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The Currents of the Sea.

— Part I. —

The Currents of the Sea in general.

The different points of view, under which the Ocean may be taken, as a subject of study, do not all present a degree of geological importance, equal to that of the climates, coral formations, or deposits of shells; nevertheless, the currents of the sea hold a very important place in geology, and form a most beautiful phenomenon which affects the entire mass of the waters of the sea; and has within the last few years, attracted the attention of U.S. mariners, with very happy results. These results will immortalize the name of Lieut. Maury, the first and most indefatigable promoter of the researches made on sea currents, who, by his publications, has presented to the scientific world, a great variety of beautiful things explained with great sagacity, and at the same time with rare modesty.

These circumstances are sufficient to make us prefer this particular subject, before undertaking the investigation of others, also belonging to the sea. Another reason justifies this preference; — the study of the currents is inseparable from that of the general map of the sea; the knowledge of which, to a certain degree at least, is indispensabe in every other kind of research pertaining to the ocean.

The work bearing the title of "The Physical Geography of the Sea, by Lieut. Maury," will be our guide in the investigations and explanation of the magnificent phenomena, presented by the currents. Nay, we cannot better commence to treat of this subject, than by quoting the passage, with which the illustrious author begins the sixth chapter of his work.

"Let us", he says", set out with the postu-
"late, that the sea as well as the air, has its sys-
"tem of circulation, and that this system, what-
"ever it be, and wherever its channels lie, wheth-
"er in the waters at or below the surface, is in o-
"bedience to physical laws. The sea by the cir-
"culation of its waters, has its office to perform
"in the terrestrial economy; and when we see the
"currents in the ocean running hither and thith-
"er, we feel that they were not put in motion with-
"out a cause. On the contrary, reason assures
"us that they move in obedience to some law of
"nature, be it recorded down in the depths below,
"never so far beyond the reach of human ken; and
"being a law of nature, we know who gave it, and
"that neither chance nor accident had anything
"to do with its enactment.

"Nature grants us all that this postulate
"demands, repeating it to us in many forms of ex-

"pression; she utters it in the blade of green grass "which she causes to grow in climates and soils "made kind and genial by warmth and moist- "ure, that some current has conveyed far away "from under a tropical sun. She murmurs it out in "the cooling current of the north; the whales of the "sea tell of it, and all its inhabitants proclaim it."

Yes, the circulation of the water of the sea is a fact ~~so~~ well ascertained, as any of those more common and familiar ones that daily occur before our eyes. Let us however point out some facts that prove our assertion beyond all doubt. And first, we may mention a fact, which if it does not prove apodictically, proves much. It is customary among mariners, to throw occasionally into the sea, empty bottles well corked, which sometimes soon after, and sometimes after months and even years, are picked up by other mariners. These bottles carry along with them the date, and the spot where they were thrown into the sea, and where these little navigators began their voyage alone; and it has been found, that even in a short time, the floating bottles have travelled a long distance.

But another evidence is afforded by Coral Islands. These singular islands which abound in the Pacific Ocean, or Polynesian Sea, are built up of materials which a certain kind of insect, stationary in these same islands, quarry from the sea water; but assuredly, the large amount of solid matter required to build whole islands, is not to be found gathered all at once in the vicinity, and at contact with the islands, and with the little mason who never abandons his post: hence the materials are carried successively to the builders, by a continual circulation of the sea water.

The temperature of the water affords another excellent argument; for should the water of the ocean remain still everywhere like that of a pond, warm water would be found only in the equatorial regions, and cold water in those near the poles. But cold water a little above the freezing point, is occasionally found at a certain depth in tropical latitudes, and volumes of warm water towards the poles. Therefore, streams of water flow from the poles towards the equator, and others from the equator towards the poles. But above all, the fact of currents existing at the surface of the ocean, is visible to the eye; there are also streams of water in the ocean, which have for their banks and bed, the water of the ocean itself; there are veins of circulating water below the surface of the sea at a greater or less depth, and made visible by their effects: thus, e.g. there is an under current setting from the Atlantic through Davis' Strait into the Arctic Ocean, as there is also a surface current setting out. Observations have pointed out the existence of this under current there, for navigators tell us of immense icebergs which they have seen drifting rapidly to the north, and against a strong surface current. These icebergs, no doubt, are drifted by a powerful under-current, perhaps at a considerable depth; for the icebergs on which the observation has been made, were high above the water, and it is well known that their depth below is seven times as great as the height above. But besides these observations, which we may call accidental, other observations have been purposely undertaken and with great success. L. Walsh and L. Lee, both of the U.S., made the following experiment. A block of wood was loaded to sinking, and by means of a fishing-line or a piece of twine, let down to the depth of 600 or 3000 feet. A small float just sufficient to keep the block from sinking farther, was then tied to the line, and the whole let go from the boat. To use the expression of the experimenters,— "It was wonderful indeed to see this barrega move "off, against wind, and sea, and surface current, at "the rate of over one knot an hour, as was generally "the case, and on one occasion, as much as 1¾ knots. "The men in the boats could not repress exclamations "of surprise, for it really appeared as if some monster "of the depth had hold of the weight below, and was "walking off with it." This is one of the many observations carried on in connection with the *Wind and Current Charts*, and one of the results of the whole system, is the map of which we are going to give a description.

It is to be observed, however, that the observations made on the subject, especially those concerning under currents, are not yet copious enough to enable us to describe them with accuracy; we shall consequently confine ourselves to the description of the surface currents. The first of all, in many respects, is the great current of the Atlantic, well known by the name of the Gulf Stream. We may commence to trace its course from the tropical regions between Africa and S. America: it runs towards the Caribbean Sea, joining on the way another smaller current, which from the river Amazon, flows up and enters with the larger stream into the Caribbean Sea. The same volume of water continues to go up and around the whole of the Gulf of Mexico, until being contracted and as it were squeezed between Florida and Cuba, it rushes out to run in the open ocean again. It will suffice for the present to say that this wonderful stream, after coming out of the Mexican gulf, expands more and more; and in the middle of the ocean between Europe and N. America, it divides into two branches, one going up to the north, the other turning towards Africa; and this latter being again contracted in the vicinity of the African shores, and having entered the tropical zone, resumes its course as before. A branch of the Gulfstream that goes up and is lost in the polar basin, passes between the British Islands and Iceland, and runs between two opposite currents coming from the north; one next to the coast of Greenland, the other contiguous to the shores of Norway and Great Britain. The first of these two northern currents finds in its way towards Newfoundland, another current coming likewise from the north, through Davis' Strait and out of Hudson's Bay. It then reaches Nova Scotia and continues to flow next to the coast of the U. States as far as Florida. The other northern current, after having environed the British Isles, follows the winding of the shores of France, Spain and Portugal, and enters with a part of its water into the Mediterranean Sea: but the main body continues its course next to the African shores, as far as Senegambia, where it divides into two currents; one still following the coast of Africa as far as the Cape of Good Hope, and beyond it towards the Antarctic pole; the other turns towards Brazil, and flows as far as Cape Horn next to the S. American shore. The intervening surface of the Atlantic between the two last-mentioned currents, has a movement from the pole towards the equator.

In the Pacific Ocean, the Gulf of Panama is the source of a current which soon acquires large dimensions, keeping however its upper limit in the vicinity of the equator as far as New Guinea, and with its lower part descending towards the Antarctic basin. The upper part or branch after encircling New Guinea and the small islands around it, passes between Celebes and New Holland, and is divided into two by Java, or rather the smaller islands which are a continuation of Java, and the upper part goes around Borneo, through the Philippine Islands into the Pacific again; the lower part divides into several branches, which fill the entire Indian Ocean. One of these branches goes down towards the pole; another goes straight to Madagascar, and enclosing that island within its waters, continues its course as far as the Cape of Good Hope, where it joins the other current next to the African coast on the Atlantic, and goes with it towards the Antarctic pole. A third branch ascends to the Arabian Sea, and enters likewise into the Arabian and Persian gulfs. The last branch goes all around the Bay of Bengal, through Malacca and Sumatra, then passes on to join the branch near Borneo, and goes together with it through the Philippine Islands back into the Pacific. There, opposite the Japan Isles, a large portion of the waters of the current, turns its course towards the middle of the Pacific, where it is lost; the remaining stream growing narrower and narrower, goes up to Behrings Strait, and through it into the polar basin. The northern part of the Pacific presents moreover a current from north to south, & next to the Asiatic shores; and the surface of the sea, from the American shore to the stream that ascends to Behrings Strait, is endowed with the same motion as far as the tropical regions, but not entirely; for a large portion is met on the way by another current opposite to it, and the two currents meeting together, apparently stop each other. Finally, the entire surface of the S. Pacific and Indian Oceans, with the exception of the currents previously mentioned, has a motion towards the equator. These are the surface currents of the sea, as obtained from numerous and repeated observations.

With regard to the under currents, the observations hitherto made are not sufficient to enable us to know, even to a certain extent, their number, their velocity, their direction, their depth, and the other peculiarities attending them; nevertheless, they tell us something; thus, we know that in all the places in which investigations have been made of the water at contact with the bottom of the ocean, it has been found to be always moving. We also know, that the direction of some under currents is up hill; and from the surface currents we may easily infer, that other under currents must have a down hill direction. It may likewise be observed, that the existence of under currents must necessarily be admitted from the very fact that there are surface currents. Again, the Mediterranean Sea, e.g. and still more the Arabian Gulf and Red Sea, do not become salty, although a surface current is continually setting into them; hence, the immense amount of salt carried in by the surface current, must, through one or more under currents, find its way out again into the broad ocean: and in the ocean, the mere fact of surface currents continually flowing, and losing themselves on their route, evidently proves the existence of under currents: the same may be said of those surface currents which meet each other, and are then lost; the water of the opposite currents evidently descends below the surface, and must create some under current, or more probably, a variety of under currents. I say a variety of under currents, for the different depth, change of direction, velocity, and other accidental circumstances of the opposite surface currents, must produce either accidental or even permanent changes in the under currents. A curious observation concerning the different directions of under currents even in the same spot, or along the same plumb line, must not be left unnoticed. We shall quote the words of Admiral Beaufort, by whom the observation was made.

