Of the conclusion arrived at by a committee of the Academy of Sciences of France, agreeably to which, tornados are caused by heat : while, agreeably to Peltier's report to the same body, certain insurers had been obliged to pay for a tornado as an electrical storm, also, abstracts from Peltier's report : moreover, quotations shewing the ignorance which existed in the Academy respecting the nature and causes of the meteor in question, prior to the publication ascribing it to a convective discharge of electricity : with objections to the opinions of Peltier and Espy / by Dr. Hare.

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MOREOVER,

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WITH OBJECTIONS TO THE OPINIONS OF PELTIER AND ESPY.

BY DR. HARE.

SECOND EDITION, REVISED AND AMENDED.

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PREFATORY REMARKS.

In consequence of an application from the Chairman of the Naval Committee of the House of Representatives of the United States, for my opinion respecting the expediency of continuing Espy's meteorological labors, as exhibited in his Reports to the Naval Department, I preferred to publish my impressions as a witness or party, rather than to express privately a juridical opinion. Consequently, in the pamphlet submitted to Congress, and to men of science, the question between truth and the French Academicians, was discussed as a subordinate object. Having to communicate the substance of that pamphlet to the Journal of the Franklin Institute, I deemed it expedient to remodel the whole, so as to exhibit in bolder relief and better type this last mentioned phase of the subject. This will be seen in the following pages, prepared mostly for the July number of that periodical.

EXPOSURE

OF THE

ERRORS AND INCONSISTENCIES

OF THE

FRENCH ACADEMICIANS

RESPECTING TORNADOS.

In June, 1845, a tornado occurred at New Brunswick, New Jersey, of which the actual mechanical phenomena were peculiarly well ascertained by various observers, and more especially by a survey made by Profs. Bache and Espy, with the compass and chain. It was generally admitted that the tornado in question, was attended by an upward blast of air, and confluent blasts from all sides to supply that upward blast; all bodies sufficiently light and movable being simultaneously carried aloft.

While by Prof. Espy, the ascentional power was ascribed to a buoyancy caused by heat evolved from condensing vapor in the upper part of a rising column of air, by me it was attributed to an electric discharge between the earth and sky, superseding the more usual process, in the form of lightning.

This explanation was made the subject of a memoir published in v. 5, 1836, of the American Philosophical Transactions, and in Silliman's Journal, Vol. 32, for 1837. During a visit to Paris, in June, 1836, I presented a copy of this memoir to Arago, and other members of the Academy of Sciences of France; a copy likewise being deposited in the Academic Library. This library it must have likewise reached, according to custom, in the volume of the Transactions of the American Philosophical Society.

In 1839, indemnity for the devastation, caused by a tornado, at Chatenay, near Paris, was demanded under a contract of insurance against thunder storms. This demand having been resisted upon the plea that a tornado is not a thunder storm, the question was referred to Arago, President of the Academy of Sciences. Under the auspices of this eminent philosopher, a report was made by an electrician, named Peltier, agreeably to which the insurers were obliged to pay. Nevertheless, in 1841, a report was signed by Arago, Pouillet, and Babinet, three of the most distinguished members of the Academy, sanctioning the idea that tornados are caused by heat evolved from condensing vapor.

Arriving in Paris in the following August, I learned from the parties

themselves, that Arago had been so much occupied that he could give no attention to Espy's application; that Pouillet, not agreeing with Babinet, left it to him exclusively to report upon the Espyan theory, and that Babinet, (more distinguished for benevolence than meteorological knowledge,) made his report in ignorance of my memoir, of Peltier's report, or the judgment against the insurers.

It follows that the report obtained by the personal application of Espy, was the offspring of exparte representations, ignorance, and error; and that either great injustice was done the insurers, in making them pay for the tornado as an electrical storm, or to scientific truth in ascribing that meteor mainly to heat!!!

It is remarkable that Arago, one of the most distinguished electricians in Europe, when requested to decide this question, did not conceive himself warranted in saying whether or not a tornado was an electrical storm. Had the damage been done by lightning, there would have been no doubt as to the nature of the cause; but as it was done by the meteor above mentioned, (called trombe in French,) Arago felt it necessary to send Peltier to examine the phenomena, in order to find out whether or not they were due to electricity. It had often been observed that electrical phenomena were attendant on such storms, and by some observers they had been ascribed to electricity; yet so vague and unsatisfactory had been the evidence or arguments in favor of this view of the question, that they seem to have made no impression on the minds of the sagacious, learned, and ingenious members of the "Academie des Sciences."*

Such, at all events, is the only inference which can be reasonably drawn, judging from the opinions expressed by those among them, who were selected as eminently competent to decide.

