METEOROLOGY

AND

THE LAWS OF STORMS

G. A. DePENNING

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BEING A

NEW THEORY

OF THE

CAUSES OF WINDS,

AND AN

INVESTIGATION OF THE NATURE OF STORMS,

CONCLUDING WITH

PRACTICAL RULES FOR THEIR AVOIDANCE.

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INTRODUCTION.

Of all the Sciences of Natural Philosophy there is none that is so generally interesting as that of Meteorology, for the great influence of the weather on the actions of man must always and naturally have given him a desire to acquire a fore-knowledge of the occurrence of its changes.

In endeavoring to acquire this information, he discovers and notes the many simple indications that forerun a change, and these are the general and first steps in the knowledge of Meteorology, and they continue, even now, to be a most valuable portion of the practical part of this Science.

The impressions left by the dark and mysterious appearances of the atmosphere on the occurrences of its storms, must next have led the reasoning mind of man to inquire as to the agency by which they are produced.

But in the darkness of ancient times the occurrences of these phenomena were attributed to the powers of evil spirits ; and to propitiate them they would consult the oracles of their sacred temples, the priests of which used to promise auspicious winds. With the general increase of knowledge however, and specially after the invention of the barometer, men began to comprehend the nature of the substance air, and to inquire into its properties.

The properties of air were determined either from the phenomena it presented, or were inferred from the existence of analogous phenomena—in this, as is to be expected, we have been partly led astray, for analogy has ever proved a dangerous guide.

The movements of the atmosphere next drew attention, and theories were assigned for the causes of its general and particular winds.

From this time we began to perceive that the winds were clearly dependent on, and due to, physical causes ; and the great attention bestowed upon Meteorology resulted in the great discovery of the rotation of some storms, and this added greatly to enrich the large accumulation of facts with which our knowledge of Meteorology was already stored. But still our knowledge of Meteorology must be considered as most unsatisfactory, for, while our information as to the facts and phenomena of our atmosphere may be considered complete, still their explanation, as referring their causes to the effects of physical forces, have not been fully made out or perfectly accounted for.

This want of continuity between cause and effect, which requires as yet to be linked, is the object of this little work to accomplish, or, at least, attempt.

METEOROLOGY.

METEOROLOGY is the science that relates to the investigation of all the phenomena of our atmosphere, and more particularly to the ascertaining of the nature of its state, and the causes of its change.

The atmosphere is the name that correctly applies to the whole gaseous portion of our planet, but it is also used indifferently with the word air for a part of the whole. The word air, in a chemical sense, however, has a limited meaning, and refers only to the substance necessary for respiration.

The state of the atmosphere is generally called the weather, and it is described either by its appearance or by any prominent peculiarity of temperature or humidity : when the peculiarity is permanent, it characterizes the climate ; when for a term only, the season, of a place.

Chemistry of the Atmosphere.—From the result of numerous analysis of the atmosphere, it has been found that oxygen and nitrogen are the two only of the gases that are always in the same proportion to one another as regards volume; they are therefore considered to constitute the essential ingredients of air.

The proportion of these two gases is invariably found to be one part of oxygen to four parts of nitrogen.

The other gases found in the atmosphere are deemed accidental, as their proportions are ever varying, while their quantities are small. They are considered the result of some of the innumerable sources of vitiation of the air.

Oxygen.—The most remarkable property of this gas is that it promotes combustion and respiration; for instance, were an iron wire heated to redness, and then inserted into a vessel containing this gas, it would burn with great brilliance.

Nitrogen—in its character, is the opposite of oxygen, as it will not support either combustion or respiration; a lighted taper for example would be instantly extinguished on being plunged into a volume of it. The use of nitrogen in our atmosphere, as a constituent of air, appears especially as a dilutent to subdue and modify the activity of oxygen.

Formation and Constitution of the Atmosphere.—We learn from the sacred Scriptures: That after the creation of the world "God said, let there be a "firmament in the midst of the waters, and let it "divide the waters from the waters."

"And God made the firmament, and divided the "waters which were under the firmament from the "waters which were above the firmament, and it "was so."

In this we have revealed to us the design and the formation of the atmosphere, for the words clearly express that the atmosphere was *made*, and after the creation of the earth, so that we can only consider the atmosphere as a new substance, a material part of our globe, attached and belonging to it in the same manner as our oceans of water.

But while we are unable to perceive any limit to the atmosphere, we know that the density of the atmosphere decreases with the height, and since the air, as we also well know, is capable of indefinite expansion, the atmosphere may therefore extend to an indefinite or indeterminable height, so that some scientific men have been led to imagine that the atmosphere may possibly pervade all space, in a very attenuated state, and that from the effect of the earth's attraction it is drawn around it, its density at the earth's surface being due to its weight, the result of the earth's attraction. Towards supporting this hypothesis, there are the appearances of similar atmospheres to be perceived, by the aid of a good telescope, around many of the heavenly bodies.

In imagining this formation of the atmosphere, scientific men must not be considered as being actuated by any feeling of disbelief in the inspired writings, nor even in entertaining a conviction of this hypothesis are they to be supposed as questioning at all the truth of the sacred Scriptures, for they only suppose that the Almighty, whose works are of infinite magnitude, has created our world, as but one of a system, and that, for His own great views, He hath but in part informed us:—He may perhaps have left it to our reason, that He has so bountifully endowed us with, to search and discover His mighty works, a labour that must be pleasing to Him, as we then the more clearly discern and know His greatness.

Now we do not doubt the sacred Scriptures, although it leads us to infer that the world was made shortly before man, yet we discover from geological researches that the world was or did exist, long before the advent of man, still in being informed that God created it within three days, we have been rightly informed, inasmuch, as it was a new creation when He made it a fit habitation for man, for the inspired history can only be considered as written with regard to us only, and it was then in fact the beginning of the world for man.

Now this new creation may be considered as the mere effort of God's will, in causing the world simply to move into the system we are at present in, where the world on arriving would have "the evening and the morning of the first day."

But though the formation of our atmosphere, as being attracted from space, appears highly probable, yet we have a fact that altogether disproves its possibility, and this is in the variations of atmospheric pressure, for the attraction of gravity being constant, it is impossible that its effects can be otherwise, and these differences of pressure could not exist, for air would be instantly drawn from space. These fluctuations of pressure then convincingly prove that the atmosphere is a new and distinct creation, and that it is not attracted from space, and in this we learn so much the more of God's greatness, who could so inspire the mind of Moses that he should truly describe the nature of our atmosphere, when, for ages after, its very existence as a substance was not known.

Our chemical knowledge, however, here comes in the way to throw in a doubt, as to the distinct formation of our atmosphere, for we find the two component gases of the air, *viz.*, oxygen and nitrogen, always in the same proportion to each other, notwithstanding the increasing sources of the consumption of its oxygen from respiration and combustion, while we are constantly decreasing the apparent (to us) sources of its supply in the destruction of our forests and our woods; and without some new source of its supply or of its generation, our alarm would not be groundless were we to imagine, that we would soon cause our own destruction, and be swept from the face of the earth, as those great monsters that have ceased to live, have been, from the inability of our new atmosphere to support their existence. Now it is possible that there is an outward source for the supply of oxygen, that keeps its proportion constant, and this supposes the constitution of our atmosphere to be of a joint nature or formation, that is to say, of the components of the atmosphere nitrogen may pertain to our globe while oxygen is attracted from space, their proportion showing either a deficiency of nitrogen with reference to the power of the attraction of gravity, or the presence of oxygen is due to the effect of diffusion, which draws it down in its constant proportion, so that, in either case, we would still have created for us a new and distinct substance, as the atmosphere of our globe, which has been made suitable for us and our existence.

This constitution of our atmosphere, while it accords with the sacred Scriptures, as a new creation of a separate atmosphere, admits in its nature of the differences of pressure, and all the other properties and phenomena that we find it possesses, while with oxygen as the occupant of space, the great and constant, light and heat-giving powers of the sun become explicable to us.

Height of the Atmosphere.—Calculations from the reflection of light, make it as extending to about 45 or 50 miles. This is probably the case, as the effect of the intense cold of the higher elevations may possibly condense the air, so as to arrest its indefinite expansion, and so give it a first or normal state. This condensation, however, if it does exist, is evidently such as not to effect its transparency.

From the observations with the Barometer we obtain the ratio of the decrease of its pressure with the height, which enables us to calculate with great precision the heights we are enabled to attain, as by the reading of the barometer (reduced to the adopted temperature of freezing water) and a reference to a simply calculated table, we obtain it very accurately.

The Properties of Air.—These, as in common with solids and liquids, may be enumerated as inertia, weight, and momentum. Air is also elastic and compressible, and exerts pressure in all directions; it contracts by cold and expands by heat, and though it offers considerable resistance to a solid passing through it, yet from absence of friction it will allow of the passing of a body of itself through it with the greatest facility : it is a bad conductor of heat, but it is singularly both a good and bad conveyor of heat also, and, lastly, it acts as a vacuum for the diffusion of vapour and other gases through it.

With most of these properties of air we are familiar, but the peculiarities of its powers are only obvious when we examine them meteorologically, and as all the movements of the atmosphere depends on these peculiarities, it is necessary that they should be first examined.