"The counter currents", says this officer, "or those "which return beneath the surface of the water, are "also very remarkable; in some parts of the Archi-"pelago, they are at times so strong, as to prevent the "steering of the ship; and in one instance, on sink-"ing the lead, when the sea was calm and clear, with "shreds of bunting of various colours attached to every "yard of the line; they pointed in different directions "all around the compass." This, certainly proves the existence of currents in all directions, at different depths of the same plumb line; for the pointing of the shreds could not be effected, unless by currents flowing in that direction. We now see how far we are from exaggerating when we say, that the system of the circulation of the waters of the ocean, is no less complete & multiplied, than the circulation of the blood in animal bodies. Nay, we can without much difficulty point out several striking traits of resemblance between the circulation and economy of the blood in animal bodies, and the circulation and economy of the waters of the ocean, with regard to the terrestrial surface. Some of the facts already mentioned, and others equally incontestable, but of which we shall speak hereafter, afford us the data for the comparison. It is well known, that the heart which stands in the central part of the body, acting like a forcing-pump, pushes the purified blood through the arteries ramified into innumerable branches, into every part of the body, even to the last extremities; it is also known, that from the last microscopical tubes of the arteries, the blood passes into the minutest veins, which convey it successively into other veins, larger and larger, until the whole of the blood is carried back to the heart, which sends it to the lungs, and receives it instantly from them purified, to recommence the same process of circulation. In a manner analogous to this, the fountain head of the circulation of the waters of the sea, is confined within the equatorial regions, and thence it sends the waters into every other part of the great basin, even to the polar extremities, and imparts motion to the whole system of oceanic circulation. But the polar basins in their turn send back to the equatorial regions, the amount of water they received from them, increasing their volume on the way, by gathering, as it were, lateral currents, which return to the fountain head, carrying with them a larger supply of fresh water than they had when commencing their course; but then the burning rays of the sun cause them to lose the superfluous fresh water, and thus render them fit to feed the fountain head, and commence a new circulation.

Among the many benefits which the circulating blood imparts to the human body, is that of heat, which keeps the body in a uniform state of temperature, well harmonized with the extreme limits of the atmospherical temperature of summer and winter, so that neither of them may injure the body. Now, the fountain head of the oceanic circulation, or original stream, is an immense river of warm water, which, keeping a large portion of the heated water below the surface, and raising it up when it expands and multiplies its branches at the surface, benefits with the diffusion of its vapours, those dry land regions near which its flowing waters pass, modifying, in a word, the rigor of the seasons with inconceivable advantage to the life of both the animal and vegetable kingdoms. Whilst, on the other hand, carrying away from the tropical regions the excessive heat which prevails there, it benefits them also in an equal manner. These currents, in fine, tend to establish an equilibrium in the temperature of the different regions, and render them fit for the preservation and good condition of the life of their indigenous vegetations and animal creatures. It may be remarked that this equilibrium is far from being perfect, and that the tropical regions have always and everywhere, a much higher temperature than that of the polar regions; but, although with less difference, the analogy between the two circulations, exists also in this particular, and it is a fact very well known, that the regions of the animal body near the source of circulation, are warmer than those which are far from the heart; and external causes affect so much the extremities of the body, as to make them as cold as the limbs of a dead animal. It may also be observed, that although the circulating blood creates heat in the animal body, it is not, however, the only cause of heat, but in all probability, respiration is the primitive cause of the production of animal heat, which furnishes to the blood the oxygen, which seems to burn, as it were, a part of the carbon contained in the substance of the organs. Again, although this kind of combustion accompanies, and in all probability follows from the action of the arterial blood on the living tissue, this is always effected under the influence of the nervous system. But all this rather adds to the analogy between the two circulations, than detracts from it, because the primitive cause of the heat on the various parts, and on every part of the terrestrial surface, is the presence and action of the solar rays; which, communicating a larger portion of heat to the tropical zone, is conveyed by the waters of that zone, to other parts less affected by the immediate action of the sun: moreover, territorial qualities, geographical configurations, mountain barriers, atmospherical circulation, and perhaps other causes unknown to us, may concur to modify the temperature of the different parts of the terrestrial surface, together with the hot streams coming from the fountain head. There is another point of difference between the oceanic circulation and that of the animal blood, viz. the oceanic hot currents, carry the heat they have received from the burning rays of the torrid zone, so to speak, mechanically; whilst the heat imparted to the animal limbs by the circulating blood, is excited by the action of the blood, in the act of pervading every part of the animal body. But ours is an analogy or comparison, not a strict similarity, much less an equality: still it is such, as to make us appreciate in some measure, the importance which lies concealed in events and natural phenomena, which, when looked at transitorily, may appear accidental and insignificant, but which in the designs of an all-wise providence, have gigantic offices to perform of the utmost importance, and at the same time originating from the simplest causes, and having an immense variety of adaptations, greatly differing from one another; showing at once the wisdom of the infinite architect, and the unbounded love he bears his creatures.

— Part II. —

The Gulf Stream.

"There is a river in the ocean. In the severest "droughts it never fails, and in the mightiest floods "it never overflows. Its banks and its bottom are of "cold water, while its current is of warm. The Gulf "of Mexico is its fountain, and its mouth is in the "Arctic seas. It is the Gulf Stream. There is in the "world no other such majestic flow of water. Its cur-"rent is more rapid than the Mississippi or the Ama-"zon." — Thus Lieut. Maury in his work already mentioned of the Physical Geography of the Sea, introduces the subject of the gulf stream, of which we gave a rapid description in the former part (Part I.), reserving for the present a more detailed account of that stream.

That we may proceed with order, we shall first speak of its qualities; then, of its probable cause, and beneficial effects; lastly, we shall compare it with another stream along the Asiatic coasts.

Among the qualities of the gulf stream, mention has already been made of its course, its permanency, and its temperature, contrasting with that of its bed and banks, also, of its fountain and mouth; to these we may add its colour, velocity, superficial shape, its expansion, its running up hill, and its limits. We shall say a few words of each of these qualities, as well as of some incidental phenomena connected with them. [illegible], the waters of the gulf stream, as far out from the gulf as the Carolina coasts, are of an indigo blue, and so distinctly marked, especially on the eastern edge, that their line of junction with the common sea water, may be traced with the eye. Sometimes one half of the vessel may be seen floating in gulfstream water, whilst the other half is in common sea water.

This colour of the gulf-stream water is supposed to arise from the degree of saltness abounding more in the waters of the stream, than in the others. This difference of saltness, has perhaps some influence in the want of affinity between these waters, and the reluctance on the part of those of the gulf stream, to mingle with common sea water. But, whatever be the cause of this want of affinity, it seems certain, that the different degree of saltness affects the colour of sea-water, from the fact, that practical men engaged in extracting salt from sea-water, are said to know beforehand, and by a simple inspection of the colour of the sea, the greater or less amount of salt they will be able to extract.

The velocity of the gulf stream is not everywhere the same, but diminishes as it advances towards its mouth. The hydraulic law, that the velocity of running fluid in any part of its course, is *inversely as the area of the section* of that part, is sufficient to give at least one of the reasons of this diminution in velocity. From the same law, it follows, that the maximum

So, the gulf-stream's velocity must be in the narrows of the straits, where the stream is compressed between Florida and Bemini, a cluster of small islands among the Bahamas; and this, in fact, is really the case: for the average velocity of the gulf stream in the Florida Pass, is about four knots or four miles per hour; whilst off Cape Hatteras, not far from the S. Carolina coast, it is only three knots, or three miles per hour: besides, other researches have shown seamen the continual diminution of the gulf stream's velocity, the more it recedes from its head.

Another singular quality of the gulf stream, is its temperature, higher than that of the contiguous sea-water; and so great is the difference, that on a winter's day off Hatteras, and even as high up as the Great Banks in mid-ocean, it reaches 20° and even 30°. When we shall speak of the origin or cause of the gulf-stream, we shall also have occasion to see the cause of its temperature. But here we must not pass over in silence, the contrast which the degree of temperature opposes to that of saltness, in the gulf stream: for, whilst the increased degree of saltness, gives to the water a greater specific gravity, compared with that of sea water generally, and consequently causes it to sink; the heat expanding it, makes it lighter, and so much lighter, as to more than compensate for the density effected by the greater amount of salt; so that the volume of the gulf stream water proves to be lighter, than an equal volume of common sea-water, in spite of its greatev degree of vastness. In consequence of this, the entire stream is continually forced to ascend, by the upward pressure of the waters of the ocean, which form its banks and bed: hence, also, the bed of the gulf stream must be an inclined and ascending bed; for the resultant of the two motions, viz: that of the current of the stream, and that of ascension, causes the whole stream to run up hill, always, however, continuing to form one mass, on account of the reluctance the gulf stream has to be mixed up with the common sea water. This, however, cannot and does not prevent the superficial expansion of the stream, which, not being a solid mass, cannot be raised above the common level of the ocean, without spreading itself laterally on both sides; and thus, the superficial form of the stream must be roof-shaped. These inferences, which are easily drawn from well-known principles of Hydraulics, are besides, in perfect accordance with observations, from which it has been found by actual measurements, from Cape Hatteras to the Capes of Virginia, that the same stratum of cold water, which forms the bed of the stream, ascends towards the surface of the sea, at the rate of five or six feet to the mile. As to the roof-shaped form of the surface of the stream, navigators, while drifting along with the stream, have lowered a boat to try the surface current. In such cases, the boat would drift either to the east or to the west, as it happened to be on one side or the other of the axis of the stream; an evident indication of the existence of a shallow roof-current, from the middle towards either edge, which, however, being superficial, does not extend deep enough, to affect the drift of the vessel.

In its course to the North, the gulf stream gradually turns more and more eastward, until it arrives off the banks of Newfoundland, where its course becomes due East. This dejection of the stream towards the East, may seem to be the natural consequence of the same direction of the American coast, and more especially of the Shoals of Nantucket above Long Island, and of the banks of Newfoundland: but we can easily show that this eastward direction of the stream, is entirely independent of that of the American coast, and that neither the Shoals of Nantucket nor the banks of Newfoundland, offer any obstacle to its natural course, which would remain unchanged, if these shoals and banks were depressed to the depth of the common sea. In fact, the effect of the diurnal rotation of the earth, is of itself, an adequate cause of this eastward direction; when, for example, the gulf stream is confined within the Narrows of Bemini, it has an eastern motion, equal and common to any other point of the circle of latitude, it actually crosses, and a velocity greater than that of the successive parallels of latitude towards the North; hence, when it comes out of the Narrows, besides the propelling force in the direction of the current, it is as it were, acted upon by a force impelling it towards the East, and both forces produce a resultant having an eastern direction, [illegible] more and more towards the East, the more the stream advances to the North; the cause of deviation being a continual one. Hence, the American shore, and more particularly the Shoals of Nantucket, cannot be assigned as the cause of this easterly inflection. For the same reason, the Great Banks of Newfoundland cannot be supposed to turn the stream aside, although they encroach upon it. But the cold current coming down from the North upon the gulf stream, and passing over the banks, may and probably does now and then assist in turning it aside. We may here observe also, that so far are the Great Banks of Newfoundland from being the cause of the stream's inflection, that it is rather the stream that is the cause of the formation of those banks in that region.