It is manifest that Arago had formed no opinion, or he would not have sent Peltier to investigate the phenomena, in order to determine the question. As this philosopher, Pouillet, and Babinet, were chosen as a committee to decide on Espy's theory of tornados, it is to be presumed that they were considered as among those members who were pre-eminently qualified to judge, respecting meteorological theories. Let us then see whether any of the other academicians were, more than Arago, impressed with the idea that electricity was the main cause of tornados.

I subjoin the opinions of Pouillet first.

"*How can this power, sometimes so prodigious, be created in the midst of the air?* This is a question to which, it must be admitted, science as yet cannot give a precise answer. Of all the vague and hazardous conjectures which have been made respecting the origin of this meteor, probably the least unreasonable is, *that it is a whirlwind of excessive intensity.* But the discussion of this point seems premature. It is necessary to multiply observations, and to compare with more precision all the attendant circumstances of the phenomena." *Pouillet Elemens de Physique Experimental et de Meteorologie.*

*Among those who alleged them to be due to electricity, Beccaria is, perhaps, the most distinguished; but how little he understood the true nature of the meteor, is manifest from his crediting the allegation that they could be dissipated by the presentation of a sword from the deck of a vessel. Evidently no vessel could come within the electrified column without being dismantled, if not wrecked; and if situated outside of the electrified column, how could the electricity reach the sword? But should it be induced to leave its wonted vertical path, in order to pass off by this weapon, how could the person presenting the sword survive an influence capable of rending the wood of trees into laths, as alleged by Peltier?

To allege a tornado to be a whirlwind, without showing how a whirlwind may be produced or sustained in the case in point, is only substituting one mystery for another. Whirling or gyration is an *effect*, not a *self*-moving power, as some meteorologists seem to suppose.

All the elucidation given by Depretz, another luminary belonging to the same illustrious Academy, is contained in the following language, which is a literal translation from his Traite Elementaire de Physique, page 329:

"*The tornado* ("*trombe*") *is seen upon the sea and upon the land. Sometimes it seems to come out from the bosom of the sea, ascending to the clouds; sometimes it descends from the clouds down to the earth.*"

"*It is a conical column of water, which revolves upon its axis, with great rapidity. The base is sometimes more than two hundred metres in diameter.*"

"*An idea may be had of tornados from the little whirlwinds of dust which suddenly form themselves in summer, revolving with great rapidity.*" Risum teneatis amici?*

That Babinet entertained no feasible idea of the part performed by electricity in the generation of the tornado, is evident; since, after a long discussion, in which no allusion is made to electricity as essential, he terminates with a conclusion favorable to the Espyan hypothesis, and in which electricity is referred to only as a subordinate participant playing a part, respecting which he shows himself incapable of throwing any light. I subjoin his "*conclusion*," as he designates his ultimate brief exposition of those inferences which his study of the question led him to make.

I use the singular pronoun, his, because Arago assured me he had nothing to do with the report, and Pouillet let it pass, because Arago could not attend, and he could not agree with Babinet; while Espy was very urgent to have the report before leaving Paris.†

* "Comment cette puissance quelque fois si prodigieuse peut-elle prendre naissance au milieu des airs? Cest une question, il faut le dire, à laquelle la science ne peut faire aucune réponse précise. De toutes les conjectures vagues et hazardées que l'on peut faire sur l'origine de ce météore la moins invraisemblable est peut être celle qui le regarde comme un tourbillon d'une excessive intensité. Mais une discussion sur ce point nous semblait prematurée, il faut multiplier les observations et constater avec plus de precision toutes les circonstances de ces phénoménes." Elémens de Physique et de Météorologie, tom. 2, page 727.

Tous les détails que Despretz donne sur les trombes se trouvent dans ces paragraphes que j'emprunte à son traité de Physique.

"*Trombe.* La trombe se montre en mer et sur la terre; tantôt elle semble sortir du sein de la mer et s'élève jusqu'aux nuages; tantô elle descend des nuages jusqu'à tèrre.

Cest une colonne d'eau conique qui tourne sur elle même avec une grande vitesse; elle quelque fois jusqu'à plus de deux cents mêtres de base. Elle est très-commune entre les Tropiques. Les navigateurs passent rarement près des côtes de Guinée sans en apercevoir plusieurs.

Les trombes produisent des effets terribles, elles déracinent les arbres renversent les fibles habitations soulèvent les voitures etc.

Ou peut se faire une idée des trombes par des tourbillons de poussière qui se forment tout-a-coup en été sur les routes et qui tournent sur eux mêmes avec une grande rapidité. Traité Elem. de Physique, parag. No. 656, pag. 828.