Absence of Friction in Air.—Friction, as generally defined, is the obstruction to motion that the surfaces of substances offer when moved against one another, and while it is effected and increased by weight or pressure, it depends altogether on the nature of substances.

The obstruction that the surfaces of solid substances offer to one another are the prominences of their atoms in their arrangement, and as these strike against one another they act as opposing forces, and so tend to destroy motion. When one of the surfaces is at rest, its obstructions re-act with a force equal to that with which they are struck, as is well known.

Where the nature of the substances is such that the cohesion of its particles is great, the reaction is equal to the full force imparted, or that with which the prominent atoms are struck; where the cohesion of the particles is small or weak, it re-acts in part only as the atoms break off. When part only of the force is thus communicated, the breaking off of atoms even assist to lessen friction, as the broken particles act as rollers to prevent the full friction or contact of the other atoms. Since friction depends so much on the inherent cohesive attraction of solids, it follows that the friction that a solid would meet in passing through a liquid must be small, as it depends on the less attraction of adhesion, for instance, were a bowl, as it floats (partly immersed in water), set rotating, it would continue to rotate for so long a time that it would almost lead to the conclusion that liquids have no friction whatever; in fact, a solid in motion through a liquid loses not so much from actual friction, as from force expended in moving a layer of the liquid which adheres to its surface, so that instead of true friction it is but force applied to the destruction of the adhesive attraction of liquids. When a stream of water moves through a body of it at rest, at a velocity above 5 miles per hour, its friction or adhesion may be seen to affect the water at rest by causing eddies or vortices on both sides of it as it moves along. But in a gaseous substance as air, where its particles have no attraction, but on the contrary repel each other, there is no such thing as friction in it, as friction depends clearly on inherent attraction, and as the following well known experiment will prove. Place three lighted tapers in a row at the distance of three inches apart; then from a distance of ten feet set the air in the barrel of an unloaded gun towards the centre of them by the explosion of a percussion cap, when it will be found that the centre light alone is blown out, and that without disturbing the other two.

This important property of air explains the many sudden movements of the atmosphere and the facility with which a body of it may move through the still atmosphere, while it admits of its continued rotation from momentum in its rotatory storms.

Convection of Heat.—Fluids both elastic and non-elastic are considered bad conductors of heat, as they do not freely transmit it through their substance; yet when they are placed under the circumstance of being heated in their lower surfaces, as when water in a vessel is held over a light, the whole body of it gets to be rapidly heated throughout, as the heat is conveyed upward by the rising of the heated portions of the water as they get heated.

Since the well known effect of heat on substances is to cause them to expand, and, as every heated or expanded portion is specifically lighter than equal bulks that are unaffected by such temperature, we naturally conclude that the heated fluid, as surrounded by the cooler and denser fluid, is in a similar position as a light body (as we call it) is, when immersed in water, that is to say, it rises because it is lighter (as we say) than the surrounding fluid. In this, though we are correct as to the fact, yet we err, as we cannot help entertaining the erroneous idea that lightness is the direct cause of floatation, as the habit of calling floating substances *light* does leave us so impressed.

Now lightness is clearly no property of substances, but it is simply a comparative term to express the lesser density of any two compared substances bulk for bulk, for while we call a substance light when compared with a fluid on which it floats, we call it heavy also, when it sinks in another fluid of lesser density.

Small density is either an inherent or acquired property of substances, when inherent it is the result of construction, when acquired it is occasioned by increase of temperature, small density is always expressed as in an inverse ratio to bulk—it is, however, not directly the cause of floatation.

Floatation is occasioned by pressure, which is the joint result of the earth's attraction and of fluidity.

Pressure as due to the earth's attraction is the weight of the direct column of fluid above any surface as its base, and from fluidity it possesses the property of communicating pressure in all directions of the same intensity at same depths. On the immersion of a foreign light substance, or on the expansion of a portion of a fluid in its lower surface, pressure from being passive becomes an active force, as it is unbalanced, for the light substance, or the expanded portion of the fluid has displaced, in the column of which it forms the base, a bulk of fluid equal to itself but of greater weight, so that the column, of which the light substance or expanded portion of fluid forms the base, has, it is evident, less pressure than is due at that depth to the surrounding fluid from their columns of height and weight: pressure therefore, acts and results in pressing up the light substance or the expanded portions of the fluid, while the fluid over the now rising substance or heated portion moves away from its facile moving nature due to fluidity. So that though raised, a light substance seems to rise as if it were a property of it, whereas lightness is only the indirect cause of unbalancing pressure, the great property of fluids.

A very good illustration that pressure is the sole cause of the floatation of light substances will be made evident in the following simple experiment. On the opened plug hole of a trough containing water place a cork of somewhat larger diameter than the hole, so that it may not be caught by it. Now we will find that the cork, which we well know is a light substance, is unable to rise, as it is held to the plug hole of the trough, and that this is clearly caused by the unbalanced pressure on its upper surface, while the greater pressure on its lower surface is removed.

Convection of heat in fluids is due then evidently to difference of pressure, as occasioned by difference of density, for the warmed portion of a fluid, being specifically lighter or less dense, it gets raised by the difference of pressure it occasions, as the pressure of the column, of which the warmed portion forms a part, is less than that due to the depth it is in.

In a similar manner, on a portion of the atmosphere becoming heated as by contact with an artificial light or fire, the particles that compose the heated portion expand and so lessen their density and gravity ; they are then necessarily forced upwards, by the greater pressure of the surrounding atmosphere, the cooler particles of which either press upwards directly, or where otherwise circumstanced, from lateral pressure and their fluid nature, insinuate themselves under the heated portion, and, in their turn, as they come in contact with the light or fire, and they get heated, they get raised in turn also, so that the rising of heated air as we call it, goes on continuously, as may be perceived in the smoke that generally accompanies combustion.

To convince ourselves that the rising of heated air is due to this cause, we have only to place a lighted taper within a glass receiver furnished with a chimney, and on a flat dish—now, by pouring a little water into the dish, we find that the light goes out, simply because the surrounding air cannot enter below the edge of the glass receiver to press upwards the heated air, and to supply the oxygen which is consumed, and of which fresh supplies are necessary to maintain combustion. It is evident now that the heated air within the receiver, except such portion as is expelled by expansion, is unable to rise, (as if it did its place would be occupied by fresh air, which would restore the flame,) and while the air is prevented from entering from below the edge of the receiver by the water in the dish it cannot enter from above or down the chimney, as it is opposed by the increasing elasticity of the heated air within. Now, if we insert a slip of any uninflammable substance down the chimney as a divider, or brattice, as it is technically called, and so divide the chimney into two passages, (as the light is about being extinguished supposing it re-lit again) we will find that it restores the flame, and that the taper continues to burn as long as the brattice is not removed. This restoration of the flame is occasioned by the extreme susceptibility of air to the smallest differences of pressure, which its fluid nature is ever ready to act upon, and the small difference of pressure is occasioned by the impossibility of so placing the chimney or the light under it, so that the air shall be equally heated on both sides of the bratice, and even were it possible to do so, the smallest quiver in the flame from the efforts of combustion would be sufficient to cause a difference, and make one side of the bratice the downshaft for the fresh pressing air, and the other the upshaft for the rising heated air, and in consequence of this descent the flame would always incline towards the upshaft.

In observing the heated air or smoke as it rises from over a fire, we perceive that it does not rise directly up, but that it floats off with the lightest current. Now, since the rising of heated air is caused by the difference of pressure occasioned by the difference of density of the heated air and the surrounding cooler air, the difference of pressure here could only be of its individual particles, or of that portion of heated air that for the time keeps together vertically over the fire, and as this is a small body, the rising of heated air in its rate of motion can only be in proportion to the small difference of pressure that so small a body of heated air could occasion, and which gives it its upward motion. So that the movement of air past an open fire is necessarily slow, in fact, it is unable unaided to maintain a coal fire, for a rapid supply of fresh oxygen is necessary for its full and proper combustion.

It is this small power of rising of the heated air or rather of its being raised from deficiency of pressure that explains the necessity that now makes us erect tall chimneys to obtain what is technically called a good draught; for the chimney holds all the heated air as it is raised, directly over the fire, or in connection with it, and so renders available the joint lessened density of all the heated air within the chimney to keep up a constant decrease of pressure within it, (as of a column,) so that the outward air at the fire grate of full atmospheric pressure being always so much the greater continually rushes in through the grate as the draught required, causing a full combustion of the fuel that is developed in the flame.

Were the slow rising of heated air from the small difference of pressure, as occasioned by the small difference of density of its particles, not necessarily a slow movement, still there are other physical causes that would prevent a body of it rising rapidly even if intensity of heat had greatly lessened its density. For if we watch the motions of heated air, (as we may in the smoke that accompanies it,) when it is caused to rise rapidly as by the puffs of a locomotive, we perceive that it does not rise up directly, but on issuing, it makes a rapid revolution in a ring; that then in rising it increases the dimensions of the ring while the smoke or heated air still continues rotating, and that yet rising it floats off with the wind (if any) now rising slowly with slower and with imperfect revolutions. Now this rotation of the heated particles is caused by their being actuated in more than in one direction at the same time, as besides rising they are caused to move laterally when they expand from the centre by their elasticity as the heated air is now raised into a higher strata of lesser density, and as these two forces cause the air to move off in the direction of their resultant, the heated air in tending so to move off, comes (from the after condensation that arises from its being moved into a higher and colder strata) under the influence of gravity, which in partly drawing it down, gives it the rotatory motion we observe. So that the rapid rising of a body of heated air is impossible, as the rising impulse is destroyed, for to rise fast it must also rotate ; while this rotation, by causing a perfect intermingling of the heated with the cooler air of the higher strata, tends quickly to reduce its temperature and increase its density, and so arrest its further ascent.