We just now mentioned a cold current coming from the North, and meeting the warm waters of the gulf, viz: the current coming down from Davis' Strait. Now, this current carries along with it icebergs from the North, loaded as is usual, with earth, stones and gravel; and the icebergs being met and melted by the warm water of the stream, of course deposit the loads they have brought with them. The Newfoundland Banks are the place, to which the icebergs coming from Davis' Strait are directed, and there consequently they are melted, especially on that part of the bank which enters within the banks of the stream. The fact is, that many such icebergs have been seen aground on the banks, and the process of transferring materials during ages to the same spot, seems altogether adequate to the formation of the banks. Another fact tending to prove the reality of this process of formation, is the sudden increase of depth, towards the South of the banks, and the gradual shelving of the sea as far their southern limits, which prove to be the brink of a precipice, suddenly descending many thousand feet. The accumulation of the materials brought from the North by the icebergs, stops where the ice is melted by the heat of the stream.

We need not dwell on the other qualities of the gulf stream which have already been mentioned, but it will suffice to add a few words concerning the variation of its position and limits. The trough of the gulf stream, says L. Maury, may be supposed to wave about in the ocean, like a pennon in the breeze: that is, to say, whilst its head is confined between the Shoals of the Bahamas and the Carolinas, that part of it which stretches over towards the Grand Banks of Newfoundland, is, as the temperature of the waters of the ocean changes, first pressed down towards the South, and then up towards the North: so that the limits of its northern edge, as it passes the meridian of Cape Race in Newfoundland, varies about 5 deg. in latitude. That is, in September, the edge of the stream touches the Cape, and in winter, is 5° of lat. to the South of the Cape, preserving a regular pendulum-like motion. But let us come to the productive cause of this wonderful stream.

To point out the true and adequate cause of the formation of the fountainhead of the gulf stream, of its permanency, of its original impulse towards the North, of all that, in a word, which belongs to the stream, is one of the innumerable problems of difficult solution; it would be much easier to show what is not, and cannot be its cause, although looked upon as such, than to show the true cause, embracing all the circumstances which make it adequate to the production of its effect. But if we cannot show the complete cause, we can certainly point out some of the partial ones; or at least, show that they are not destitute of good foundation, when they are considered as agents in the formation of the stream. First, however, we shall see how the causes, supposed previously to the recent investigations of mariners, and the diligent study of the subject made by the oft-mentioned L. Maury, bear no proportion whatever with the gigantic effect; and therefore, in consequence of their inadequacy, must be rejected. Among these various causes, there are three, which either on account of some apparent proportion with the effect, or the merit of those who advanced them, have enjoyed some celebrity. — The first is of early writers, maintaining that the Mississippi River was the fountain of the gulf stream: this supposed cause was overturned by Capt. Livingston, by simply showing, that the volume of water which the Mississippi empties into the Gulf of Mexico, is not equal to one thousandth part of that which escapes from it through the gulf stream. To which, if we add that the water of the gulf-stream is not fresh like that of the Mississippi, but salt, and even more so than common sea-water; no doubt can be entertained with regard to the insufficiency of the Mississippi being taken as the origin of the gulf stream. But C. Livingston substituting another cause for that which he had so completely overturned, was equally void of success: and his opinion, attributing the existence and velocity of the gulf stream, to the action and motion of the sun, has been abandoned by all. The opinion maintained by Dr Franklin, is the one that has been most generally received. According to him, the cause of the gulf stream is the trade winds, which forcing the water into the Caribbean Sea & the Gulf of Mexico, and preventing them from coming back the same way, compel them to escape into the ocean again, through the Strait of Florida. But this opinion, in spite of the authority of Dr Franklin, and of its having been, and being still deeply rooted in the minds of seafaring men, is less adapted for explaining the fact, than even the preceding. It is the glory of L. Maury, that he has upset it victoriously. In fact, even granting the higher level of the sea in the Gulf of Mexico, effected by the water forced in by the trade winds, and the descent of this water towards the Strait of Florida, we could never infer the formation of the stream, going up some thousand miles to the North. For, let the current created by the descent of the water from a higher level to the Narrows of Bemini, be as rapid as we please, it will soon stop, when the waters are free to expand in the open ocean. An example of this kind is offered to us by all the rivers that enter the sea, and a very remarkable one is observable in the Niagara, an immense river descending into a plain with astonishing velocity, and yet, instead of preserving its character in Lake Ontario as a distinct and well defined stream, at least for some miles, it spreads out immediately, losing its waters in those of the lake. Hence the supposed higher level of the sea in the Gulf of Mexico, which is the only immediate effect that can be granted to the action of the trade winds, is not a sufficient cause for a current continued in the ocean for some thousand miles, like a stream of oil. Moreover we have already seen that the bed of the gulf stream ascends like an inclined plane, and taking into account the velocity of the current, and the area of a section, we may demonstrate with the greatest desirable precision, ~~that~~ the force required to impel the volume of water which forms the current; and we should find that this force would be at the least, sufficient to drive ninety thousand millions of tons, at the rate of three miles an hour, up an inclined plane having an ascent of three inches to the mile. If, now, we remark, that those well-known circumstances, in which water, by the action of the winds is accumulated on one side of a lake, or at one end of a canal, are rare, sudden, partial, and for the most part confined to sheets of shoal water, where the ripples are proportionably great; even in the most favorable supposition of the action of the trade-winds accumulating water in the Gulf of Mexico, we must, for many reasons, infer the inadequacy of this elevation to produce so gigantic an effect. A still more convincing argument, in opposition to the cause of the Gulfstream being the greater elevation of the water in the Gulf of Mexico, is taken from the various currents existing in the ocean, and moving in all directions; more especially the current from Baffin's Bay, coming down just opposite to the gulf stream, and running with a portion of its waters into those very reservoirs, from which the gulf stream sets out. ..... Let us now pass to see those agents, which, with good foundation, may be supposed to be at work in forming the gulf stream.

The principal agents having for effect the circulation of the waters of the sea, are heat, evaporation, and precipitation: for each of these causes, acting partially in different regions, produces a difference in the specific gravity of the waters of the ocean, and consequently gives origin to the motion of those waters, i.e. to the currents. We say that these are the principal agents, for others of minor importance, as the secretion of solid matter made by sea-shells for their structure, and especially that made by those innumerable insect inhabitants of the equatorial regions, to form coral islands, are likewise at work to produce the same effect: and perhaps others also, of equal or even greater efficacy, but unknown to us, may be powerful agents in effecting the circulation of the waters of the ocean; but of course, we can only take into account such agents as are known to us. With regard to these agents, we may remark in general, that their joint effect, will and must be various, according to their various combinations, energy, and other circumstances, either promoting or opposing their action. It will be sufficient for our purpose, to see under what circumstances heat, evaporation, and precipitation, may and probably do concur to form the current of the gulf stream. And first, we may remark, that in the trade-wind regions at sea, evaporation is generally in excess over precipitation, and the vapour being saltless, causes the water in those regions to become salter. Now, taking only the N.E. trade-wind regions, which embrace an area of at least three million square miles, we shall find upon calculation, that the amount of the salt left by the vapours is such, as to be sufficient to cover the British Islands to the depth of fourteen feet; but in the extra-tropical regions, in which precipitation exceeds evaporation, the quantum of salt is diminished: and, independently of any cause, it is a well-known fact, that the water of the northern seas contains less salt than that of the others. Hence, the preponderating pressure of the waters in the tropical belt, over that of the polar basin; the natural effect of which, is first, to impart a vibratory motion like that of waves; and then, to give origin to a current: And in fact, there is a regular current from the shores of Africa across the Atlantic, following both in direction and extent, the N.E. belt of trade-winds; and these winds may indeed, by their constant force, influence the direction of the current, and even assist in pushing its waters into the Caribbean sea, whence they escape by the channel of the gulf stream in preference to any other. It would, at present, be a useless attempt, to endeavour to assign the true cause of this preference: we may however remark that the water carried by the tropical current into the Caribbean Sea, will prefer to escape on that side, where they find less obstacle to overcome, and this is none else than the pass between Yucatan and Cuba, through which, the Caribbean Sea communicates with the Gulf of Mexico. The same tropical current, besides entering the Caribbean Sea through the islands of the same name, invades as it were all the other islands ranged before the gulf, and forces a part of its waters through the Bahama channel up to Florida, in this manner obstructing for the waters pushed into the Caribbean Sea, all the passages except the entrance into the Gulf of Mexico, whence the only outlet left for the waters to escape into the ocean again, is the Florida pass; where, meeting the waters running up through the Bahama channel, they are apparently com-

[illegible] towards the [illegible] next to them, forming the stream in the Strait of Florida. But, be this as it may, in order to see the other agents that appear to concur in the formation of the gulf stream, and to give it such qualities as it possesses, we must retrace our steps. The current, entering from the equatorial belt into the Caribbean Sea, is a surface current; for although abounding in salt, on account of the constant evaporation effected by the trade winds, and even by the heat of the torrid zone; still, partly on account of the expansion produced by the same heat, perhaps sufficient by itself to compensate for the increased saltness, partly also on account of the increased force of aggregation, which the salt seems to impart to the particles of the water, it is kept afloat, and enters the Caribbean Sea as a surface current, hot, and salter than ordinary sea water. We must not forget, that here we merely aim at pointing out the agents concerned in the formation of the gulf stream; for, to assign with accuracy, to each one of these agents, the action belonging to it, and define the result arising from the concurrence of all the partial actions, is a problem, which in the present state of our knowledge, cannot be resolved. We have then, a well-ascertained fact, viz; that the waters which supplied the trade-winds with vapour, are collected in the Caribbean Sea and Gulf of Mexico. But these waters, besides the continued flowing inside the Caribbean Sea and

Gulf of Mexico, find there another agent that tends to make them hotter and salter, and consequently more fit to be held together in the same channel, if the temperature of these waters and their greater saltness, are the cause of their reluctance to mix with those of the ocean, as they seem to be. The agent alluded to, is the constant and burning heat, reflected by the mountain ranges, within which the waters find themselves enclosed on almost every side; but most especially by the lower part of the Cordilleras of the Andes, which, by the natives, are called *tierra calienti* or burning land. This range of mountains which stretches from the Isthmus of Darien below Panama, over the plains of Central America and Mexico, is continually harrowing with its heated rays, the seas that bathe its feet. Let what we have said suffice concerning the agents employed in the formation of the gulf stream, one of the most marvellous things in the ocean; which, besides its beneficial effects to the rest both of sea and land, employs a part of its waters for its own preservation. For the southern part of the enlarged stream, which being refreshed by abundant precipitation, bends towards the Canaries; before reaching the African shores, is turned directly to the South, in order to join the surface current which carries the waters into the Mexican seas, to feed the head fountain of the stream. So that this stream encloses within itself a large portion of the Atlantic, and circulates about it. We might infer that the basin formed in this manner, and thus keeping the waters confined, would be a sea uninfluenced by surface currents in communication with the rest of the sea; and such is really the case, especially in the space between the Azores, Canary, and Cape Verd Islands, which bears the name of the Sargasso Sea, covering an area equal in extent to the Mississippi valley, and which appears perfectly tranquil. Hence, all floating substances conveyed by the stream, which happen to be cast into the Sargasso Sea, remain there until they become heavy enough to sink. In fact, the surface of the Sargasso is so thickly matted over with gulf weed (fucus natans), that the speed of vessels passing through it, is often considerably retarded. To the eye, at a little distance, it seems substantial enough to walk upon. Columbus first found this weedy sea, in his voyage of discovery, and there, according to observations made nearly three centuries after its discovery, it has remained to this day.