† M. Arago, before the Academy, in my presence, stated that the subject required to be considered. All the members of the committee acknowledged the error which had been committed, and promised to have it rectified by an amended report. But after two reports so utterly irreconcileable had been made, it was difficult to contrive a third which should be consistent with justice and the reputation of the Academy. It is to this, I presume, that the non-performance of their promises is to be ascribed.

Babinet's "Conclusion."

"In conclusion, Mr. Espy's communication contains a great number of well observed an well described facts. His theory, in the present state of science, alone accounts for th phenomena, and, when completed, as Mr. Espy intends, by the study of the action of ele tricity when it intervenes, will leave nothing to be desired. In a word, for physical geogr phy, agriculture, navigation, and meteorology, it gives us new explanations, indicatio useful for ulterior researches, and redresses many accredited errors.

"The committee expresses then the wish, that Mr. Espy should be placed by the gover ment of the United States in a position to continue his important investigations, an to complete his theory, already so remarkable, by means of all the observations and a experiments which the deductions even of his theory may suggest to him, in a vast cou try, where enlightened men are not wanting to science, and which is besides, as it wer the home of these fearful meteors.

"The work of Mr. Espy causes us to feel the necessity of undertaking a retrospecti examination of the numerous documents already collected in Europe, to arrange then and draw from them deductions which they can furnish, and more especially at the prese period, when the diluvial rains, which have ravaged the south-east of France, have direc ed attention to all the possible causes of similar phenomena. Consequently, the com mittee proposes to the Academy to give its approbation to the labors of Mr. Espy, and t solicit him to continue his researches, and especially to try to ascertain the influence whic electricity exerts in these great phenomena, of which a complete theory will be one of th most precious acquisitions of modern science."

Mr. Espy is to study the action of electricity "*when it intervenes.*" C course, it was only a visiter, according to Babinet's opinions.

Such was the state of knowledge respecting tornados in 1836, whe I handed to Arago and other members, copies of my pamphlet, in whic I attributed those awful meteors to a convective discharge of electricit in these words: "*After maturely considering all the facts, I am led to sug gest that a tornado is the effect of an electrified current of air supersedin the more usual means of discharge between the earth and clouds in tho sparks or flashes which we call lightning.* While the air is thus carrie up by the concurrent influence of electrical attraction and the reaction o its own previously constrained elasticity, other bodies are lifted both b electrical attraction and the blast of air to which it gives rise. Henc houses within the sphere of excitement are burst by the expansion of th air which they contain, their walls being thrown outwards and their roo carried away, while by the afflux of the atmosphere requisite to the re storation of its equilibrium, trees, houses, and other bodies are throw inwards towards the vertical current from before as well as from eithe side."

This rationale of the tornado had been in the hands of the academician and the library of the Academy for about three years, when, agreeabl to an article published at Paris, on July 17th, 1839, in the *Journal de Debats*, that the tremendous tornado occurred about the last of the preced ing month, at Chatenay, which led to the claim upon certain insurers, t which reference has been above made, as inducing an examination an report by Peltier, and a decision in favor of the electrical character of th storm.

From the following narrative, translated from his report, it will be see that Peltier adopted my opinion, that a tornado is the effect of an elec trical discharge.

"Up to this time there had been thunder continually rumbling within the second thund cloud, when suddenly an under portion of this cloud descending and entering into con

unication with the earth, the thunder ceased. A prodigious attractive power was exerted thwith, all the dust and other light bodies which covered the surface of the earth ounted towards the apex of the cone formed by the cloud. A rumbling thunder was ntinually heard. Small clouds wheeled about the inverted cone, rising and descending th rapidity. An intelligent spectator, M. Dutour, who was admirably placed for obser-tion, saw the column formed by the tornado terminated at its lower extremity by a cap fire; while this was not seen by a shepherd, Oliver, who was on the very spot, but en-loped in a cloud of dust.

"To the south-east of the tornado, on the side exposed to it, the trees were shattered, ile those on the other side of it, preserved their sap and verdure. The portion attacked peared to have experienced a radical change, while the rest were not affected.

* * * * *

"Finally, it advanced to the park of the castle of Chatenay, overthrowing every thing in path. On entering this park, which is at the summit of a hill, it desolated one of the st agreeable residences in the neighborhood of Paris. All the finest trees were uprooted, youngest only, which were without the tornado, having escaped. The walls were own down, the roofs and chimneys of the castle and farm house carried away, and nches, tiles, and other movable bodies, were thrown to a distance of more than five ndred yards. Descending the hill towards the north, the tornado stopped over a pond, led the fish, overthrew the trees, withering their leaves, and then proceeded slowly along avenue of willows, the roots of which entered the water, and being during this part of progress much diminished in size and force, it proceeded slowly over a plain, and finally, the distance of more than a thousand yards from Chatenay, divided into two parts, one which disappeared in the clouds, the other in the ground."