Solar Heat—as affecting the atmosphere, does not do so directly, at least to any sensible extent, for the reason that the air is a transparent substance of small density. But the solar ray, in passing through the atmosphere, heats the earth's surface, which, from its greater density, absorbs the greater portion of the solar heat, so that the lowest strata of the atmosphere at the earth's surface gets first warmed by contact. The air thus heated from below warms gradually and proportionately upwards, to a limited height however, not so much from its own powers of convection, as from absorbing heat from contact with vapour, which from being specifically lighter, is raised through the air.

Where the earth's surface is of the same nature as in the great extents of its plains and its seas, all the air on those extents, heated in this manner to a certain height would rest unaffected by convection, for convection, as we know, depends on the introduction of cooler and denser air from laterally and from below the heated air; but here there is none near that could so introduce itself, for the natural decrements of temperature for differences of latitude are too gradual to possibly be the occasion of any lateral motion towards the heated air.

In certain situations in India, especially in the plains that are banked on the windward side by mountains, this resting of heated air on the plains is distinctly visible, from the reflection of the vapour on its upper surface. Colonel Sykes describes seeing such a state of the air resting upon the heated plains below the Ghauts in the Concan. And it is well indeed that we have this wonderful provision of nature given us, otherwise were air able to convey heat perfectly by rising up directly and rapidly on absorbing the heat from the earth's surface, we should be frozen even at the equator.

Calms—are these restings of air on portions of the earth's surface ; they are but a sign of equilibrium of pressure between the air on the portion and the surrounding atmosphere, and until this balance of pressure is disturbed, the air, so resting in a state of calm, cannot be put into motion, be the solar heat ever so intense. Calms are of frequent occurrence, and often recur for many successive days : within the tropics and in the hot weather they are very oppressive and distressing, and though we feel the sun as very powerful, still we need not fear that it will cause the air to rise bodily off the earth's surface, and so leave a perfect vacuum behind ; nor need we imagine these calms a suspension of nature's powers, when preparing or brewing for a tempest or a hurricane. —In fact, we must regard calms more favourably than we have done, as they are not the causes of storms.

Calms, however, have been known to precede a storm : their connection will be shown hereafter.

Winds.—When air is in lateral motion, we call it by the general name of wind ; and we express its intensity by many familiar terms, as gentle, light, strong, stiff, high, &c. When winds are peculiar to any locality or position, or are accompanied by some phenomena, they are then called by particular names, as the trades, the monsoons, the land and sea breezes, the hill and valley breezes, the gales, also whirlwinds, thunder storms, squalls, &c.

But when air is in violent motion, besides the general term storm, we endeavour to express, not only intensity, but also some undefined peculiarity of their nature, in the words gale, tempest, and hurricane, and in some other terms borrowed from foreign languages.

But our present advances in the science of meteorology render it desirable that we should be more precise in the use of terms, so that they should clearly express both the nature and intensity of these violent movements of the atmosphere. The late Mr. Piddington, who perceived the necessity of a proper and exact definition of storms, made the happy suggestion of the word cyclone for those of a rotatory nature ; with this term to express the intensity of a rotatory storm, of the strength of what is now called a gale of wind, and the word hurricane to signify rotatory storm of extreme violence and intensity, we have the words gale and tempest to express the different intensities of straight or rectilinear storms.

The cause of Winds.—Air, from a state of rest or inertia to be put into lateral motion as a wind, must require the action of some physical force. This is evident to us, at least, when we try to do so artificially by means of bellows or fans; in doing this we observe and know that pressure, whether it be obtained directly from compression, or indirectly from the partial vacuum in opening the bellows, or as in the rotating fans, where the inclined beaters from continuity of motion expel the air, and so leave a partial vacuum at its centre, for the pressure of the atmosphere to supply, and since we find and are convinced that pressure so artificially occasioned can cause the motion of air as wind, and since, besides the force of pressure, we know the effects of temperature, the nature of the centrifugal force, and are certain of the influence of outward attraction as that of the moon—now, if we could clearly trace the origin of the different winds to the action of these forces jointly or separately, we shall have determined within the meaning of philosophy the physical causes by which their movements are produced.

The Land and Sea Breezes.—These are winds that are truly due to convection, and they are occasioned by the difference in the nature of the land and sea, in their powers of absorbing and radiating heat. The land from its opacity absorbs and retains at its surface nearly all the heat imparted by the solar ray, which warms the air in contact to a greater intensity than the air over the sea adjoining, for the sea being a transparent substance, the solar ray strikes through it, and heats it to a depth proportionate with its density, so that the heat is distributed through a large body of it, the air therefore over the sea is not warmed to the same intensity as that over the land. So that where the land and sea adjoin, the cooler and denser air over the sea moves from its superior pressure towards the land and under the air over it, and the air that was over the surface of the land now so raised joins and moves off with the upper currents of the atmosphere, this wind from being off the sea is called the sea breeze; it generally sets in about 9 A. M., as at that time the sun's effects begin to be felt sufficiently to cause the difference. It ceases to blow about 4 P. M., when, from the sun's declining, and the gradual warming of the air over the sea, an equilibrium of temperature and pressure is established, and the air either rests or moves with the regular winds of the position. At about 9 P. M., the sea, owing to its slow radiating powers, retains the air over it in a warm state during the night, as the solar heat which it has absorbed from being distributed to a certain depth, is unable to escape quickly; whereas the air over the land has chilled from rapid radiation, the difference of density being now reversed in favour of the land, the air moves towards the sea as the land breeze.

The Hill and Valley Breezes.—These are occasioned by very nearly similar causes as the land and sea breezes, with which, when the situations favour, they act conjointly. The hill breeze is a nocturnal wind, blowing down the sides of the slopes of a hill into the valley at its base; it occurs, however, only where circumstances are favourable as a sheltered valley with a pass or opening into the country or to the sea; the hill tops during the night not only lose the heat which they had acquired during the day, but from radiation, and owing to their exposed position, reduce their temperature below that of the surrounding atmosphere of their height, so that they are clothed with a layer of air cooler and denser than the surrounding atmosphere, or that which hangs over the sheltered valley, as the valley, from its slower radiation, retains the air over it warmer than that due to its height. This cold air, gathering about the hill tops, sinks from its density down the hill sides, and then sweeping the surface of the valley, it escapes into the country or the sea, and it may do this even without affecting the sheltered warm air hanging over the valley, which, as long as it remains undisturbed, continues to keep up the difference, and cause the continuance of this breeze.

The Valley Breeze is felt in the day on the hill sides, sweeping upwards to its summit; it is caused by the air being greatly heated on its surface by contact and by its being forced up by the colder and denser air of the different strata adjoining, which are not equally affected. This breeze is often not an actual movement from the valley, though apparently so.

The Trades.—These are regular currents of circulation of the atmosphere, and they are due to the action of the centrifugal force, aided by the expansive power of temperature. Now we know that the temperature of the atmosphere, as obtained from solar radiation, decreases in its intensity as we depart from the position where the sun is vertical, so that, at the time of the equinoxes, when the sun is vertical over the equator, the atmosphere, in expanding from the effects of temperature, must, it is evident, expand to a greater height at the equator than at the poles.

The accompanying wind charts, though they are constructed without regard to the proportion that the atmosphere bears to the earth, yet, as they well represent these effects, they are necessary and desirable for illustration.

The Trades at the times of the Equinoxes.—In wind chart No. 1, suppose the dotted line E,A,D,B,F,X,E, equi-distant from the earth's centre of gravity G, to represent an outline of the atmosphere unaffected by temperature,—the effects of solar heat, it is evident, would cause it to assume some such form as L,A,H,B,K,Z,L, the positions A and B being supposed to be the positions of its mean temperature, H and Z over the equator, as due to its expansion from the great temperature of the equator, while L and K are to be considered as due to the effects of cold, as from not knowing where to reckon the commencement of temperature, we may regard cold as a separate agent.

Now the effect of centrifugal force arising from the earth's diurnal rotation, would, it is evident, cause the air, (which is free to move,) to rise to a greater height over the equator than that even which is due to temperature, so that the atmosphere at the equator, from having a position higher than its proper level must overflow on both sides to seek its level (naturally, as it is said), for fluids from their nature, and from being under the influence of gravity, must rest in their upper surface equi-distant from the centre of attraction, as the upraising of a portion from bringing pressure at the foot of the portion raised (if at no lower position) into play, would, it is evident, put the fluid into motion towards the direction or directions it is unopposed.