But, what is the office assigned by the Creator of all things, to this gigantic stream, which takes for itself alone, so large a portion of the Atlantic Ocean? Behold here, another problem, whose full solution will probably for ever here below, elude the curiosity of man; and form one of those innumerable intricate knots, which in spite of human pride, prove evidently and continually the truth contained in Ecclesiastes (III. 11.) "*He (God) hath made all things* "good in their time, and hath delivered the world to their consideration, so that man cannot find out the work which God hath made from the beginning to the end." But we have another fact of experience which shows us, that all good things made by God, have not only one office, but many to perform in the economy of His divine Providence: and if all do not, some at least of their beneficial influences manifest themselves to the eye, especially of the assiduous seeker after truth. Now, if we do not know all the offices assigned to the gulf stream, we know that it conveys salter water out of the trade-wind regions, to be mixed up again in due proportion with the other waters of the sea; and perhaps it also constitutes the great highway, along which migratory fishes travel from one region to another. It is certain that young sea-nettles or medusæ, have often been met by navigators, drifting along with the gulf stream, and occasionally a vast number of them cover the stream to a great extent; and those which have been met with on the coast of Florida, have been recognized to be the same as those seen as far up as the Azores or Western Isles, a great place of resort for whales. Now, it is well-known that sea-nettles constitute the principal food of the whale; and we certainly should not leave unnoticed the fact, that the Gulf of Mexico is the harvest-field, and the gulf-stream the gleaner, that collects the fruitage planted there, and conveys it thousands of miles ly, to the hungry whale; which thus, like the birds of the air, (Matt. VI. 20.) although they neither sow, nor do they reap, nor gather into barns, are fed by their Creator. From this very fact we ought to infer, that the gulf stream cannot fail to be beneficial in many ways to man, who is of much more value than the whale, even if no trace of the benefit could be pointed out by us: but we can point out this benefit, and in more ways than one. In the first place, it proves an excellent refuge from the snow storm to the frozen mariner. To form some idea of the importance of this benefit, suffice it to say, that before the temperature of the gulf stream was known, vessels disabled by the cold in winter voyages, knew of no place of refuge short of the W. Indies, unless they were prepared to encounter those terrific snow storms and gales, which mock the seaman's strength and set at nought his skill. For, in a little while his bark becomes a mass of ice; and with her crew frozen and helpless, she remains obedient only to her helm. Besides this, the gulf stream serves the navigator as an excellent landmark or beacon in all weathers, so far as the American coasts are concerned; and the position of the ship could not be marked more clearly, if the stream were a strip of land. Dr. Franklin was the first, who conceived the happy idea of directing the attention of seamen to the temperature of the gulf stream, as a landmark; this he did in the year—

1790, although this thought had come into his mind fifteen years before; but it seems, that for political reasons, he did not make it known, as the U. States were at war with England during this interval. But the influence of the gulf-stream upon climates, makes it also beneficial to large portions of land. ... We have already remarked that the Mexican seas, both on account of their geographical latitude, and the peculiar features of the surrounding land and islands, are continually heated; and if left there, or if instead of water, the two basins were filled with dry land, the climate of that region would probably be the hottest in the world, and the most pestilential. But the circulation of the waters, which take for themselves a large portion of the heat radiated from all sides, and convey it along with themselves into the open ocean, prevent in this manner, the excessive heat of the climate and the noxious exhalations. To form some idea of the heat, daily carried off from the Gulf of Mexico into the ocean, it is sufficient to take the approximate difference of the temperature of the water when entering into the Caribbean sea, and when escaping through the Strait of Florida. A simple calculation founded on this difference, and on the amount of water daily discharged into the Atlantic, shows that the specific heat carried off by the gulf stream daily, is sufficient to raise mountains of iron from zero, to the melting point; and to keep flowing from them a stream of molten metal, greater in volume than the waters daily discharged from the Mississippi River. Such an enormous amount of heat, which at first sight appears almost incredible, does not surpass the efficacy of the agents employed in effecting it. The apparatus of plane mirrors, imagined by Fr. Athanasius Kircher, to explain the possibility of Marcellus' fleet being destroyed, as was reported, by Archimedes' burning reflectors; has been successfully employed to melt metals. Now, the Mexican seas are for several thousand miles environed by truly burning reflectors, incessantly adding to the heat, which the waters of the tropical current, carry with them, when entering the Caribbean Sea: and mountains of iron, of even the largest dimensions, when compared to the amount of heat thus multiplied, are what a small grain of iron would be to the heat of the sun, radiated upon one spot by some hundred pieces of plane mirror, each embracing a surface of two or three square inches.

This is the heat which the gulf stream carries into the Atlantic, to benefit navigators, as we have shown already, especially in winter time; but still more to benefit extensive tracts of land beyond the Atlantic. That this is one of the offices assigned to the gulf stream, is made evident in various manners: first, when the stream enters the ocean, the heat which it is allowed to impart to the atmosphere is not copious, since the breadth of the stream at contact with the air, is then comparatively narrow. The rest of the heat below the surface, is admirably preserved by the banks and bed of the river, which are of cold water; and it is well known, that cold water is one of the best non-conductors of heat. This providential arrangement claims our particular attention. For if the warm water of the gulf stream were sent across the Atlantic, in contact with the solid crust of the earth, all its heat would be lost on the first part of the way. It is evident, therefore, that the gulf stream in the oceanic economy, has amongst others, also this office to perform; viz: to convey heat from the Gulf of Mexico, where otherwise it would become excessive, and disperse it over far regions for the amelioration of their climates. France and England participate most in this benefit; and indeed, the gulf stream has only to impart a small quantity of the heat brought from the Mexican seas, to ameliorate the climate of those countries considerably. It has been found, upon calculation, that she was discharged over the Atlantic by the gulf stream on a winter's day, would alone be sufficient to raise the entire column of atmosphere that rests upon France and the British Isles, from the freezing point to summer heat. Let us now examine somewhat more closely, the process of this beneficial influence. The hot vapours and air continually ascend from the surface of the gulf stream, to the higher regions of the atmosphere, to be carried by the winds somewhere else, according to the direction of these atmospheric currents. Now, the prevailing winds that cross the northern part of the Atlantic, from the American to the European shores, are West winds. These winds, therefore, necessarily pass over the stream, and carry with them a portion of its heat to Europe, especially to England and France, to temper in those regions the northern winds of winter. Hence arises the striking difference of temperature on both sides of the Atlantic, although on the same circles of latitude. Thus, ex. gr. whilst the coasts of Labrador on the western side of the Atlantic, are fast bound with fetters of ice; the ponds in the Orkney Islands to the North of Scotland, in latitude near 60°, are not frozen in winter: so that the temperature on the European side, in latitude 55° or 60°, is the same as that on the American side, in latitude 35° or 40°. We say that France and England particlimate more in the influence of the gulf stream, but other parts of Europe enjoy the same benefit. When it has reached the 40th deg. of lat., it overflows its liquid banks, and spreading itself for thousands of sq. leagues over the cold water around, covers the ocean with a mantle of warmth, carried by the winds over a large portion of Europe. Nor should it surprise anyone when we assert, that the winds carry the heated air and vapours of the gulf stream to a great distance from it: for we have sufficient evidence of the power and activity of the winds, in carrying from great distances, the impalpable substances which they pick up in the regions, through which they happen to pass. Suffice it to mention a single fact. The red fog or sea dust, occasionally encountered by seamen, especially in the vicinity of the Cape Verd Islands, and which is of a brick, red or cinnamon colour; comes down sometimes in such quantities, as to cover the sails and rigging, though the vessel may be hundreds of miles from land. This dust, when subjected to microscopic examination, is found to consist of infusoria and organizations. It is not our intention to examine here, whether such organizations are produced in one or more regions: it is enough to mention, that the specimens of sea-dust taken for examination, from Cape Verd, Malta, Genoa, Lyons, and Tyrol, have all been found similar, and of that form which is known to be found in the basins of the Amazon, and of the Upper and Lower Orinoco in S. America. They may also be found in other unexplored countries; but be their birthplace where it may, the fact which answers our purpose, is, that the winds carry them to an immense distance.