"In this hasty account I have, with the intention of returning to this portion of the sub-t, omitted to speak particularly of its effect upon trees. All those which came within influence of the tornado, presented the same aspect; their sap was vaporized, and their neous fibres had become as dry as if kept for forty-eight hours in a furnace heated to ety degrees above the boiling point. Evidently there was a great mass of vapor in-ntaneously formed, which could only make its escape by bursting the tree in every ection; and as wood has less cohesion in a longitudinal than in a transverse direc-n, these trees were all, throughout one portion of their trunk, cloven into laths. ny trees attest, by their condition, that they served as conductors to continual discharges electricity, and that the high temperature produced by this passage of the electric fluid, tantly vaporized all the moisture which they contained, and that this instantaneous va-ization burst all the trees open in the direction of their length, until the wood, dried up l split, had become unable to resist the force of the wind which accompanied the tornado. contemplating the rise and progress of this phenomenon, we see the conversion of an inary thunder gust into a tornado; we behold two masses of clouds opposed to each er, of which the upper one, in consequence of the repulsion of the similar electricities h which both are charged, repelling the lower towards the ground, the clouds of the er descending and communicating with the earth by clouds of dust and by the trees. is communication once formed, the thunder immediately ceases, and the discharges of tricity take place by means of the clouds, which have thus descended, and the trees. ese trees, traversed by the electricity, have their temperature, in consequence, raised to h a point that their sap is vaporized, and their fibres sundered by its effort to escape. shes, and fiery balls, and sparks accompanying the tornado, a smell of sulphur remains several days in the houses, in which the curtains are found discolored. Every thing ves that the tornado is nothing else than a conductor formed of the clouds, which serves passage for a continual discharge of electricity from those above, and that the differ-e between an ordinary thunder storm and one accompanied by a tornado, consists in presence of a conductor of clouds, which seem to maintain the combat between the er portion of the tornado and the ground beneath."

Less than two years after the allegations and inferences comprised in preceding abstracts were reported to the Academy, and after the in-ers had been obliged, as *Peltier informed me*, to pay for it as an elec-al storm, Babinet sanctioned the idea that the main cause of tornados he heat imparted to an ascending column of air by condensing vapor, ctricity occasionally intervening, but not being in the least essential he generation or endurance of the meteor.

There is another narrative published in the *Comptes Rendus*, or Journa of the Proceedings of the Academy, which confirms that of Peltier i every essential particular. Both of these narratives agree with that whic I had given respecting the tornado of New Brunswick, excepting tha the chemical effects upon the trees appear to have been more violent a Chatenay.

Although Peltier made his report (of which abstracts have been given three years after I personally handed my pamphlet to Arago and othe members, leaving one in the library of the Academy, he alluded to m memoir only in order to show that he owed nothing to it. In the poi of the greatest and most evident importance I had manifestly anticipate him. I allude to the inference, that during a tornado an electrical dis charge takes place by means of the column or trunk, superseding th lightning by which, during ordinary thunder storms, discharge is effected There is, *so far*, a perfect identity between his inferences and mine. These with the facts established by the survey at New Brunswick, and by hi own statements, shew that there can be no rational explanation of a tor nado, but that of its being the result of a convective discharge. I ar not in the least disposed to contest any honor which he may have acquire from so much of his explanations as are inconsistent with that given b me.

That the idea of Peltier that the cloud acts as a conductor is untenable must be evident, since the light matter of which a cloud is constitute could not be stationary between the earth and sky in opposition to tha upward aerial current of which the violence is admitted by him to b sufficient to elevate not only water, but other bodies specifically muc heavier than this liquid.

Moreover, I have ascertained that dense fog produced within a glas vessel, does not act as a conductor so as to discharge an electrified kno of iron. When subjected to the exciting power of an electrical machine the knob gave sparks as well when the fog was present, as when it wa away. The knob was made red hot, to prevent the interference of con densing moisture.

But independently of this experimental evidence, were moisture in th state usually designated as fog or cloud a conductor, how could it issu from an uninsulated high pressure boiler highly charged with electricity As soon as, by the escape from confinement, the pressure is relaxed, on portion of the steam is resolved into low pressure or rare steam, whil another portion precipitating, assumes the state of the aqueous matter i a cloud.

