliver stability of funding for the Met Office Hadley Centre.

Working within the spirit of the recommendation DECC and Defra Secretaries of State agreed that the two departments would continue to fund a new programme jointly but via a strengthened agreement, and would develop a cross-departmental Memorandum of Understanding (MoU) for this purpose. This approach would provide a greater level of stability than the current contractual relationship, while ensuring that both DECC and Defra continue to have a strong customer relationship with the Met Office Hadley Centre.

Signing of the MoU was deferred earlier this year, due to uncertainty over the future status of the Met Office. With the recent move of the Met Office to BIS consideration is being given to the most suitable governance arrangements for the future Hadley Centre Climate Programme. This is very much a live issue, but while the details remain under discussion, DECC and Defra have committed to continued funding support for the Met Office Hadley Centre.

2. *There was a discussion about BIS working on a business case for supercomputing resources. We would be grateful if you could give us further details of this (any information you can share with us on the potential return on investment), as well as details of the timetable for putting this business case together? The Committee would also like to know how BIS is working with other Government departments to develop this business case (for example, is Defra making a case based on the benefits of potential earlier flood warnings). The Committee is also keen to know about the extent to which the Met Office and other organisations have been feeding into this process.*

Government recognises the benefits that increases in Met Office super-computing capacity would bring, in terms of increasing the accuracy of forecasts across all time and spatial scales and with regards to climate change modelling. We also recognise that the costs to gain these benefits are significant thus the case for increased investment is a matter for detailed consideration around both affordability and value for money.

There is an opportunity to increase the capacity of the Met Office's current supercomputer and therefore speed up the application of currently available science and the delivery of associated benefits, as described in the Met Office's supplementary memorandum to the Committee on increased supercomputing resource.

Separately, further economic benefit as a consequence of ongoing advances in the science will de delivered through the routine scheduled replacement of the current supercomputer currently planned for 2015. Within this context, the Met Office, working closely with BIS has recently commenced work on developing the business case for the next generation of supercomputing capacity. This will be based on standard HMT methodologies to assess value for money, including broader socio-economic benefits and capacity to deliver improved performance against key government objectives, and will be balanced against affordability. The current timetable sees this process taking up to 18 months.

As part of this planning process input will be sought from a range of government and non government sources including, but not exclusively, HMT, DECC, DEFRA, the Natural Environment Research Council (NERC), the Public Weather Service Customer Group, MOD, and the broader science and research community.

Met Office continues to explore options for international supercomputing collaboration.

3. *Can we have clarity from you about the discussions that are taking place between the UK and the USA with regard to the potential delay to the launch of the next generation of polar-orbiting satellites due to budget cuts in the USA? We were not clear from the discussion this morning whether these discussions are taking place at Ministerial level. A short note on this would be much appreciated.*

Discussions are not taking place at Ministerial level. Such issues are normally resolved effectively within the meteorological community and it is very rare that Ministers need to be called upon for support. John Hirst has been discussing the issue with his US counterpart.

President Obama has publicly stated that this is a priority for the US Government (see below), however the programme is being delayed by the challenges of getting the US budget passed by Congress. This is a US political issue and therefore Ministerial involvement is unlikely to be of assistance at this time, however support has been offered to Mr Hirst on this matter should the situation change.

President Obama (In an interview with NBC's "Today" show): the president acknowledged the need to reduce federal debt but said *"really important" priorities include ensuring "government functions like food safety or weather satellites are still up there."*[65]

In a statement issued to EUMETSAT by the US Government in February 2010 they stated that: "The President's FY2011 budget contains a major restructuring of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) in order to put the critical program on a more sustainable pathway toward success. The satellite system is a national priority—essential to meeting both civil and military weather-forecasting, storm-tracking, and climate-monitoring requirements."

4. *There was a bit of confusion over the purpose of "Government representation" on science partnerships with the Met Office. Can we please have clarity on this matter? I refer you to paragraph 2.6 of the Government submission and the exchange between the Committee, John Hurst and Julia Sligo on 2 November (http://www.publications.parliament.uk/pa/cm201012/cmselect/cmsctech/uc1538-ii/uc153801.htm Q 113–114). In particular: (I) can BIS explain what the purpose of Government representation is? (ii) When you talk about a government representative on these partnerships, does that mean a Minister? Someone from GO Science or the network of CSAs? BIS officials? Staff from TSB/RCUK/others? (iii) What assurances can the Government give that there is no conflict with the Haldane principle? (as mentioned by Julia Sligo)*

The Haldane Principle applies to science and research which the Government funds through the Research Councils and National Academies as set out in The Allocation of Science and Research Funding 2011–12 to 2014–15: investing in world-class science and research published in December 2010.[66]

The Haldane Principle does not apply to the research budgets of government departments, which are used to fund research to support their departmental policies and objectives, and does not apply to the science and research undertaken by the Met Office and Met Office Hadley Centre funded by Government.

Clearly there is potential for research funded from research councils and other funders to be of relevance to Departmental decision-making. In suggesting that the proposed Met Office science partnerships include representation from Government the aim was to help ensure coherence—in particular to help ensure awareness of policy-relevant research being conducted and to minimise unnecessary research overlap.

We note that collaborative activity with Research Councils is already facilitated through initiatives such as the Met Office/NERC Joint Weather and Climate Research Programme (JWCRP) and LWEC.

Whilst we do not necessarily envisage Government representation in all scientific collaborations engaged in by the Met Office, we consider there may be some strategic partnership relationships where departmental representation might be of value. This would most likely be at CSA or official level from core customer Departments.

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[65] *June 20, 2011. (See http://www.federaltimes.com/article/20110620/AGENCY03/106200303/1004/AGENCY03)*
[66] http://www.bis.gov.uk/assets/biscore/science/docs/a/10–1356-allocation-of-science-and-research-funding-2011–2015.pdf

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