It now remains for us to show some points of resemblance between the physical features of the gulf stream of the Atlantic, and another gulf stream near the coast of Asia. We allude to the current which makes its escape through Malacca, and being joined by other warm streams, flows into the Pacific towards the Philippines; then it attempts the great circle route for the Aleutian Islands and Behring's Strait, tempering climates, and losing itself in the sea, on its way towards the N.W. coasts of America. Now, the points of resemblance between this current and the one issuing from the Gulf of Mexico, are many and striking. First; what the Mexican seas are to the stream of the Atlantic, the Bay of Bengal is to that of the Pacific Ocean; both being supplied with water from the South of the ocean, and sending it into the ocean again towards the North, after it has been heated by the burning rays of the sun, reflected by the land. For the land around the Bay of Bengal is even more adapted to reflect rays of burning heat, than either the shores of the Caribbean Sea, or those of the Gulf of Mexico. The heated waters of the Bay of Bengal find their way into the Pacific, between Malacca and Sumatra, which are exactly what Florida and Cuba are to the heated waters of the Mexican Sea; and as the waters escaping thence through the Mexican Gulf, meet another current directed towards the North, between Florida and the Bahamas; so the waters coming from the Bay, meet another current between Borneo and Malacca, going up to the North together with them. The coasts of China correspond to those of the U. States: the Japan Isles to Nova Scotia and Newfoundland. As with the gulf stream, so also here with this China current, there is a counter current of cold water between it and the shore. The climates also of the Asiatic coasts, correspond with those of America along the Atlantic; and those of America along the Pacific, correspond with those of W. Europe. Moreover, the N. Pacific like the N. Atlantic, whither the warm water goes, is enveloped in mists and fogs, formed uninterruptedly by the copious vapours ascending from the hot currents, which, meeting in the northern regions with the low temperature, are changed into fogs. ... This remark explains to us also, why England is constantly covered with mists. But the most renowned region for fogs and mist, are the Grand Banks of Newfoundland in the Atlantic; the Aleutian Islands in the Pacific come next. In geographical position, Behring's Strait answers to Davis' Strait in the Atlantic, or rather, to Davis' Strait and the wide pass from the Atlantic into the Arctic Ocean; for Behring's Strait is the only pass between the Pacific and the Arctic. Thus also, we might in some manner compare the Aleutian Isles to Greenland. To these points of resemblance between the gulf stream and that of the Pacific, we must add some contrasts or points of difference between them. In the first place, although both of them, at nearly the same parallel of latitude, begin to expand, and direct a part of their waters to the East; the Atlantic stream continues to increase its expansion in the Atlantic, and sends a large quantity of water into the Arctic Ocean; whilst the Asiatic stream, loses its waters in the depths of the Pacific, as soon as it begins to turn towards the East, and sends up to the Arctic but a small surface current through Behring's Strait. If to the East of Alaska there were means of escape into the polar basin, as there is to the East of Greenland, probably even this difference would not exist between the two streams; for the Asiatic stream would then take that means of escape to go to the Arctic Ocean, and Behring's Strait like Davis', would allow a cold water current to pass from the Arctic to the Pacific Ocean. Yet, even in this case, icebergs would not pass through it, since Behring's Strait is too shallow to admit mighty under currents, or to allow the introduction of any large icebergs into the Pacific from the polar basin.

Other investigations will probably enable seamen to detect other points of resemblance and difference between the two streams; such as, the ascending of its bed, the roof-shaped form of its surface, its colour, &c... Nay, with regard to its colour, it is said that the difference of colour between ordinary sea water and that of the Asiatic stream, is well known to the inhabitants of Japan, who are accustomed to call the stream which passes so near that island, the dark sea: this dark quality is common to the Atlantic stream.

We may remark, before concluding, that although much still remains to be explored, concerning oceanic circulation, yet, if we compare our actual knowledge with that of past ages, it is undeniable, that much light has been thrown on the subject, especially in our own days; and this is very fit to direct and encourage other researches, with well-founded hope of success.

Storms.

Storms.

The study of the gulf stream has naturally led us to detect a close connection, existing between the currents of the ocean and those of the atmosphere, i.e. the winds. For, confining ourselves to the great stream of the Atlantic, we saw that the surface current, which supplies the Caribbean Sea with water salter than ordinary sea water, owes in a great measure, this higher degree of saltness, to the action of the trade winds; which appear likewise to assist the current in entering the Mexican seas, in circulating therein and becoming hotter and salter, and then, without interruption, feed the head fountain of the gulf stream. The winds also concur with the stream, in benefitting the lands over which its heat is diffused. But, there is another connection between the atmosphere in motion and the waters of the stream, and this connection is a very remarkable one, although its cause is hitherto unknown: viz; storms that take their rise even at great distances from the stream, seem to be attracted towards it, to join, and travel along it. There are instances of gales that have commenced on the African coast, as far down as 10° or 15° N. lat., and have made straight for the gulf stream, join^ed^ it, and recross^ed^ the Atlantic upon it. The storms over which the gulf stream seems to exercise so much control, are for the most part called whirlwinds, or as some modern writers prefer to call them, Cycloins; they are better known by the name of hurricanes. These are the terrific storms which mark their path with wreck and disaster; and it is to this class, we shall cheifly direct our attention. This we shall do, not only on account of the connection they have with the gulf stream; but also, because no other storms manifest so gigantic a power, either in activity or extensiveness, nor such a variety of motions and effects, at sea or on land, as these hurricanes do. A few rapid sketches which we shall give of particular instances, will justify our assertion; but in order to appreciate them better, we shall also notice the other classes of storms.

By the word storm, we understand any unusually violent commotion of the atmosphere, either alone, or more frequently saturated with vapours; which, being condensed in large quantities, fall copiously, and, so to say, tumultuously, under the various forms of rain, snow, and hail. A violent wind without precipitation, is commonly called a tempest or wind storm. The appellation tempest, is also given to the wind, when accompanied by a precipitation of rain: if the condensed vapours fall in the form of snow or hail, the atmospheric agitation is then called snow storm or hail storm. When the storm is accompanied by thunder and lightning, it takes its appellation from the electrical phenomenon, and is called a thunder storm. — A strong wind is also called a gale; although, as lexicographers remark, the meaning of this word is rather indefinite: and even in the language of seamen, it signifies a vehement wind or tempest, and also a hurricane. But, in all these and other storms, the inseparable agent is the atmosphere, and its action is a vehement motion: hence, a natural way of separating storms into different kinds, is offered by the various manners in which the agitated atmosphere is moved. Now, we can only conceive three different ways, in which a volume of atmosphere, like any other body, can be put in motion: viz; by a motion of translation, either straight or curved; by a motion of rotation; and finally, by the joint concurrence of the motions of translation and rotation. A furious wind, ex. gr. carries straight from North to South, a volume of atmosphere; and on its way, it meets another current coming straight from the West: evidently, in the act of collision, both vol ones will change their motion, or pass through a succession of changes, at once mixing the air of the two currents into one volume, which is finally carried along by a motion resulting from the other two. Before the collision, we have two simple currents of air, differing from each other; and then only do they begin to form one volume, when they meet together: thus, we may easily conceive the formation of whirlwinds, which, momentarily at least, may also remain stationary on the same spot. The volume of the air of both currents when mixed together after impact, may indeed take the direction of a single current, straight like the preceding; but most probably, at least for some time, it will embrace a variety of motions, carrying along with it other larger or smaller whirlwinds. Conflicting winds, therefore, whether two or more, and of any kind, can have no other effect than that of imparting to the atmosphere, one or more of the 3 motions mentioned above; and this, either in the act of conflict or collision, or after it: In all cases, therefore, when air is in motion on some determined spot, its motion is that of a current passing straight from place or place; or else, a rotary motion like that of a top, turning about an immovable axis; or finally, a complex motion combining the other two. We may here remark, that although we are led to infer these consequences from the nature of the agent, nevertheless, to determine with precision the various effects, with all their modifications in particular cases, or deduce from the effect, the entire process of which it is the consequence; are problems of extreme complication and difficulty, partly arising from the nature of the agent at work, which is fluid and elastic; partly, from the uncertainty with regard to the directions, velocities, and extensiveness, of the different volumes of air conspiring to produce the effect; and partly, from the temperature, the amount of vapours mixed with the air, &c.. So that considering this meteorological phenomenon simply under a mechanical point of view, it contains in its full development, difficulties which are insurmountable. All these difficulties, however, do not prevent our anticipating, that air, whatever may be the cause of its motion, will move in one of the three manners repeatedly mentioned. This inference, deduced from the nature of the agent, is confirmed by the experience of all ages. Thus, the ancients distinguished three kinds of winds: first, a direct current of air, which they supposed to come [illegible] from the [illegible] in a [illegible] of immense large dimensions, and which the Greeks accordingly called εχνεφιας, corresponding, as Pliny tells us, to the latin procella. The second sort of wind mentioned by the Greeks, is the τυφον, corresponding to the vortex or turbo of the Latins, which likewise they thought came down from the clouds, and which, on account of its whirling motion, was believed to carry along with it a portion of the clouds. The third kind is called πρηστης by the Greeks, and retains the same appellation among the Latins: it does not differ from the τυφον, except in presenting the luminous phenomenon of electricity, and perhaps, in being a whirlwind of larger dimensions than the τυφον. Seneca, in his 4th book of natural questions, speaking of the present subject, distinguishes the three different kinds of winds, in the same manner as Aristotle and Pliny the younger: a passage of his, concerning the vortex or τυφον, and the πρηστης, deserves to be mentioned....

"Sepius (the wind) in se volutatur similem-
"que illis, quas diximus converti, aquis facit
"verticem. Hic ventus circumactus, et eum-
"dem ambiens locum, et se in ipsa vertigi-
"ne concitans, turbo est: qui si pugnacior
"est, et diutius volutatur, inflammatur et

"efficit quem πρηστηρα Græci vocant. Hi fere "omnia pericula venti erupti de nubibus "produnt, quibus armamenta rapiuntur, "et totæ naves in sublime tolluntur."...

I have chosen this passage of Seneca, in preference to others, because it seems to indicate the whirling motion of the air about an immovable axis, like a top spinning on the same spot. This in fact, is one of the manners in which we conceive the mobility of the air. Although commonly the whirling motion of the air is accompanied by the progressive, this also, might be inferred from the last words of the passage just quoted. But Pliny (Book II. cc.49.50) who coincides with Aristotle, speaking of the various kinds of vertical commotion of the air, says explicitly, that these kinds of motion travel from place to place, causing great disaster to the various objects they meet in their way: - "qui Typhon "vocatur," says the naturalist", hoc est vibra- "tus Ecnephias...... locum ex loco mutans ra- "pida vertigine: præcipua navigantium "pestis non antennas modo verum ipsa na- "vigia contorta frangens." - Modern naturalists do not differ from the ancients in dividing the different motions of the atmosphere, and those winds which blow steadily as the current of a river, take their name from the direction whence they blow; but the winds which blow perpetually, and always in the same direction towards the equator, are called *trade-winds*: with this class of winds are connected the so called *Monsoons*, an appellation supposed to derive its origin from the Malay word *Moussin*, which signifies season. And in fact, these steady winds take place at certain seasons; viz, when trade-winds are turned back or diverted by overheated districts, from their regular course; they prevail in the Indian Ocean, the China Seas, the Gulf of Guinea, and the West Indies. The same regions are also celebrated for their furious hurricanes; and indeed, all circumstances concur to give origin to whirlwinds of the most gigantic dimensions, which possessing the whirling common to the τυφων of the Greeks, have received the appellation of Typhoons: but on account of their noisy commotion of the sea, and of their raising foam and mist, they are also called *white squalls*: they are known besides under the appellation of Tornadoes & Cyclones. This last appellation is to be found, at least equivalently, among the Alexandrians, who, as Olympiodorus testifies, called ανεμοσουρις or κυκλανεμος, what by seamen was usually calle. τυφων. The ancients to whom the seas in which these immense whirlwinds are frequent, were unknown, could not have any knowledge of them, espec[illegible] to the direction of the rotation, which [illegible] hurricanes of the Northern hemisph[illegible] in general (as appears from recent obse[illegible]s) for all rotary storms, is from right to left, or opposite to the movement of the hands of a watch: while for those of the Southern hemisphere, the rotation is from left to right, or with the movement of the hands of a watch. This is a fact singularly remarkable also on account of the coincidence of the motion of the various points of the circular gale about its centre, and of the various points of the hemisphere on which the gale travels about the corresponding pole. Thus far we have described some of the principal features of rotary storms, to which we must now add such particulars as have been observed in various instances, relating mostly to their enormous power. Nor should anyone be surprised when we say that the mechanical power of the air, even without the concurrence of other agents, is capable of producing effects at first sight incredible; for the power which the particles of the atmosphere do not possess, on account of their mass being too light, they may and actually do acquire with increased velocity; and the effects thereof, however surprising they may appear, are in perfect conformity with the laws of mechanics. The velocity of this kind of storms, both of translation and rotation, is enormous; and although on one side of the storm, the motion of translation being opposed to the rotary motion, diminishes the absolute velocity of the storm; on the other side it increases it in an equal quantity, thus condensing a large quantity of air, which on this account becomes more powerful, and imparting to it a prodigious rapidity. To assign with precision this velocity, would be rather difficult; first, because in the various parts of the same storm, it is not the same, partly on account of the reason just mentioned, and partly because at various distances from the centre of rotation, the velocity is likewise various: again, both the velocity of translation and that of rotation, are now greater and now less, for different storms, and even for the same storm: and the latter (velocity of rotation) is difficult to be determined in all cases. Concerning the velocity of translation, or as we might say, the velocity of the centre of the storm, some make it amount to 30 and some even to 40 miles per hour. But, be it as it may, all certainly agree that the velocity of the atmosphere within the limits of the storms, is exceedingly great, and the effects produced