The upward current of air, and the carrying up of movable bodies, whic has been fully established to be characteristic of tornados, and of whic Peltier himself confirms the existence, is irreconcilable with conduction but is just what a carrying discharge would involve as a matter of course

Subsequently to the publication of my memoir on the cause of tornados in the *American Philosophical Transactions*, and *Silliman's Journal*, fo the year 1837, Faraday distinguished that species of electrical discharg which takes place by a current of air, or by the movement of bodies situ ated between the electrified surfaces, and consequent alternate contac therewith, as the "*convective* discharge;" while the discharge by mean of sparks or lightning were designated by him as *diruptive*.

The employment of these terms renders the demonstration of my rationale more easy to state. These modes of discharge have been witnessed by every person who has ever been present when the most common routine of electrical experiments has been exhibited, in which not only the spark is shown, but the dancing of pith-balls, or of puppets, the ringing of bells, the rotation of wheels, or the blasts produced by electrified points, causing such wheels to rotate.

It is notorious that either of these modes of discharge may be made to take place, by varying the distance, or the form or character of the masses employed.

Thus, in the experiment in which pith-balls are made to resemble hail, by dancing between oppositely electrified disks, an approximation of one of the disks towards the other induces a spark or diruptive discharge, and thus causes dancing to cease. In Cuthbertson's balance electrometer the movable ball approaches that which is stationary, in obedience to the convective process; but as soon as the interval between the balls is reduced within the striking distance, a diruptive discharge ensues, indicated as usual by a spark.

It follows that by a slight variation as to distance, the same degree of electrical excitement may be productive either of a convective, or of a diruptive discharge. Excepting a prodigious disparity in magnitude, the diruptive spark discharge is universally recognised as perfectly similar to lightning. Both the one and the other process are admitted to be due to discharges of electrical accumulations, differing only as to magnitude. Since, agreeably to this exposition, susceptibility of commutation exists, as respects diruptive discharge in its minuter forms, and convective discharge upon the same scale, does it not follow that the former, as produced by the gigantic processes of nature, should be commutable with a convective process of corresponding immensity? But if the spark be exemplified by lightning, how is the convective discharge to be exemplified? Where is there any gigantic meteorological process which can supply the deficiency, excepting that of the tornado or hurricane, which last may be viewed as a tornado on a scale of pre-eminent grandeur?*

* Experience shows that the denser portion of the atmosphere, which lies between the storm clouds and the earth, is competent to act as an electric; since otherwise there would be no thunder gusts, nor any atmospheric discharges as displayed in the form of lightning. That air, rarefied to a certain degree, becomes capable of acting as a coating does in the instance of the Leyden jar, is proved by the fact that the inner surface of a glass globe, within which the air is rarefied by exhaustion, may be charged like a Leyden jar, if to the outer surface a conducting body be applied, and a due communication made with an electrical machine in operation.

As it is well known that the terrestrial surface is a conductor, it follows that in that surface, the denser air in proximity therewith, and the rarefied conducting air above, we have an electric between two conductors competent to act as coatings. Thus the dense air acts as a glass pane between two coatings, or as the glass in an exhausted globe acts between the rarefied air within and the hand of the operator without. We have, therefore, all that is requisite to the reception of an electrical charge.

That the means of disturbing of the electric equilibrium are abundantly prolific, the terrific discharges of lightning in electrical storms can leave no doubt.

Using the language of the Franklinian theory, I urged that, in the concentric spaces occupied by the earth and that occupied by the rare conducting medium above alluded to, there must be two oceans of electricity, which could not fail from mechanical or chemical causes to be in different states. But assuming that electricity is a result of the polariza-

If from a point electrified by a machine, a blast of air may proceed as strong as from a blow-pipe supplied by a bellows, may not an enormous blast be emitted from every terrestrial prominence, electrified by the powerful apparatus of nature, as much greater than that of a blow-pipe, as spark of lightning of a mile in length, exceeds that yielded by an excited conductor or charged jar? So long as there is an ascent of air consequent to electrical convection, there must be a confluence of the same fluid from two or more opposite quarters, to supply the deficit thus created; and the air as it follows the electrified column being successively similarly electrified, that enduring trunk or column is formed and sustained which characterizes tornados or water-spouts.

Within this traveling trunk, which, in its form, contortions, and deleterious power, resembles that of an enormous elephant, as mischievous as gigantic, bodies are not only subjected to the same convective influence as the air, but are also exposed to the upward force arising from a vertical blast. On each side of the track which marks the progress of the trunk bodies are subjected to the confluent blasts, which rush in to supply the upward current.