Now, centrifugal force has a constant tendency to keep the air raised over the equator, there is therefore a constant overflow at the equator; but as the centrifugal force is unable to draw or send the air from immediately below from off the surface of the earth at the equator, as that air cannot quit the surface without leaving a void,(which would bring the superior force of pressure into play,) the centrifugal force therefore draws or sends the air from a distance of about 5° from both north and south of the equator as we find it, and where the inclination prevents the occurrence of a void or vacuum.

The centrifugal force in sending the air from a distance does so, however, with an enhanced force, which increases with the distance, for the air even to the tropics C and R in moving with the earth in its rotation moves very nearly at the same rate as the air over the equator, as the difference of circumference is small, the air therefore on those positions are nearly alike affected by direct centrifugal force, but besides this, the air at the positions C and R in moving round with the earth move true round their respective centres M and P, while the direction of gravity is towards the centre of the earth G, (and it is the attraction that holds the air to the earth.)—So that the air of the positions C and R, from not being held or attracted towards the true centres M and P, around which they move, increase their centrifugal force or tendency to fly off, for like the governor balls of an engine, these particles of air from their individuality are free to move tangentially from indirect centrifugal force in one direction, though yet restrained by gravity to the radius of the globe, that is to say, it moves therefore along the earth's surface towards the equator, as the trades. This constant flow to the equator and its consequent overflow, of which we are convinced, does as convincingly establish the existence of upper currents towards the tropics from the equator, and which observations on heights have confirmed.

Now if we refer again to the wind chart No. 1, we will observe that the air of the polar circles to about 60° of latitude is represented as moving along the earth's surface, and then flying off to the upper surface of the atmosphere towards the positions A and B. That these north-east currents exist, the observations of æronauts have established; and that they must exist, our knowledge of the effects of centrifugal force must convince, for the air of those regions in moving with the earth would move in the direction represented from the great effect of indirect centrifugal force, as gravity could not here restrain the air from flying off to the outer surface of the atmosphere (as at the equator). The accumulation and consequent descent of the cold and dense air on the positions A and B are clearly shown in the frequent rain and fog of those latitudes.

A and B being the positions of the meeting of the upper currents, their meeting, it is to be expected, would occasion an accumulation of air and consequently of pressure over those positions, and this our barometrical observations have ascertained. Now, the effect of these accumulations of air and its consequent pressure is to cause the arriving currents to sink, the upper current from the equator either to return with the trades, or to blow into the temperate regions as the westerly gales, and the upper currents from the poles either to join and supply the trades, or blow into the temperate regions as the easterly gales, their reciprocity of action depending on time or season or the influence of outward attraction as of the moon.

Direction of the Trades.—The trades have been observed to blow about the position of the 30th degree of latitude, where they are found to commence in almost in an easterly direction, and that they gradually, as they approach the equator, take a direction nearly from true north and south. Their easterly tendency is rightly attributed to their inertia, when they are the continuance of the current from the poles, but when from the upper current of the overflow from the equator the easterly direction is the result of the momentum of these currents, as they turn downward in the plane of their motion. Of these two forces that give easting to the trades, that from inertia must be the weakest, as the power of gravity must evidently be always tending to destroy it, as the trades themselves evince. When, therefore, we find the trades at their commencement, and at these times of the year, blowing from towards the north, or with more northing or southing than usual, we may be certain that the air is from the upper polar current.

In the fact that gravity exerts so small a force both in restraining the momentum of air, or in causing it to lose its inertia, we have a convincing proof that the gaseous substance air, unlike solids and liquids, is free to be impressed or acted on by the centrifugal force, as its elasticity seems to balance gravity, whilst its repulsiveness prevents its attraction on it as a body.

Now, as the earth in its annual revolution round the sun, is constantly altering the sun's declination, so is it also continually altering the position of the line of greatest heat, and since these changes in the line of greatest heat must be continually altering the configuration of the earth's atmosphere as influenced by temperature, a circumstance that must considerably influence its currents and its winds, it is necessary that we should first ascertain the nature of its effects, and if we do so at the times of its greatest changes, we shall then clearly understand what occurs between these times and changes.

The Trades in the month of June.—Wind chart No. 2 represents the trades and currents of the atmosphere in the month of June, when the sun is vertical over the tropic of Cancer. At this time, from the effects of differences of temperature, the atmosphere, it is evident, must assume some such form as the outline L,A,D,Z,K,X,L represents. This being the summer of the north, the air over the north pole must, it is evident, extend to a higher height than the air over the south pole, which is now in its winter season, while the sun, from being vertical over the tropic of Cancer, the atmosphere, it is evident there, extends to its greatest height; but from the effects of indirect centrifugal force the high air over the tropic of Cancer at Z, would, it is evident, be driven to the point H, over the equator, instead of flowing down in the direction Z, K, on which a pretty high level would be maintained from the effects of its confined summer temperature, and this leading direction thus given to this upper current, together with the rising of air from centrifugal force at the equator, determines the direction of all the currents and winds of the atmosphere for this time of the year.

This continued rising of the trades at the equator, whatever the declination of the sun and the position of the line of greatest heat, establishes clearly in itself the fact that the trades are due to centrifugal force alone, for the effect of temperature have seemingly only the power to alter, to a few degrees, the position of the rising ; we accordingly find that, at this time of the year, it is moved to 4 or 5° north of the equator.

Now, the air in moving from the position Z towards H, will have caused greater pressure there by the overflow than the actual atmospheric pressure of the position, (as due to direct centrifugal force and the effects of temperature,) for the centrifugal force that has driven the air from Z to H is that which is due to its indirect action,—from the effects of this pressure part of the air might possibly return in the direction D, B, as a centre current, and here it may be joined by the rising air of the equator as represented to sink and to return again as the north-east trade, the rest of the overflow Z, H, would continue to flow in the direction H, A, there to sink and return to the equator as the south-east trade.

The Trades in the month of December.—Wind chart No. 3 represents the trades and currents of the atmosphere in the month of December, when the sun is vertical over the tropic of Capricorn; as it is exactly the reverse of wind chart No. 2, no description is needed. The occurrence of calms, between the trades at the equator, and to the north and south respectively of the two trades, have been noticed. That at the equator, as before mentioned, is evidently due to the inability of the centrifugal force to effect it; those at the north and south limit of the trades are from the counteraction of the upper currents or from the position being between the turning of the trades and the overflow of the upper current into the temperate regions.

The Monsoons.—From the irregular division of the earth, with regard to the portions occupied by land and by water, (as the Continent of Asia lying to the north, with the Indian Ocean to the south of it,) this distribution of differing surfaces is undoubtedly the effect and the cause of destroying the north-east trades in the summer season of those positions and substituting in its place a wind, the south-west monsoon, as they are called.

Wind chart No. 4 represents the south-west monsoon of the Indian Ocean, together with the corresponding currents of the atmosphere in the month of June, when the sun is vertical over the tropic of Cancer.

From the increased effect of solar heat on the land of the Asiatic Continent in raising the temperature of the atmosphere over it, (as compared with its effect on the oceans where the north-east trades prevail at this time of the year,) the air assumes a higher level, so that the upper air lying between B and Z over this Continent joins the current from Z to H, as represented as it only can, and in consequence of this great overflow, it reaches to a lower level, and from being carried further it has a greater momentum (than in the case of the trades of the same time, as represented in wind chart No. 2), at H, a small portion may be turned down and there join the upper current of the south-east trades as it rises at the equator, the rest continuing in its course it again either returns from the southern tropic, first as the south-east trades, and then as the south-west monsoons, or it flows into the temperate regions as the westerly gales.

In like manner the Continents of Africa and America have been found to disturb the regular currents of the trades.

The Moon's influence on the Atmosphere.—From its not being apparent in the temperate regions, which are too remote to be directly effected, the influence of the moon on the atmosphere has been doubted by many eminent men of science, but in the region of the monsoons, where there are circumstances favourable to its development, and where its effects are more immediate, the influence of the moon on the weather is very apparent, and it is therefore most confidently believed in both by those who inhabit and by those who visit those regions. And indeed, when we come to consider the great attraction that the moon exhibits on the waters of the earth, we have no reason to doubt but that it must also considerably influence the atmosphere which is so much nearer to it. Now we have no reason to expect that the influence of the moon on the atmosphere will be apparent in any difference of pressure as to be indicated by barometrical observation, as the effect of the moon's attraction on the atmosphere is not from any raising or heightening of the atmosphere under it, (as the density of the atmosphere is too small for it to be so directly effected,) but by the attraction of the moon in the frequent changes of its declination lying in or against the direction of the currents, which accordingly accelerates or retards the winds at the earth's surface, and in this manner her influence is manifest enough.

The crossing or interchange of the upper currents across the equator.—That these do frequently occur we have every reason to expect, as occasioned by the moon's influence; and this crossing is no doubt the cause of the great electricity and rain of the tropics.

Gales and Tempests.—The influence of the moon, in increasing or retarding the winds of the atmosphere, often leaves a deficiency of air in the temperate regions, either in the northern or southern hemisphere, by its accumulation in the opposite hemisphere, as the liveliness of the barometer in those regions clearly prove. On the commencement or removal of the moon's influence, and for the restoration of the atmosphere to its proper circuits, these deficiencies of air lying between long belts of latitude makes itself evident in the decrease of pressure, and so either assists in drawing down a gale or increases the violence of the gales of those regions as to make them tempests. Lateral accessions of wind accompanied by squalls often change the direction of a gale or tempest, so that they have frequently been mistaken for rotatory storms.