by the action of the storms are the best evidence thereof. A full description of all the destruction caused by storms at sea and over land would require full volumes, even were we to limit ourselves to such facts as are well authenticated. Some of them however, may be here mentioned. At Barbadoes, the most Eastern of the Carribbean Islands, on the 10th of August, 1831, in the hurricane which desolated the island & killed 2500 persons, the force of the wind was such, that a piece of lead 400 lbs. in weight, was lifted and carried to a distance of 1800 feet. And in the year 1780, on the 10th of October, the fury of another gale carried a cannon of large size to the distance of 300 feet: and it is by no means surprising that the power of the wind of that terrible hurricane was sufficient to blow away a heavy cannon like a feather, since the impetuosity of the Whirlwind levelled to the ground the principal town of the island, emptied the harbour of the ships sheltered therein, rooted up trees, and desolated the whole land. A minute description of the various effects of this hurricane, has been given by the historian of the War of Independence. -
(C. Botta. St. della guerra dell' Indip. degli S.U.

d'America. Lib. XII. an. 1780.) Similar to this is the description sent by Alvaro Nuñez to Europe from Cuba, where he had been an eye-witness of a furious hurricane. He also relates that all the ships in the harbour were destroyed, the houses and even the churches ruined, trees rooted up and carried away by the vehemence of the wind, and a small boat taken up from the water and thrown upon land at a distance of half a league. C. Lyell in his valuable work on Geology, (C. Lyell. Pr. of Geology, B. III. C. XIV.) tells us of a dreadful inundation of the sea, on the coast of Coromandel in Hindoostan, caused by a hurricane which raised the water so much, that it rolled inland to the distance of about 20 miles from the shore, sweeping away several villages, drowning more than 10,000 people, and leaving the country covered with marine mud, on which the carcasses of about 100,000 head of cattle were strewed. This terrible event gave credit to an old tradition of the natives, (regarded until that period as fabulous, by European settlers), of a similar flood said to have happened about a century before. The country is certainly exposed to such catastrophes, and so late as May, 1832, this very Coromandel coast was the scene of another event of the same kind; and when the inundation subsided, several vessels were seen grounded in the fields of the low country about Coringa. We may here remark that Lyell is of opinion that many of the hurricanes have been connected with submarine earthquakes, as is shown by the atmospheric phenomena attendant upon them, and by the sound heard in the ground, and the odours emitted: and such, he adds, were the circumstances which accompanied the swell of the sea in the storm of 1780, mentioned above, & which, as the historian of the American war relates, after visiting Barbadoes, went up to Jamaica, where a tremendous earthquake added to the destruction of the storm, and a great wave or rather an enormous swelling of the sea, covered the land to a great distance from the shore, desolating the Western coast of the island, and bursting upon Savanna-la-Mar, swept away the whole town in an instant; so that, adds another historian, (*Edwards, Hist. of the West Indies*), no vestige of man, beast, or habitation, was seen upon the surface. If the cause or causes productive of earthquakes, were known to us in their integrity, and also the origin and formation of whirlwinds, and the various stages of the process, and the circumstances which accompany hurricanes; we should be enabled to point out the connection alluded to by the distinguished geologist: but in the almost total ignorance in which we are concerning these elements, we must be satisfied with the bare fact; we may however observe that the supposed connection is not destitute of foundation, for history almost uniformly commemorates atmospheric phenomena attending earthquakes. Such, e.g. as irregularities in the seasons preceding or following the shocks; sudden gusts of wind, interrupted by dead calms; violent rains at unusual seasons, or in countries where such phenomena are almost unknown; a reddening of the sun's disk, & a haziness of the air, often continued for months; an evolution of electric matter, or of inflammable gas from the soil, with sulphurous and mephitic vapours. This last phenomenon throws some light on the connection existing between the underground noises and agitation, and the unusual commotion and changes of the atmosphere. We may also find in this phenomenon, the reason why a sensation like seasickness, and a dizziness in the head, is on such occasions experienced by men, while animals utter cries of distress and alarm. As these are the phenomena commonly attending earthquakes, there is good reason to suppose that such an extraordinary commotion of the atmosphere as that of hurricanes, being so full of electricity, and pouring down torrents of rain, proceeds from the same principles as those which occasionally produce the shaking of the earth; and this, independently of any fact that might be adduced in proof of this connection. And in fact, it seems rather difficult, or at least a thing subject to illusion for those that are overtaken by the storm, on account of the general and terrible concussion of every thing, the rapid succession of events, and more especially on account of the perturbation of mind caused by the terrific event, to ascertain precisely which are the agents at work, whether to the action of the wind is also joined the trembling of the earth, whether the noise accompanying the storm is an effect of the electricity of the atmosphere, or one of those underground noises like the rolling of carriages, or the discharge of artillery, or distant thunder, and which usually attend earthquakes. We are told, e.g., as we have related before, that one enormous wave produced by the swelling of the sea, swept away Savanna-la-Mar in an instant; so that no vestige of man, beast, or habitation was seen afterwards upon the surface. Nobody remained on the land to tell how the destruction happened, but all agree in admitting that the town was destroyed by the furious hurricane; and if the earthquake which is said to have accompanied the gale, was noticed on some other spot of the island not involved in the hurricane, or if some vestige of it remained visible after the storm, we may also easily admit the action of the earthquake, joined to that of the storm in desolating the land: no doubt likewise can be entertained concerning the inundation; but whether this occurred, as it were, in an instant by the sudden swelling of the sea, or gradually by the force of the whirlwind pushing and heaping waves upon waves, none either on land or at sea are able to tell. To all this we may add, that those individuals who were fortunate enough to escape death, were so frightened at the imminent danger, and so intent upon saving their lives, that their testimony with regard to the various particulars of the event, is not to be relied on. But let what has been said of these facts suffice; certainly they are sufficient to give an idea of the enormous power of tropical hurricanes, unknown or almost unknown to the inhabitants of the temperate or frigid regions. I say almost unknown, because there are instances of storms which occurred out of the torrid zone, and yet bore a great similarity to the tropical gales. Thus Angelo di Costanzo in his 6th book of the history of Naples, relates that a formidable storm took place, which, to use his own expression, was unexampled. It crossed the southern part of Italy, coming from the Adriatic, and entering into the Mediterranean Sea. Francis Petrarch who was at that time in Naples, a town included in the broad strip of land visited by the storm, gave in a letter, a vivid and pathetic description of the disasters effected by it both on land and at sea; and these disasters bear a great resemblance to those of the tropical hurricanes mentioned above. Another storm similar, though less terrible, is related by two other historians, Machiavello and the Ammirato, which occurred in August, 1456; coming like the one previously mentioned, from the Adriatic Gulf, and crossing the central part of Italy, and then entering the Tuscan Sea. Fr. R. Boscovich in an excellent dissertation (*Sopra il Turbine... Diss. del P. Ruggero Giuseppe Boscovich, d. C. d. G. Roma 1749*).

written by him on the subject of storms, relates these events in the same passages of the above-mentioned historians, and quotes Petrarch's letter at length: and yet he says that none of the extratropical storms, either on account of the extensiveness of the country embraced, or of the duration, surpasses that which in 1669 desolated a large portion of France, and of which a description is given by Du Hamel. But this class of storms is of rare occurrence out of the torrid zone: nevertheless, though whirlwinds of enormous size are not frequent, smaller whirlwinds or tornadoes are very frequent in some extratropical regions. Fr. Boscovich in his dissertation chiefly directs the attention of the reader to this class of storms, treating the subject with his usual ability and with great erudition:- and especially the manner in which these whirlwinds raise water-spouts, and carry away even heavy objects to a great distance, is very satisfactorily explained. Following in his footsteps, we shall endeavour to give an extract of his doctrine, which in several points is applicable to the gigantic tornadoes of the tropical regions; and these probably differ from the extratropical whirlwinds in this point only, that as their size is larger, so also their power and activity are proportionably greater.