The alternation of the convective and diruptive discharges was well exemplified in the phenomena of the Providence tornado of 1838, as described by a most worthy and well informed observer, Zacharia Allen, Esq. As soon as the trunk reached the river, the water throughout the included area, rose up as in a state of ebullition by the convective influence; but a diruptive discharge, in the form of lightning, taking place the foam subsided momentarily, yet rose again, until by another spark of lightning another subsidence ensued. Were ever facts more accordant with an explanation than those observed by Mr. Allen, with the hypothesis which I advanced?

Against the idea that there could be any adequacy in the apparatus of nature, such as to make bodies dance between the earth and sky, as puppets and pith-balls are seen to dance between electrified brass disks, it has been urged by Prof. Espy, that a stratum of an elastic fluid like air could not perform the part of a solid metallic disk.

The answer to this is, that whatever state of things is competent to sustain electrical charges, is competent to produce any of the phenomena of *dis*charges. Just as much stability is requisite to enable the diruptive discharge of lightning to take place, as to enable the convective discharge of the tornado or water-spout.

To conclude, I claim to have laid before the scientific world a memoir in which the tornado is made to bear the same relative position to lightning that the carrying discharge does to the electrical spark, and to have

tion of the ethereal fluid, to the undulation of which light is ascribed, we are led to substitute for oceans of a specific fluid, the idea of a boundless ocean of ethereal matter, which by peculiar affections may become competent to perform, within the concentric spaces alluded to, the part assigned by Franklin to one fluid, by Dufay to two fluids.

Consistently it may be inferred that an atmospheric charge may extend all around the globe, so as to make one great battery analogous to that above described of the exhausted glass globe; the rarefaction being in one case internal, in the other external. Agreeably to these considerations, there are no limits to the possible extent of atmospheric accumulations of electricity, while the rapidity with which discharges pervade conductors is such as to render distance no obstacle.

een the first electrician that ever pointed out this simple and true relation etween those awful meteors. I urge that the language, proceedings, and eports of the French academicians show, that they were entirely unpre- ared for this new view of the subject. Hence, nearly five years after- ards, notwithstanding the tornado at Chatenay and Peltier's Report, and at I had sent them meanwhile a pamphlet containing a translation of my emoir into their own language, they still remained in utter darkness: ut that meanwhile, Peltier, with the approbation of Arago, the President the Academy, had adopted essentially my explanation; attempting, owever, to put my theory in the back-ground, by substituting *conduction* r *convection*.

As I have elsewhere said, Franklin by aid of a kite-string demonstrated e identity of lightning with the electrical spark or diruptive discharge. hope to have shown, by reasoning and a reference to experimental vidence, that the tornado is identical with the convective discharge of lectricity.

On the State of Atmospheric Strata holding Accumulations of Electricity s in Thunder Storms.—In order to sustain the inferences which I have dvanced, it is sufficient, as already urged, to point out that no diffi- ulty can be ascribed to the existence of an electrical accumulation com- etent to produce a convective discharge in the form of a tornado, which oes not apply equally against any accumulation of the same nature, ca- able of producing diruptive discharges, as in the case of lightning. he precise mode in which a thunder cloud becomes a reservoir of elec- icity, and afterwards emits it as lightning, was not suggested by Franklin, nd is still undecided. That this precision of explanation has not been tained in the case of the tornado, cannot then be fairly or consistently vowed as an objection to our considering this meteor as the offspring of the me parent.*

If we strive to electrify a ball suspended to a steelyard or scale beam, s in Cuthbertson's electrometer, so as to be equiponderant with a counter- eight on the other arm of the beam, it will descend as soon as charging ommences. Wherefore, then, do not thunder clouds descend in obedi- nce to an incipient charge? I believe this question has never been an- wered.

I would suggest that, agreeably to Faraday's researches, we are justi- ed in supposing that the charge consists more or less of the polari- ation of the aerial particles, by which they assume a certain arrangement ndispensable to an electrical charge, and which grows with its growth, nd strengthens with its strength.