The time most favourable to gales are during the winter months and at the times of the equinoxes, as a reference to the wind charts will enable us to perceive.

Cyclones and Hurricanes.—These are rotatory storms, their nature being first clearly determined by the late Mr. Redfield of America ; they are due to deficiency of pressure extending over a large surface, both of latitude and longitude, but frequently of longitude only. The deficiency of pressure may be due either to the moon's attraction in drawing off the air to the temperate region, or it may be due to the translation of expanded air from off the heated land to a position over the sea, where, from the consequent sudden contraction, it forms a partial vacuum which occasions the rotation. *The rotation* is due to the equal tendency of all the surrounding atmosphere to move towards the vacuum together and at once, but as this simultaneous movement would contract the circle, and so effect the elasticity of the air, the surrounding air is unable to move towards the partial vacuum, while the leading wind of the position or direction of greatest pressure prevailing, it gives to the air the first direction and their rotatory movement. The rotatory movement once communicated to the air, its momentum increases with every rotation, especially from the continuous action of the force that begun and occasioned the movement, while from the absence of friction the rotation is perfectly unrestrained.

The configuration of a cyclone or a hurricane, whether it be a circle or an ellipse, would depend much on the nature of the vacuum and the force that gives the storm its progressive motion; if the vacuum lies on equal extent of latitude and longitude, and if it be simply under the influence of the leading wind of the position, it will be circular, but if the vacuum lies on a belt of longitude only, and the hurricane is moving to a position of lesser pressure from a position of greater pressure, the configuration will be elliptical.

Thunder Storms.—These are local disturbances of the equilibriun of pressure, occasioned either from excessive continuance of the prevailing wind from momentum or attraction, when on its discontinuing to blow, it leaves a dimunition of pressure, or they are the first effects of the moon's attraction against the prevailing wind causing it to cease, and then by its attraction drawing the air suddenly from the opposite direction and from the upper strata.

In the region of the monsoons, and especially at the commencement of the season, they are very frequent; they are to be guarded against, as they are often very violent, and they have been known to be the precursor of a hurricane.

The nor-westers of India seem, however, to be partly due to a partial vacuum being caused by the contraction of air on an eastward position from the lesser altitude there of the sun at the time, and when the moon's influence, by stopping the current of the monsoon, draws the air from the north and west as it only can.

Squalls—Are the accessions of new air to the prevailing wind or storm, and partly from a new direction; they are generally accompanied with arched clouds as thunder-storms, and are frequently accompanied by rain.

They are considered as a favourable sign in tempests and hurricanes, as shortly preceding their discontinuance.

Whirlwinds—Are eddies in a wind occasioned by its fitfulness or its constant small changes of direction; this, giving to portions of air an inclined direction to another portion that has preceded it, and which it meets, causes the air of the two portions to turn round a centre, and this rotation, once commenced, is kept up by its momentum. The centrifugal force, which is brought into play by the rotation, and which, from driving the air from the centre, expands the air in the centre so as to form a partial vacuum, adds to the effect, as the partial vacuum tends to keep up a continuity of motion.

This partial vacuum of the centre frequently attaches the whirlwind for a time to a spot, destroying its progressive motion with the wind; it is at last overcome by the wind with which it is carried off. Deflection from an object as a tree or a grove is sufficient to occasion a whirlwind, while permanent whirlwinds are to be seen at the angles of some buildings.

The intense heat, however, of the tropics seems to aid the formation of these whirls from causing the sudden expansion of air as it strikes the heated ground, for in a wind there are constant accessions of cool air of the upper strata that are caused to fall or move downwards,—whirlwinds therefore are to be seen most frequently in the hot and dry weathers.

Waterspouts—Are occasioned by a partial vacuum in the regions of clouds, formed, without doubt, from the condensation of vapour.

The waterspout in appearance seems as an inverted cone of clouds descending to the sea, but without any visible appearance of rotation.

The rotation of the air round a waterspout is not seen from its not having visible vapour within it, as all the vapour that is or may be in the air rotating round the vacuum (which is seen and is called the waterspout) either loses their visible form from the rapid motion of the air, or the vapour is attracted to the central vacuum, from the rotating air surrounding, as the visible vapour unlike air is formed of separate or distinct particles, and is unaffected by that elasticity that forms the unbroken bond or circle of air around the vacuum. The descent of the waterspout is due clearly to the partial relief, from pressure, of the air below the waterspout, while the air springs up continually and in succession to join the rotation. The inverted conical shape is evidently due to the greater and increasing densities of the lower air as the rotation descends, while the vapour from the effect of gravity descends down the still or slow moving centre as the visible waterspout we so often witness.

Clouds.—The diffusive property of air increased by the action of solar heat enables it to cause water to vapourize proportionally with the temperature. This vapour, which is invisible, except in a vibration of the air that it causes, is raised through the atmosphere from its lesser specific gravity, and as it is raised, it is partly absorbed by the air it passes in contact with, from diffusiveness ; but air is unable to absorb vapour to saturation as the effect of temperature, and the small gravity of the vapour causes it to disengage itself from air above that point ;—air is found to be saturated with moisture only when its temperature is reduced.

The excess of vapour raised by evaporation or that which is not absorbed by the air rises through the air, and floats at such an elevation and as a strata where its own specific gravity balances the density of the air, and here when affected by a decrease of temperature, it undergoes its first step of condensation, which renders it capable of reflecting and intercepting light, and in that state it is visible to us as clouds.

Rain—Is the complete condensation of the visible vapour of the clouds, and it is effected by cold air sinking through it. This condensation is visible to us in the darkening of the clouds, as the particles of vapour have now become particles of moisture, and remain suspended in the air as water (as minute particles of it may be caused to do from the scrubbing together of two wet brushes). These particles of moisture, as they now attract each other from their proximity and their adhesion, fall when they acquire sufficient density or size, and where foreign attraction as of electricity assist their joining, the drops acquire a large body, and then fall as heavy rain. The descent of cold air through the clouds is that of the upper currents from the colder region; from its being of greater density than that due to the strata in which they are or from being of greater density than the strata below of which the clouds are a part. This is clear to us here in the time of the monsoons, even under a virtical sun, as it is only the effects of the cold upper current (or the N. E. trades, which has been uplifted by the monsoon) that occasions the incessant rains, and keeps the atmosphere in a state of perfect saturation. The entrance of the trades also marks these effects, from the conflict of the currents, while their regular wet season make known to us the influence and existence of the falling upper current, which may be frequently seen in the high clouds moving in an opposite direction to the wind.

The moon's influence on the weather in occasioning rain in its phases of new and full is very evident within the tropics, even at those times which are not the regular rainy season; it does so no doubt by its attraction on the upper currents, frequently by drawing so large a volume of air from the temperate regions, that its descent as a thunder storm with heavy rain is almost certain in some position,—the continuance or return of the moon's attraction in causing thunder storms may even be noted and clearly seen for two or three successive days.

The Barometer.—The principle and construction of this instrument are well known, but its indications as representing atmospheric pressure must be considered as faulty, as the lateral motion of the air does greatly affect it, as is apparent in the fall of the barometer during a storm. The fall of the column during a storm is occasioned by the barometer being always under shelter, as it is even so in its very construction ; and all air sheltered from the storm has necessarily a diminished pressure. The diminution of pressure of sheltered air is occasioned from its being in part freed from the full atmospheric pressure as that is unable to affect the sheltered air directly.

For suppose D,N (Fig. 1) to represent an obstruction to the storm moving in the direction of the arrow C,D to A, and this obstruction as sheltering the air and a barometer B. Now it is clear, that the air in motion as the storm is affected by two forces,—one, the force that has occasioned the storm and moves the air in the direction from C to A; and the other, the force of gravity that gives the air its weight or pressure, and if we estimate the strength of the storm as one-twentieth that of gravity, and suppose the arrow C,D to represent the direction and intensity of the storm, while P,D represented the direction and force of gravity, acting at right angles to it, it must now be allowed, for it is evident, that the effect of the storm in the direction that it is moving, would deflect the direction of the force of gravity or its consequent pressure in the direction of their resultant D,R,—the air therefore within the space D,R,N is evidently relieved by this deflection from the direct pressure of the atmosphere; it must therefore lose density from the elasticity of its nature, a density which is given it by direct pressure. The loss of density also by this deflection must always be in proportion to the intensity of the storm, as the deflection is occasioned by the power of the storm.

But though D,R would be the resultant and direction of the storm and atmospheric pressure, were pressure fully active, but as pressure is passive as long and so far as it is opposed by elasticity, the storm is never so affected by full atmospheric pressure: atmospheric pressure is therefore unable to turn down the storm in the abrupt direction D,R,—and were the lessened density of the air within the space D,R,N not occasioned by the inability of pressure to act directly on it, the storm, it is evident, would continue in the direction C,D to A, leaving all the contained air below that line unaffected by the movement of the storm,—but this our experience shows us is not the case.