The whirlwinds or Typhoons, whose motion is well compared to that of a top spinning about its axis, usually assume the shape of a trumpet, or that of a funnel, with the broader part turned towards the sky, and touching the ground with the other extremity. Now in the internal part of the trumpet, and in the vicinity of the axis, the air becomes rarefied, precisely on account of the atmosphere whirling about it, as we shall see presently. Hence, the equilibrium between the pressure of the external atmosphere, and that of the internal column of the whirlwind, is disturbed; and if there be any communication between this rarefied column and the external air, the latter will rush into it and ascend: hence, likewise, a current of air is created all around the mouth of the trumpet, of greater or less velocity, according to the greater or less degree of rarefaction, and the greater or less amplitude of the rarefied column. If the mouth of the trumpet would touch the level of the water at sea, or on lakes and rivers, the pressure of the external atmosphere would in this case, cause an ascent of the fluid to a greater or less height, according as the difference between the pressure of the external atmosphere and that of the column about the axis of the whirlwind, is greater or less. This simple fact of the inequality of pressure, affords us the means to explain several phenomena observable in Typhoons, both on land and water. But we must first resume the fact of the rarefaction of the air about the axis of the whirlwind, from its source: and in order to facilitate our researches, let us conceive the whirlwind as divided into strata perpendicular to its axis; the particles of the atmosphere contained in each of these strata, being endowed with circular motion, tend to separate from the centre, as we know from Mechanics; and the air being a fluid, and an unelastic fluid, they will consequently fly from the centre, and form, as it were, a ring of condensed air, with a diameter as large as the external pressure of the atmosphere on one side, allows it to be, and on the other, the velocity of the rotary motion, and the extensiveness of the air whirling about the axis, are capable of effecting. The interior of this ring, partly owing to the elasticity of the air, and partly to the gradual diminution of the absolute velocity of the particles of air from the ring to the axis, will not be a perfect vacuum; but from the brim to the centre, the air of each stratum must

become more and more rarefied. Applying the same observations to all the strata, we see clearly that the internal column of the whirlwind is a column of rarefied air, and rarefied by the rotary motion of the air itself. We may also observe, that, everything else being the same, if the external lateral pressure of the atmosphere diminishes, the strata of the whirlwind must have a larger diameter: now the pressure of the air does in fact, gradually diminish by ascending; hence, if the rotary motion remains the same throughout the whole length of the axis, we may find some reason to explain how it is that whirlwinds appear funnel-shaped.
I say some reason, because the equality of the rotary motion throughout the entire axis, is a mere supposition; and secondly, the air of the whirling column becomes itself more rarefied, on account of the less superincumbent weight, and consequently possesses a lesser quantity of motion which can be counteracted by a smaller lateral pressure than is required by the lower strata. But, on the other hand, since the shape assumed by the whirlwind is ordinarily that of a funnel with the wider part upwards, the reason we have assigned is not entirely destitute of foundation. We may

also remark here, that although the funnel-shaped form is the one usually assumed by the whirling air, yet it is not the only one, for it occasionally assumes that of a column. This difference was also remarked by the ancients, as we may infer from a passage of Pliny, in which, specifying the different classes of storms, he speaks of the form of a column as observable in some cases: these are his words; "*Vocatur et columna, cum spissatus humor,*
"*rigensque ipse se sustinet ex eodem genere*
"*et in longum veluti fistula nubes aquam*
"*trahit.*" (*Lib. II. cc. 49. 50.*) --- Boscovich is of opinion that the rarefaction of the air on some occasions, and especially in the case of terrestrial whirlwinds, is not exclusively the effect of the whirling of the air, but that there is besides, the concurrence of some chemical or electrical effect: an opinion which is supported by very plausible arguments. Certainly, in the state of ignorance in which we at present find ourselves, with regard to the agents which concur complexively in the formation of these whirlwinds, as also with regard to their combination and mode of action, no reason can be found to prove the improbability, much less the impossibility of such being the case. The terrestrial whirlwinds, or the πρηστῆρα of the an-

c[illegible]ts are frequently inflamed, that is, they flash while travelling, and leave after them sulphuric exhalations, which are symptoms of combustion or electricity: and we know that either of these two causes, rarefies the air. It is also true that in some cases, combustion proves to be the cause of a sudden and immense production of elastic fluids — for example, a few grains of gunpowder when inflamed, develop such a quantity of elastic fluid, as to burst asunder even compact rocks; and this case has not been overlooked by Boscovich, as we shall have occasion to see, when we return to this subject hereafter.

Assuming as a fact that the air is rarefied in the interior part of the whirlwind, and supposing it to travel over land; if, as is frequently the case, its lower mouth does not touch the ground, this rarefaction causes the air around it to rush into the funnel, and ascend within it, thus creating all around a current more or less strong, according to the greater or less degree of rarefaction, and the greater or less progressive velocity of the whirlwind: but evidently, the greatest rapidity of the current towards the whirlwind, must be behind it. Leaving aside the velocity of pro gression or translation, of which we have already said something; to form some idea of the current rushing to the funnel of the whirlwind, even supposing a moderate degree of rarefaction, it is enough to observe that the pressure of fluids, besides being equal in all directions, is, as we well know from the laws of Hydrostatics, proportional to the height of the superincumbent column, when the fluid is homogeneous: and the velocity which this pressure imparts to the fluid, when allowed to issue from an orifice, is the same as that which a falling body would acquire by descending through the whole height of the homogeneous fluid above the orifice, under the influence of the force of gravity and opposed by no obstacle. The air indeed, is far from being homogeneous, or of uniform density throughout; but this want of uniformity does not diminish the pressure, which is the same as that of a homogeneous column five miles high; as many, namely, as the atmosphere would have above the level of the sea, were it of uniform density.

Now, a body falling freely with the force of gravity through a space of 5 miles, would acquire the enormous velocity of about fifteen miles per minute, which would amount to no less than between 800 & 900 miles per hour. With a velocity less than this, we may easily conceive the effects which are commonly witnessed in terrestrial whirlwinds; viz: how various objects carried away by the impetuosity of the current, and brought to the mouth of the funnel; there, on account of the current's ascending with increased fury, since the air rushes in on all sides, and being confined within a narrow neck, are likewise forced to ascend, and are thus carried to a great distance from the place where they were picked up. We also see that the greatest amount of destruction will take place along the line traced by the whirlwind's axis, both on account of the air rushing in on every side, and because the whirling air is exceedingly compressed, & hurled with great force. We know instances in which parallel walls have fallen upon the street lying between them, which happened to be passed over by the axis of the whirlwind: this certainly, is in perfect accordance with the theory just mentioned. We can also give a very easy explanation of another fact, viz. that of trees planted circularly, which all fell towards the centre; in fact, if the axis of the whirlwind passed in the vicinity of that centre, we see immediately, that the falling of the trees is the effect of the vehemence with which the air rushes in from every side to the funnel. The same explanation is given to a curious fact related by Montanari, in connection with a whirlwind, which on the 29th of July, 1686, travelled over the plains of Lombardy. The whirlwind, passing over several circular towers having their tops ornamented with battlements, or with walls in the shape of a royal crown, the battlements all fell on the roofs of the towers. Boscovich, who wrote his dissertation on the occurrence of a similar storm, which in June 1749, coming from Ostia, crossed a part of the City of Rome, and himself examined the facts which took place on that occasion, tells us that the trees of a semicircular yard all fell towards the centre, through which the axis of the whirlwind had passed, (and the path traced by this axis was conspicuous from many effects); also, that various objects were carried away to a considerable distance from walls, which had fallen in the direction of the progressive motion of the whirlwind, with only two exceptions, in which the walls fell in an opposite direction; and both things are well explained by the principle just mentioned: for, in the first place, it is natural that the walls should rather fall by the action of the more vehement current, than by that of one less powerful, which they might be able to withstand. Now, the stronger current follows the whirlwind; hence the explanation of the fact stated. With regard to those walls that fell in an opposite direction, it may have happened, that being already in a state of decay, and unable to resist the shock of the current towards the funnel before its arrival, they have fallen in consequence of it, towards the side opposite to its progressive direction; or else, having been made to vibrate by the force of the current following the whirlwind, and repelled by a reaction which can easily be conceived, they have fallen rather in the direction contrary to that of the whirlwind. Nay, it seems that this was really the case in one of the instances observed by Boscovich: he likewise relates that the trembling and shaking of the buildings met by the storm, ~~was like that which~~ accompanies earthquakes, was everywhere common. We leave aside many more par ticulars concerning this and other land whirlwinds: the twisting of metals and trees, the heaping up of bricks in one spot; the thick walls perforated like paper by ship-masts, and many others, all of which are easily explained by the same principle. One fact, however, must not be left unnoticed. — We read in Pliny, amongst other things, a passage in which he relates that various solid substances had fallen copiously from the clouds like rain. Leaving out the dross of iron, for which a different and more probable explanation is given, "Effigies (ferri) says he "*quæ pluerat spongiarum fere similis fuit. ..... L. autem Paulo, C. Marcello, Coss. lana pluit circa castellum Carissanum, juxta quod post annum Milo occisus est. Eodem causa dicente lateribus coctis pluisse in ejus anni acta relatum est.*" (*Pl. L. II. c. LVI.*) Livy also frequently mentions that showers of stones had taken place during those periods of which he relates the history. Without having recourse to ancient historians and naturalists, we know of similar facts which have occurred in times much nearer our own. These events may certainly be referred to the action of whirlwinds. Let us suppose the axis of the whirlwind to pass over a shallow river. the rushing of the air may force the water up into the funnel, and afterwards, a large quantity of the gravel covered by the water; the whole ascending & whirling with the agitated air, until the whirlwind finishing its gyrations, these substances fall down at some distance from the place whence they were taken up. But there is no need of recurring to hypotheses when facts are at hand. The storm which visited Lombardy in 1686, (the one we mentioned before), passing over a place called Battaglia, almost destroyed a paper-mill; and carrying off the sheets of paper, caused them to fall upon the lagunes of Venice, about 20 miles from Battaglia. Montanari, to whom we owe the particulars of this fact, also relates, that in 1689, the roofs of the houses in the city of Bologna, after a heavy rain accompanied with impetuous wind, appeared covered with flax, so that at a distance, they seemed to be whitened with dew: but the spot whence the storm had carried the flax could never be found, probably on account of its great distance. The same author likewise relates, that a vessel sailing in the Adriatic from Smyrna, with a cargo of rams' skins, was overtaken by a whirlwind which took away the skins, and carried them off a good distance, then letting them fall again. This however must suffice concerning the facts that accompany or follow the phenomenon of whirlwinds travelling over extratropical lands, which in comparison with those of the tropical regions, may be justly denominated miniature exertions. The facts we have related bear abundant witness to it; and indeed, if we compare the extensiveness of the hurricanes or tropical typhoons alone, with the whirlwinds of extratropical regions, we may from this single fact infer an enormous difference in their effects. The diameter of the funnel of the storm which Boscovich minutely describes from his own observation, was judged by him not to exceed 100 feet; a mouth, wide enough certainly to absorb a large volume of air, and create vehement currents: but what comparison is there between a cylindrical base of 100 or even 500 feet in diameter, and another whose diameter is several miles. We noticed, at the commencement of the present essay, that the circular base of tropical hurricanes has occasionally a diameter of some hundred miles, and although the internal column or funnel of rarefied air has certainly not the same diameter, still the enormous power which keeps the immense typhoon in a state of rapid revolution, makes us conjecture the corresponding dimensions of this internal column. In a map representing one of these storms, which occurred in 1848, published by L. Maury in his physical geography of the sea, the line of minimum of the barometric pressure, or the line traced by the base of the rarefied column, embraces an extent of about 20 miles. This sort of tropical storms does not seem to occur, except at sea, or on those tracts of land that are near the sea; and on islands which happen to be in the way traced by them. But for the unexplored regions of central Africa, and chiefly for the great sandy desert, there is every reason to conjecture, both from the qualities of the soil, and the geographical position, that they form an immense theatre in which numerous whirlwinds of gigantic dimensions hold their tournaments. A large quantity of sand, ascending through the wide throat of the funnel, would change the day into the darkest night, and suffocate all living creatures involved in the vortical cloud: it would likewise be carried away, and fall down again at a great distance from the spot whence it was taken up. A few observations in connection with, and in confirmation of the conjectured fact, will not be void of interest. In the first place, although travellers cannot penetrate far into the interior of the African deserts, still we know that they are occasionally overtaken by sandstorms of the most terrific character, having as far as we can judge, the same whirling and progressive motion as common whirlwinds; this fact makes us conjecture that there are similar and much greater atmospheric commotions in the interior of the deserts.