Thus there may be a simultaneous and commensurate affection, by hich the opposite polarities, usually called the opposite electricities, reated at the surfaces of the electrified (or, as I would say, polarized) ratum of the atmosphere, are produced, together with that arrangement

* Peltier's suggestion of the simultaneous existence of two charges, one upon each queous vesicle severally, the other upon the external surface of the aggregate mass rming the whole cloud; one discharging itself, only diruptively in lightning, the other ly by *conduction* in tornados, seems untenable; since either mode of *dis*charge must elong to any charge, and since, agreeably to Faraday's researches, the vesicular charges ithin, would by a repulsion extending to the surface, prevent any outer superficial charge om accruing.

of the aerial atoms in rows, like iron filings situated between poles of a magnet. Hence the same electrifying causes which induce in the extreme surfaces a reciprocal attraction, cause in the intermediate atoms a proportional indisposition to undergo the derangement which any obedience to that attraction would involve.*

Objections to Espy's Hypothesis.—It is well known that, when suddenly rarefied, air is refrigerated; hence, when a receiver is first subjected to exhaustion, a cloud appears within it, arising from the condensation of aqueous vapor. Dalton found that when the air thus rarefied was devoid of aqueous vapor, it became much colder than when this vapor was present. This he ascribed to the latent heat given out by aqueous vapor on condensing. Before I had the pleasure of knowing Mr. Espy, I contrived an apparatus for showing the cold and cloud produced by rarefaction. *Silliman's Journal, Vol.* 13, *p.* 4.

This apparatus, as well as that employed by Dalton, does not differ essentially from Espy's nephelescope, which is the name given by him to

* If when there is a great accumulation of electricity, sufficient for the emission of lightning, we suppose the atmospheric stratum which holds the charge to perform the part of the glass in a charged pane, the cloud and the earth acting as coatings, the following rationale may be countenanced by the facts.

This rationale assumes that electricity consists of opposite polarities, resulting, as Faraday supposes, from an "*action*" of atoms in proximity, or as I infer, from a polar *affection* resulting from the polarization of ethereal matter associated or combined with ponderable matter. The same reasoning would apply were the hypothesis of two fluids assumed, in which the phenomena are ascribed no less to repulsion than to attraction.

Let us suppose a stratum of the atmosphere to be situated just above the height of three miles, and of course to have only half the mean density of a stratum resting on the terrestrial surface. Let it be supposed that these strata are oppositely electrified, as in the case of thunder storms. Of course, the oppositely excited strata will have a tendency to approach each other, while the terrestrial surface, similarly electrified with the lower stratum, will repel this, simultaneously attracting the upper stratum. But will the attraction of the earth for the sparse and remote air of the upper stratum balance the repulsion exercised by it towards the contiguous and denser stratum below? Will not the force in the latter instance be greater, first, because, in the same space, there are twice as many atoms to repel, and in the next place, because they are in proximity to the earth? See *Silliman's Journal*, Vol. v., n. s., p. 345.

Again, while the similarly electrified aerial particles in either stratum must repel each other in consequence of their similar excitement, will not this effect in the lower stratum be twice as great, (if not quadruple,) in consequence of there being twice as many atoms in the same space? Thus while gravitation is counteracted by electrical repulsion, the gaseous elasticity of the air is increased by the same cause. Hence arises an expansive and ascensional power. Although the whole of the atmospheric stratum similarly electrified by the terrestrial surface must be repelled thereby, yet the force being equally distributed, is insufficient to cause the whole to be elevated so as to create a vacuum. It is under these circumstances that either the diruptive discharge may take place in the form of lightning, in which case an intermediate row of aerial particles become instrumental to the meeting of two opposite waves of electro-polarity; or a convective discharge may take place by a concentration of the forces on a comparatively minute columnar space. Within this space all the forces are exaggerated which have been assigned to the aggregate. Hence, while the aerial elasticity is assisted by a reciprocal electro-polar repulsion, the whole mass of the air and bodies within the space are violently repelled by the earth. Hence the expansive power by which houses are burst, and bodies, sufficiently light and movable, are borne aloft, accompanied by an electrified aerial blast.

An exemplification of this concentration of force is to be seen in the perforation of the glass of a charged jar.

Were the mean height of the upper stratum only $1\frac{1}{2}$ miles, the difference of density would be only one-fourth of that assumed, but still evidently there would be a diversity more than sufficient to account for the expansive and ascensional power.

instrument answering the same purpose as that employed by Dalton.
toriously, the density of the air diminishes, in a geometrical ratio, as
e place of examination is higher; so that at the altitude of three miles
is only half as dense as upon the earth's surface.

Davy, in his elements, ascribed the formation of clouds to the refrige-
ion arising from the rarefaction of ascending columns of air, and to this
ised to advert in my lectures, nearly thirty years ago, using the nephele-
ope, which I had contrived, as above mentioned, to illustrate the idea.

Thus it became evident, from the experiments and suggestions of Dal-
n and Davy, that when the different portions of air, in an upward cur-
nt, successively reach a height sufficient to rarefy and cool them to a
rtain extent, the aqueous vapor which they hold must form a cloud,
d at the same time render them lighter and warmer than the surround-
g air.