Now, suppose the storm, as in Fig. 2, in moving from C to D, (from not being affected by the full active pressure of the atmosphere) to continue on in its direct course from its momentum to some position X, it is clear if it were not before affected by the lessened density of the sheltered air, it would there be acted on by a force occasioned by it. Then let P,X represent the active pressure from this lessened density equal to C,D, or D,X, the force of the storm (as it can only be equal to it), then their resultant X,E must, it is evident, be the direction to which the storm will be bent. At E, however, lateral pressure would be acting in the direction L,E, at right angles to X,E,—the direction of the storm would evidently then be turned to S, and by continuous lateral pressure from S to T, and then by its momentum from T to F, where, completing a rotation, it again joins the storm in the direction F,E,M,—the return current F,E,M helping in part to overcome the lateral pressure, and to lessen even further the density of the sheltered air, while it causes the sheltered air to extend to such space as D,F,E,M,H represents, occasioning, where favorable, even another rotation as at M, within the sheltered air during the continuance of the storm. The small arrows used show merely the direction and not the intensity of the storm, as the depression D,F,E, not before alluded to, is the result clearly of the lessened density of the sheltered air, and it would also be the true path of the storm, as the storm would not continue so directly to x, or turn down so abruptly as the direction x,E represents.

A very pretty illustration of these effects will be seen, were one of a set of flags hoisted to the lee of an obstruction, freely suspended in mid air (as a backed topsail) and during a stiff breeze, when the flag immediately behind would be found to point inwards towards it, while the other flags will be found to fly with the wind, as represented in Fig. 3.

These return currents of air are often to be perceived on a grand scale in bays that are sheltered on the windward side by high mountains, as for instance, at the Cape of Good Hope, where vessels may frequently be seen sailing both in and out of the bay with the wind from opposite directions. The spreading of the table-cloth as it is called also well illustrates the attraction of the lessened density on the lee side of the mountain for condensed vapour, for it is to be seen as a fog or mist spreading and moving down the sides of the mountain, while the wind blows over the mountain and rotates at a distance as they have been observed by Sir John Herschel to do over the Jetty, this rotation being visible from the small portion of visible vapour that the wind has been able to carry with it.

The oscillations of the barometer during a storm are then evidently occasioned by the lulls and gusts, as they succeed each other, causing a variation of density in the sheltered air,—the calm centre or vortex of a cyclone or hurricane is also indicated by a low barometer, as the centrifugal force drives off the air to the circumference of the storm or rotation, and maintains a partial vacuum there.

Smoky chimneys, in opposition to a brisk fire, are often occasioned by the lessened density of the sheltered air within a house, as the difference of pressure makes the chimney the downshaft, even against convection or the supposed rising powers of heated air.

The barometer has been found to be scarcely affected by differences of pressure within the tropics, as the regular winds of those regions, namely, the trades and the monsoons, together with their upper currents, are, in their movements, so well regulated, that they ever keep the pressure of the atmosphere well-balanced; but in the temperate regions, which is the position of the overflow of these winds, and the sources of their supply, the barometer records constant differences of pressure, and as these differences of pressure frequently precede changes of the state of the atmosphere, it has caused the barometer to be looked upon as a weather-glass, and hence the use of the terms Fair, Change, Rain, &c., generally marked on them.

The Water Barometer.—The small density of water, as compared with mercury, enables atmospheric pressure to support in the vacuum of a tube a column of nearly 30 feet in height of water, and as all variations of pressure are proportionally represented, the water barometer, from its larger indications, has been considered the more delicate instrument as compared with the mercurial barometer, as it has been found to show such small differences of pressure as are not perceptible in the mercurial, as even to indicate the lessened densities occasioned by the puffs of a storm—when its movements have been likened to the respirations of life. But it is not in the mere delicacy of its indications that makes the water barometer so valuable, as the timely notice that the small adhesiveness of water, as compared with mercury, enables it to give of the tendency of the atmospheric pressure either to increase or decrease, (and so also of a change in the weather,) and in this it has been found to precede the mercurial barometer by more than an hour.

It is much to be deplored that the difficulties attending the construction and the filling of this valuable instrument have prevented its general adoption, but although it is desirable to have as perfect an instrument as can be constructed, still there is no occasion to sacrifice the great utility of the water barometer to the expectation of making it a permanent or standard instrument, which however the perishable nature of water will never admit. It were better, as it is sufficient for all practical purposes, to adopt some simple means for frequent refilling or of correction, as may be done by the use of two stop or turn-cocks, one fitted to the foot below the water level of the cistern and the other to the head or top communicating with a reservoir of water (and within which it should work, as the water would prevent the admission of any air). Where long glass tubes are not to be procured, a simple and perfect instrument may be made with a portion of four to six feet of glass tube attached to one of metal, which may be perfectly insulated from the atmosphere by being passed through a larger tube kept full of water, so as to cover the joint. A water barometer so constructed may be easily refilled or corrected daily or whenever there is a doubt as to its indications, for we have but to turn and stop the lower cock, (which may even be done by any convenient mechanism from above,) and then open the upper cock within the reservoir, for the admission of water, which would expel all the air if any had risen into the vacuum from the water. Now on closing the upper and then opening the lower cock, the only possible air that could gain admittance into the tube would be that of the new water, and which, from its small quantity, would scarcely affect the indications of the barometer, and were the water previously acted on or kept under the influence of the vacuum caused by an air pump, such a barometer for all practical purposes would be perfectly or sufficiently correct. Now were such water barometers erected in all our light-houses, much that is now lost might be saved, as its early indications would enable those in their charge to give timely warning of expected changes,—at least its indications, from showing the evident tendency of the atmospheric pressure either to increase or decrease; it would put them on the guard to watch carefully for the corresponding movement in the mercurial, which may otherwise be passed by unnoticed.

The Thermometer—is the well known and useful instrument by which we ascertain or measure the temperature of substances, and particularly of the atmosphere.

Now, although cold is considered the absence of heat, yet as we can never determine the point or degree where heat is perfectly absent, we may therefore, with propriety, look upon cold as a separate agent and allude to it as such.

In the graduation of thermometers it is a pity that we have so many different scales; it is time enough that we should adopt one standard, even if we have to give up our favorite Fahrenheit.

Thermal observations to be of importance require that they should be taken uniformly, but the fact is, the majority of observations taken and registered are useless, as the thermometers are generally so placed as to be affected by conducted or reflected heat. We often hear of 100° to 110° of Fahrenheit in the shade. Now this can scarcely be said to occur, as the temperature at the centre of even an open house, of or about 100 feet square, during the hottest day that is anywhere experienced, will rarely come up to 98° of Fahrenheit, while with closed windows the air may be always maintained under 95°,—and the lowest temperature that can be thus obtained, without other artificial means, is clearly the proper reading of the real temperature of the weather.

Observations of the thermometer taken at sea, or in the saloon of a vessel, should never be compared with observations ashore, but should be separately considered, for even were a correction obtained and allowed for any one degree of temperature, it would be inadequate for a higher temperature, as the power of the conduction of materials is known to vary with differences of temperature.

Sudden changes of temperature have been found very frequently to forerun a storm : sudden variations of temperature, therefore, as exhibited by the thermometer, should be carefully noted, as showing the commencement of, or a tendency to, a change in the weather, for it is clearly the effect either of the turning of the wind itself, or of the currents of the upper strata.

Actinometry—Or the measuring of the direct heat of the sun's rays is most desirable, for the dependance of climate and season rests much on the actual amount of heat received and of the quantities intercepted by the clouds: hourly or more frequent observations should be recorded. The heating powers of the sun's rays is best measured directly by a blackened thermometer, which should be sheltered from the influences of the weather, and this should be compared with another that is fully exposed to it and also with the one usually placed in the shade;—together with this, were the sun's effect on a body of water exposed in an uniform description of vessel also obtained by the indications of a thermometer placed in the water, from their differences, compared as well with the indications of a dry and wet bulb placed in the shade, we should be enabled to determine the exact influences that are at work, and which go to constitute the weather and climate of positions.

It is a popular belief that the equator, or a belt of one or two degrees on both sides of it, is the hottest portion of the globe—it may be so as regards the mean amount of heat, but as regards direct heat at those periods when the sun is vertical, which can only be considered as the most favorable time for its full and highest intensity, were actinometrical observations obtained for all positions of our globe, there is no doubt on comparison that there would be found positions both in India and Africa of as high a latitude as 25° and even 27° north (when the sun is vertical over the northern tropic,) that are even for the season hotter, or more affected by the sun. This is occasioned by two causes that differently affect the two positions : in the first place, the belt of the equator at the time of the equinoxes is partially relieved from the sun's rays, as from being the mid-position of the up-turning of the trades, which at this time turn back to their circuits, there are no cross upper currents to carry off the large quantities of vapour which they leave behind, and which as mist intercepts and reflects back the rays of the sun ;—on the other hand, the more northerly positions, when under the sun, have, from their regular upper currents which carry off the vapour, cloudless skies, while aided by the nature of their soil and their well sheltered positions, they are better enabled to retain the heat emitted from the sun, so that these positions have thus a hotter season. It is from the same cause, namely, the presence of a large quantity of moisture that makes the weather of Calcutta cooler in June, when the sun is vertical, than in March or April, when the sun's rays are much inclined, as there is a constant descent of cold air through the strata of the S. W. monsoons, which keeps the air imbued with moisture, which as mist and clouds intercept the sun's rays.