Another indication of it is given by the rains of sand, carried in immense quantities by the Libyan or S.W. winds, which come precisely from the desert. Whole caravans are said to have been overwhelmed by these falling sands. The dust has evidently been taken up from the interior of the desert, and apparently not gradually and successively, but rapidly and violently, and also in a much larger quantity than that carried by the winds to great distances; for these winds, by their long travelling, and probably diminishing power, will only convey the minutist particles swept away by the storm.

Again, the sands of the African deserts, have been driven over all the lands capable of tillage on the Western banks of the Nile, excepting such as are sheltered by mountains; an evident sign of their having been driven by Western winds. So great is the quantity of this sand, accumulated in process of time, that the ruins of ancient cities have been buried and preserved by it, as appears from the statues and other ornaments of the great temple of Ipsambul, which, though covered by the dry and impalpable dust for centuries, had received no injury from it. So minute was this dust, that when it was removed from the various parts of the temple, it resembled a fluid put in motion. We shall now proceed to notice those peculiarities that attend whirlwinds at sea, and more particularly such as present the phenomenon of water-spouts.

These water-spouts are of frequent occurrence in the Mediterranean, Adriatic, and Ionian seas, where they are known by the name of trumpets, on account of their apparent shape, which, as we have already remarked, is ordinarily that of a trumpet, or inverted cone, with the broader side towards the clouds, to which it frequently seems to be attached, and with the narrower side at contact with the sea. They usually travel in a standing position vertical to the surface of the sea, but not always; for in some cases, the progressive motion of the upper part connected with the clouds, is different from that of the lower part clinging to the sea; and then the cone or trumpet becomes inclined, and travels in an oblique position. Sometimes, also, when the difference of the progressive velocity of the various parts is too great, the waterspout is broken in two. When they begin to be formed, they frequently appear to come down from the clouds over a spot on which the sea shows a protuberance or swelling, accompanied by ascending vapours, which, uniting with those descending from the clouds, finish the apparent form of the water-spout. Sometimes, however, the ascent of the vapours from the sea, precedes the descent of those from the clouds; it also happens, that the inverted cone or cylinder formed by the ascending vapours, has sometimes no connection whatever with the clouds. These are some of the most conspicuous features of water-spouts, and are in perfect harmony with the agents engaged in their formation. We have already mentioned, that when the whirlwind has one of its extremities at contact with the water, on account of the rarefaction of the air in the funnel, and of the external pressure, the water is forced to ascend to a certain height, which would amount to nearly 34 feet in the case of a perfect vacuum in the funnel. This, however, is not the case, although the prominence of the water above the common level, may appear to ascend higher than 34 feet. But we must remark that the rapid whirling of the air which becomes like a pipe through which water ascends, imparts a similar motion to the water, which being thus moved ascends laterally all around, and is depressed in the middle, assuming the form of a concave surface more or less deep, according as the whirling motion imparted to it is greater or less. Examples of this kind are familiar to everybody, and may dispense us from entering into the reason of the fact. But the sides of the aerial funnel are not so steady as those of a cylinder of glass or metal, or as those of a tumbler, besides, the funnel itself moves forward in a progressive direction, and the water ascending in it with a somewhat sudden impulse, and being unable to acquire the rotary motion of the air all at once, the supposed cavity is of course liable to many and great inequalities, and in fact, we know from observations, that before the formation of the visible foot of the water-spout, the water on that spot besides ascending above the common level, bubbles and foams, and vapours rise from it just as if the water were in a state of ebullition. Thevenot, to whom we owe several accurate observations on the subject, is of opinion, that the whirlwind which gives rise to the vapours, and forms the water-spout, is in full activity from the surface to the cloud, (commonly not very high) at the commencement of its formation: an opinion which has been adopted by Boscovich, and not without good reason. For while the water at the foot of the whirlwind commences to ascend, and bubble, and send up vapours, the cloud above enters into the funnel-shaped hollow of the whirlwind, until the vapours from the cloud join those ascending from below. The reason of this fact is easily seen; for the same rarefaction of the air which causes the ascent of the water below, and the formation of vapours, causes likewise the descent of the cloud; which, being no longer supported by the air which the whirlwind had displaced, sinks on account of its natural weight, and fills the funnel. In this manner, we also perceive that water-spouts differ from common whirlwinds in this respect, that their rarefied funnel is filled with vapours, giving it a visible form: and limiting the appellation of water-spouts to this visible form which vapours give to it, we may safely affirm (and this is the common belief), that for the most part, water-spouts come from the clouds. This frequent descent of the cloud in the apparition of water-spouts, has induced some to think, (not entirely without reason) that a violent production of vertical wind from the cloud itself was their cause, and that the internal column or funnel of the whirlwind would rather press the water on which it rests, than suck it up and cause the ascent. But numerous facts, besides those already mentioned, contradict this opinion; still it does not seem to be entirely condemned, since instances are not wanting in which sudden and interrupted compressions from above, have been noticed; and Boscovich who maintains the general ascent of the current or other substances through the funnel, does not omit mentioning some instances of this downward compression, which is sudden, however, and of short duration. We shall shortly allude to some probable cause of this circumstance. Let us now see one of the few instances in which the facts connected with water-spouts, could be observed by one who happily escaped safe from the whirlwind, in which he had been involved. A few periods extracted from a letter written on the subject and afterwards published, (*Pianciani.. Institutioni Fisico-Chimiche v. III. p. seconda pagina 554.*) will be sufficient for our purpose. The ship in which the writer of the letter was travelling in the Ionian Sea, was overtaken by

a water-spout on the 1st of Nov. 1832: he thus de-
scribes the event. - As soon as the water-spout was
over us, the ship began to turn round like a top,
with great rapidity: then it began to shake, as if
acted upon by a subsultory earthquake. The wind
at one moment pressed the boat down upon the
sea, at another, it raised it up, and after an un-
interrupted whirling, it began to depress the
ship, chiefly at the stern. We, amidst our fears
and prayers, were all looking up, motionless,
at the funnel, as if from the bottom of a deep well,
when the depression suddenly ceased, and the
water-spout left us, giving the boat a terrible
shaking.

As for the causes of these sudden and
lasting impulses from above, it may be said,
that the collision between the ascending and
descending vapours, or a rapid contraction
of the funnel, or a diminution in the rotary
motion of the whirlwind, in consequence of
which, a copious quantity of vapour and air
would concentrate along the axis of the fun-
nel, may be assigned as these causes. To these,
which are all of a mechanical nature, may
be added some others, proceeding from the con-
currence of the various agents at work in the
storm, concerning which, as we do not possess
sufficient data, much cannot be said: but we
may remark, that from all appearances elec-

tricity is one of the chief agents the roaring & flashing which accompany them, especially when they are no longer on the conducting water, as also the sulphuric exhalations, show clearly, that if electricity is not the primary cause of this class of storms, it is a concomitant cause, or an active effect. These remarks hold good in any supposition, whether we consider the whirlwind as being in activity from the surface of the water to the cloud, or not: for there are cases, as has already been remarked, in which the waterspout has no connection whatever with any cloud; and there may be some whirlwinds that never descend so low as to touch the ground or the water: it may also happen, that the whirlwind which unites the surface of the sea with the cloud, is not put into activity all at once, but either ascending or descending gradually; in the former of these two cases, the water spout would in every respect ascend from the surface of the water towards the cloud; in the latter, it would really descend from the cloud. Among the various circumstances attending the storm particularly examined by Boscovich, we notice that whenever the storm met on its way some strong and high obstacle, the ground or buildings immediately following, had suffered no injury: an evident sign that the huge obstacle had cut off, as it were, the lower part of the whirlwind; and the air rushing into the funnel, being far from the ground and lower buildings, had not injured them. But soon after, the destructive power of the whirlwind manifested itself in the fields and houses; an evident sign that it had descended again to the ground. Why then should a whirlwind be unable to commence among the clouds, and gradually descending, finally reach the ground, or surface of a river or lake, or that of the sea?

We shall conclude this subject with a comparison between the water-spouts and tropical hurricanes, which, for the most part happen at sea, and which, from this comparison, will still better appear not to differ from the water-spouts, or other whirlwinds over land, except in their size, and corresponding activity and power. The most striking feature of water-spouts, which consists in the column formed by the ascending and descending vapours, cannot be observed in hurricanes, on account of their enormous size, which makes them cover a large portion of the sky, even when seen at a great distance. But that they carry along with them an enormous quantity of vapour, is clearly indicated by the heavy rains that accompany them. The water at the foot of the whirlwind in water-spouts, besides the apparent state of ebullition in which it is in, appears whitish, and murmurs like a rapid torrent: that this is the case in tropical hurricanes, is evinced by the appellation of white squalls, given by seamen to this kind of storms. As for the ascent of the fluid through the rarefied funnel, there exists the same difficulty in seeing it, as for the column or funnel made visible by vapours; but the effects seem to leave no doubt as to the fact being so. We have seen how the typhoons that visit the Indian coast of Coromandel, & coming from the sea, raise the water so as to make it roll many miles inland. Also, how Savanna-la-Mar in Jamaica, was swept away by an enormous swelling of the sea, or as writers call it, a great wave, when, in 1780, that island was desolated by a similar storm. Here we shall stop, and calling the reader's attention to the stormy winds which as the psalmist says (Ps. CXLVIII. v. 8.), fulfill (the word (of the Lord), in a manner like that just witnessed, we shall not hesitate to exclaim with the royal prophet: —

"Wonderful are the surges of the sea: wonderful is the Lord on high." (Ps. XCII. v. 4.)

— Finis. —