It was first assumed by Espy that the rise of temperature thus caused,
ould create a buoyancy like that of a balloon, and an upward force,
d so great an acceleration as to produce the phenomena of a tornado
the foot of the column affected. In fact, the buoyancy thus arising is,
this ingenious author, considered as universally the cause of storms.

Admitting his estimate of the buoyancy consequent to the condensation
vapor to be correct, I aver that no buoyancy thus created in the up-
r part of an aerial column, would cause any disturbance of the column
low the level of that upper part.

Count Rumford first showed that water may be boiled at the top of a
ntaining vessel without warming the liquid lying below the part where
heat may be applied. This fact has been demonstrated by me on a
ge scale during each of thirty courses of lectures. *In Mr. Espy's*
sence, about five years ago, I demonstrated that this law is equally true
the case of air.

A large bell-glass was so supported in an inverted position, as to allow
axis of a spirit lamp flame to be concentric with the bore of the neck.
the next place, a tuft of cotton, nearly equalling in diameter the mouth
the bell, was moistened with alcohol. By means of tongs, this tuft,
ng held just above the mouth of the bell, was inflamed. Of course,
difference of temperature thus created was incomparably greater than
which could be producible by the latent heat yielded by condensing
por. Moreover, the whole lifting influence was concentrated upon the
nparatively narrow area of the bore in the neck; yet the smallest ac-
eration could not be perceived to take place. The flame was not in
slightest degree disturbed. Subsequently, at the meeting of the as-
iation at Cambridge, in 1849, an apparatus was constructed by which
experiment above described, was repeated with an improved arrange-
nt.

nside of the inverted bell, so as to cover the bore of the neck imme-
tely over which it rested, a disk of wire gauze was placed, supporting
ew thin fibres of carded cotton. About half an inch above the mouth
the bell another disk or tray of wire gauze was upheld by appropriate
ans, on which there was put a stratum of carded cotton sufficiently
ious. These preparations being completed, the cotton above the bell
s ignited. Notwithstanding the enormous rise of temperature thus

produced in the upper part of the column of air, of which the lowe portion occupied the bell glass, so entirely was this lower portion unin fluenced that there was not the least perceptible agitation produce among the most delicate fibres of the cotton.

This perfect immobility of the air subjacent to a column of that fluid to which a great ascensional power seems to be imparted by the ignitio of the cotton, as above described, will not exite wonder, when it is re collected that the buoyancy is not the consequence of absolute levity but of comparatively lesser weight. The ascent of a balloon is not spontaneous; it is the effect of coercion. It is forced to ascend by the superior gravity and consequent pressure of the surrounding air. But while this displaces the balloon, it does not, on that account, relax its pressur on the subjacent portion of the atmosphere.

It is admitted, that, on reaching the rarefied region where the atmospheric clouds appear, the consequent condensation of aqueous vapor wil make any body of air containing it warmer than it would otherwise be and from the lowest level above which the heat is applied there woul be a more or less disturbance, in consequence of the greater buoyancy of the column warmed by the condensation of vapor. But this disturbance would, as I conceive, be much less abrupt and forcible than the Espyan hypothesis of storms requires.

Even after the condensation of aqueous vapor is effected, the wate which formed it will remain within the column, and still add to its weight so that the total weight will not be diminished. Moreover, by swelling upwards, as it naturally will do, towards the region where there is leas resistance, it will become as much taller as rarer, and thus compensate by its greater height for the loss of specific gravity. In a non-elastic fluid, any superiority of elevation, in any portion expanded more than the rest, would be rapidly compensated by the overflow of the excess; but in an elastic fluid, where the summit must be so rare as to have scarcely any perceptible weight, no such active overflow can take place as would be requisite to produce any violent exchange of position between the column thus affected and the surrounding portion of the atmosphere.

If, as represented by Espy, all that is requisite to produce a tornado is an upward current of air, pre-eminently warm and moist, and penetrating into the region of the clouds, the conditions are abundantly realized in the vicinity of the equator. The trade winds have long been ascribed to the ascent of air from the regions on each side of the equatorial line, in consequence of the rarefaction arising from a comparatively superior temperature.

As, in consequence of the warmth to which its ascent is attributed, and an ample contact with the oceanic surface, this upward current must be replete with aqueous vapor, all the requisites which the Espyan theory requires for the production of a perpetual gigantic tornado are present; and yet none is produced.

With the hypothesis which ascribes tornados to an electrical discharge, it is quite consistent that there should be no thunder storms within the region of the vertical current, or the trade winds produced thereby, since there is a perpetual discharge by convection, preventing of course any electrical accumulations.