The Anemometer—is a mechanical instrument for recording the direction and duration, and for measuring the rate and intensity of the winds. They are of various constructions and of principle, the latest and most approved is that of Robinson's. These instruments are of the greatest importance to Meteorology, as the particulars that they very accurately ascertain are the data for calculating the averages of the season and climate of countries or of positions of the world. But though anemometers are not very costly instruments, and though they have been invented and in use for many years in England and in Europe, it is a pity that they are not more generally used or set up in all parts of the globe, as the comparisons of climate are of the greatest importance to Meteorology; while the facts that they would accurately ascertain are now subjects of mere conjecture, especially in positions as India, which may be considered as the theatre of storms, we have not even one to indicate or show what goes on about us. It is to be hoped that before long we shall have many of these and other meteorological instruments erected in different positions, so that we may have from their establishment so many Meteorological Observatories spread over the country, which, by the aid of the Electric Telegraph, will enable one head office to fore-cast the coming weather of many days before (as is now done in England by Admiral Fitz-Roy)—a fore-knowledge, the infinite importance of which to mercantile interests it is not necessary here to enlarge upon, as its practical results in England have been already fully acknowledged.

The Hygrometer—is an instrument for ascertaining the humidity or measuring the amount of moisture in the atmosphere. The simplest form of this instrument is that of the well-known wet and dry bulb, the indications of which depend on the rate of the evaporation of water. The hygrometer invented by Daniel, though a very delicate instrument, has the great objection of not acting continuously, or being permanent. A change in the state of humidity or the amount of moisture in the air is evidently the result either of a change in the direction of the wind itself, which brings with it air of a different state of humidity, or it is the result of a change in the direction of the currents of the upper strata, the air of which, from its greater density, descends through, and thus lowers the temperature of the lower strata on the earth's surface, causing an increase of moisture in the air, so that to attribute humidity to small elevation alone is evidently erroneous, for the air of low countries, which is generally supposed to be very damp, is (as well as that over the surface of the sea,) at times so free from moisture, that the wet and dry bulbs show greater differences than that of the most reputed dry climates in the world. By observing and distinguishing between the causes of a change in the state of humidity, we have an index to the movements of the atmosphere and especially of the upper currents, by which we would be greatly assisted in our foreknowledge of the weather, as a change in the state of humidity very frequently precedes a storm.

THE LAWS OF STORMS.

The Laws of Storms—may be considered as the supplementary science to Meteorology, as it is a further and fuller investigation of the nature of storms, from which we deduce certain rules or directions, which, practically applied in navigation, enables us to avoid their dangers.

To have a thorough knowledge of the nature of a rotatory storm, we must be acquainted not only with the causes which occasion its commencement, but we must ascertain the nature of all the particular phenomena that marks its continuance, as also the causes of its progression and cessation.

The Origin of Rotatory Storms (as stated in Art. Cyclones and Hurricanes in Meteorology)—is clearly due to the occurrence of a partial vacuum, or a diminution of pressure, as regards the mean pressure of the atmosphere, and the occurrences of these vacua are evidently due to the withdrawal of a portion of the mean amount or quantity of air from over any extent of surface of the earth, and this may often result in some positions, from the circumstance of time or season rendering the withdrawal of air necessary for the purpose of keeping up the regular winds or currents of the atmosphere; for instance, the position of the temperate regions in their winter seasons (as we may perceive by a reference to the wind charts) being the position of the frequent descent of the upper current of the trade winds, as the westerly gales, (but which, in the opposite hemisphere, steadily turns back into the trades,) so that the trades of the winter portion, from the want of this return or supply and from the effect of what might be termed its draught, draws the air from the upper strata of the temperate regions and so leaves in consequence a deficiency of air or a partial vacuum in those regions, especially when the influence of the outward attraction of the moon lying in its direction causes an excessive or increased flow from the temperate region, the single source of its supply.

A partial vacuum may also be occasioned in certain positions by the interruption of the regular trades, where they blow or strike on the shores of continents or large extents of land at some distance from the position of their termination, and that then, from the irregular action of solar heat on these continents or large extents of land, the trade winds are at times caused to be continued in their direction excessively, or diverted into a new direction, so that the upper current is occasionally without a source of a supply, while the momentum of the leaving upper current draws off a portion of the air, so that a diminution of pressure is the result. This is clearly evident in the frequent hurricanes off the West Indies, the Mauritius, and in the China seas, while in those positions where the trades are uninterrupted, these storms are of rare occurrence.

On the occurrence of a partial vacuum, and on the diminution of pressure being perceptible, as regards the surrounding atmosphere, the air surrounding would naturally tend to move or expand towards this partial vacuum, but, as before stated in Meteorology, no simultaneous movement from expansion could possibly take place from the surrounding atmosphere, as the elasticity of the air would be so affected as to prevent any such movement, for were the surrounding air to move simultaneously, it would be contracted into a smaller circle or space as it was moved towards the partial vacuum, so that its density would increase while its own pressure and elasticity would cause the air to spring back.

That no other than a simultaneous movement of the atmosphere surrounding a partial vacuum from expansion could possibly tend to take place, is clear, as any movement for one side alone to restore the equilibrium of pressure would be but an extension of the partial vacuum, as the air of this lateral position (which we can only suppose of mean atmospheric pressure), in supplying the deficiency, would deprive itself of a portion, so that a deficiency, though of lesser amount, would now result and continue over both portions, and which would gradually diminish as the source of supply extended in extent or went backward in distance. Now this manner of restoring an equilibrium of pressure would necessarily be a matter of time, which the nature of pressure, to our knowledge, does not admit of, as its action is well known to be instantaneous, so that from the simultaneous tendency of movement of the surrounding atmosphere towards a partial vacuum, but which, as shown, it is physically unable to do, the vacuum continues intact, till it causes the leading wind of the position to be drawn round the vacuum, when a rotation ensues, which is kept up by the continuous effect of the partial vacuum.

The Nature and Form of Rotatory Storms.—Let us suppose a partial vacuum to occur over a position A, B (Fig. 4), and the dotted line, E, N, M, F, to represent (without regard to proportions) the outline of our atmosphere as surrounding the earth, H, C, A, B, D, K, then the dotted lines, N, A and M, B, being vertical or perpendicular to the earth's surface at A and B, may be said to contain the partial vacuum. (In the fact of the occurrence of a partial vacuum, no actual depression of surface or lessening of height takes place, although there is a virtual deficiency in the quantity of air, for the elasticity of air would cause it to spring up to, and maintain its usual surface.) As long as the diminution of pressure continues over the position or spot A, B, there will certainly be a pressure (equal to the difference of pressures) of the surrounding air towards it, and this pressure will be of all the air directly lateral or at right angles to the lines N, A and M, B, considering these two lines as representing the whole circumference or sides of the partial vacuum or of all the horizontal air over A, E and B, F. Now this pressure must be regarded as an existing but restrained force, which can therefore only be tending in one direction, straight to the partial vacuum which has occasioned it, for it is clear that the partial vacuum could not affect the air along the earth's surface to any considerable distance, as at K, for there the curved surface of the earth alters the direction of pressure, as the straight or tangential line K, T, the only direction by which pressure of the position K could affect the partial vacuum, is evidently thrown up above it by the earth's rotundity. So that, though the surrounding air of the vacuum over the horizontal lines B, F, and A, E are from their tendency or pressure drawn into the rotation of the storm, the lower air of the positions K and H, from not being influenced by the partial vacuum, is left unaffected, and may be in a state of calm while the clouds above are to be seen moving in rapid motion. This generally calm position, surrounding the body of the storm, may well be called the *range* of the storm, as its upper strata is evidently within the influence of the storm.

It is most probable that the original partial vacuum or diminution of pressure, as left on the withdrawal of part of the air, is never fully maintained, as from the surrounding pressure and tendency to move towards it, a partial supply of air may at times take place, so that a proportional diminution of pressure is caused to exist in the surrounding air, extending to the points F and E, and from the effects of which the actual body of the storm may be caused to extend to some surrounding positions, as C and D, contracting at the same time the vortex V, at the earth's surface, as represented, similar to the inverted conical forms assumed by waterspouts.

Direction of Rotation.—It has been found that the rotation of cyclones and hurricanes for the northern and southern hemispheres are invariably in opposite directions, namely, N., W., S., E., or against the hands of a watch for the northern hemisphere; and S., W., N., E., or with the hands of a watch for the southern hemisphere. As the commencement of the rotation clearly depends on the leading wind of the position where the partial vacuum occurs, this difference of rotation for the two hemispheres follows as a natural result, as a reference to Fig. 5 will enable us at once to perceive. For, in the regions of the trades, we know that the wind commences in nearly an easterly direction, and, then after a gradual curve, moves directly to the equator as represented, so that on the occurrence of a partial vacuum in any position of its course, as the greater part of the circle of the partial vacuum is covered by the curve of the trade, from the force of the difference of pressure (toward the vacuum) acting laterally on it, the trade, the leading wind, is easily caused to increase its curve while its momentum takes it round the partial vacuum.

In the regions of the monsoons, the occurrence of a partial vacuum generally stops the wind of the monsoons and restores the trades: the same law of rotation is therefore kept up ; but it is possible, from the effect and direction of the monsoons, that the law may be reversed at times, it becomes necessary, therefore, that in those positions we should be certain of the direction of the rotation of a storm from the veering of the wind before we act or try to avoid its danger.

In the temperate regions the direction of rotation clearly depends upon the joint action of the great gales of those latitudes, the westerly from its polar tendency affects the inner or equitorial side of the storm, while the easterly, from its opposite tendency, curves in on the polar side.

But since the temperate regions are the positions also of great tempestuous gales, we require to distinguish carefully between them and these rotatory storms, as the squalls that run into these gales from the south and west for the northern hemisphere, and from the north and west for the southern hemisphere, give them all the appearances of rotation.

In the higher latitudes of the frigid zone the severe westerly gales or rather tempests may frequently be the result of great polar vacua, so as to make them immense polar cyclones, with the wind in one constant direction.

Progression of Rotatory Storms.—Although all rotatory storms have been found to progress, or to move along varying directions or tracks, still the progressive motion of some have been found so slow, while others have been known to be arrested for a time that they have been separately regarded and called stationary storms.

In this difference we can only conclude that there must exist a new force that is the occasion or cause of the fast progression, and it is evident that this must also considerably affect the nature and alter the configuration of fast progressing storms.

Taking first into consideration stationary or slow progressive rotatory storms, it is evident that whatever the outline of the vacuum, when it first occurs, that the joint effect of the surrounding pressure, of the rotation and of the centrifugal force about the vortex must cause what may be called the body of the storm, to assume a circular form, as represented in Fig. 6.

In this figure the converging dotted lines are used, merely to represent the contraction of space or circle that affects the elasticity of the air, and which would result were there a direct and simultaneous movement to the central vacuum on its occurrence, and it is about this circle, that, owing to the condensation of the air from this contraction, 'that a slightly high barometer is frequently noted, as experienced, before the commencement of one of these storms.' The only evidence of the storm here, to a vessel at sea. and at some distance would be the appearance of a bank of clouds on the horizon. Now, were we to suppose ourselves (as in a vessel) to enter and to move across one of these storms, we would first enter, what has just been called the range of the storm; here we would experience either a calm or light wind, or perhaps have an occasional squall, while the clouds and scud above would be moving regularly and rapidly with the neighboring storm, of which, in fact, it forms a part; here also we would first observe a small fall of the barometer from the gradual spread of the vacuum, which increases as we enter into the body of the storm, (and it is within this, the range of a rotatory storm, that the wild appearance of the atmosphere from being unfelt leaves a peculiar impression on the mind that has given rise to the expression of 'nature's preparing and brewing for a hurricane'). Now, as we enter the body of the storm, we would observe a sudden and greater fall of the barometer, while we would experience the movement of the air, which would generally be of the intensity of an ordinary gale of the temperate regions, so that we might well call the storm here a cyclone, according to the accepted definition of the term, or, in alluding to the intensity, we might call it cyclonic. Proceeding further, we would enter the hurricane circles of the storm, where we would have the greatest fall of the barometer, as it would there, in a great measure, be due to the lessened density of the sheltered air. Passing through the hurricane circles we next come suddenly into the calm vortex, where we find that the barometer rises considerably, though it still continues low, as here it is unaffected by the lessened density of sheltered air, while the barometer merely indicates the true amount of the partial vacuum which is the occasion of the storm.

It is in this calm vortex that there always is a break in the clouds and scud, which seems to give 'a promise of fair weather,' which the apparent rise of the barometer helps to make the more promising, though so delusive, as has been so often experienced; this is owing to there being no cross upper currents here to condense the moisture into visible vapour.

Passing through the calm vortex, we fall again into the hurricane circle, and so experience all the storm in reversed order, having the winds of equal duration and intensity as they can only be for these stationary or slow progressing storms.

In fast progressive rotatory storms it has been observed that after the passing of the vortex over a position, and on the change of the direction of the storm to the opposite quarter, that it is then of the greatest intensity or violence; but that its duration is small as compared with the preceding portion of the storm, or that before the passing of the vortex. In these peculiarities we clearly perceive the effect of the force that has occasioned the fast progression. So that even assuming that the rotatory movement of the storm to be always truly or nearly circular, still the difference of the duration of the preceding and concluding portion of the storm evidently places the vortex eccentrically or nearer the concluding portion of the storm, as in Fig. 7. This evidently arises, as before mentioned, from the force that affects the whole body of the revolving storm in the direction of its progression, or track, and this can only arise from the difference of pressure in the direction of the track, occasioned by the partial vacuum that must lie in the direction of the progression, for these partial vacua must often occur in long belts as our knowledge of the movements of our atmospehre will easily lead us to conceive.

The Intensities of Rotatory Storms.—From the fact that it does blow harder in the inner hurricane circles than in the outer cyclone circles, we can with certainty conclude that the air in rotatory storms, while rotating, moves also inwards towards the vortex, so that while this fact shows that rotatory storms do not move bodily as a disc, or as a wheel with fixed radii, it becomes also a convincing proof that the origin of rotatory storms is certainly due to the occurrence of a partial vacuum, as this inward vorticular movement can only arise from the constant lateral pressure that is always maintained towards the partial vacuum of the vortex—the greater intensity then of the hurricane circles (which is primarily due to this inward vorticular movement) depends clearly upon the circumstance of the momentum of the air in motion being caused to act upon itself as the circle of rotation is decreased, and this may be well illustrated by the familiar experiment of twirling a small weight as a stone around a finger by a string fastened to both, when we will find that the velocity of the movement of the stone would increase as the length of the string was shortened, and so much so, that it would very suddenly move round and smartly strike the finger.

This constant inward movement, which is arrested by centrifugal force at the vortex occasions, without doubt, an ascent of air around the vortex, which, rising and spreading from it, descends again to join the storm at the earth's surface, being drawn in as it approaches the positions E and F, in Fig. 8, as represented by the small arrows B, M, S, B, and A, N, R, A, so that it adds its momentum to increase the storm. It is however not to be expected that the ascending movement of air about the vortex will be apparent, as owing to the large extent of the circle, a small inclination upwards, which would be imperceptible, would be sufficient to draw off the moving air.

The great intensity of the *head* (as it may be called) of the hurricane circles in fast progressive rotatory storms, is evidently due to the contraction of the channel as it were from the pressure in the direction of its track, while on the opposite side the intensity is proportionally lessened as the hurricane expands in the greater extent of space of the body of the storm, as we may perceive by a reference to the preceding figure, No. 7.

The intensity of storms, referring to its violence or destructive force is, in as a great measure, due to the difference of pressure towards the negative side of an object (from the lessening of the density of sheltered air,) as to the mechanical effects of its momentum, for, from the minuteness of the particles of air (of which, in fact, we have no notion, for we can only speak of it correctly as in portions,) the mechanical result of momentum, whatever may be the rate of movement, must be inconsiderable, as is evident in the indications of Lind's anemometer. In this, gaseous air is different from liquids, as there the inherent attraction of adhesion, in giving liquids, mass and body, results in adding to its momentum, when in motion, a proportionate percussive blow or force.

The Tracks of Rotatory Storms,—Or their direction of progression may depend on one of three separate causes or forces, or on their joint or opposing influences.

1*st.*—It may result from pressure where the partial vacuum lies on long belts and where the rotation commences at one extremity, for there must then be a lateral pressure of the atmosphere (equal to the difference of its pressure and that of the partial vacuum) on the separated body of the rotating storm, that must eventually carry it in the direction of the other extremity. This will account for the sudden fall of the barometer so very frequently noted, on what may be considered the positive side, as well as the long previous low barometer felt on the opposite or negative side, or the side of the partial vacuum, and which is as frequently met with, indicating its approach.

2*nd.*—The direction of the progression of a cyclone may also be the effect of the leading wind, and it will then be against or nearly against its own course, as the leading wind, in being drawn round the storm, would evidently first strike or press with greatest force on the side opposite to its own course, as the N. E. trade would on the S. W. of the cyclone, so that the track of the storm would be from S. W. to N. E.

3*rd.*—The track of a rotatory storm, when the two before-mentioned forces do not influence it, may even be occasioned by the earth's rotation, for as the revolving storm draws into its rotation the comparatively more inert air of the greater latitudes, and as gravity but slowly acquires its weak hold on the individual particles of air, the difference in their conditions allows the earth to slip under the storm, and so gives to the storm a westerly tendency as its path of progression, and this, indeed, has been found to be the track for all storms that have occurred near the equator, where the two before-mentioned forces are unable to influence them. In these progressive storms, from the greater hold that gravity has on calm air, the vortex is held back eccentrically; while the consequent compression increases the intensity of the storm in the *head* of the hurricane circles.

Contemporaneous and Consecutive Rotatory Storms.—Where the partial vacuum lies on long belts, the leading wind, from impinging on many points of it at the same time, may frequently cut it up into two or more contemporaneous cyclones, and these, if there be no differences of local pressure, may follow the same or nearly the same path of progression, interfering occasionally or even merging into one another, causing sudden and irregular changes in the direction of the storm, which may so appear in some positions to move contrary to its known laws.

Where the atmosphere surrounding the partial vacuum is in a state of stable equilibrium, the leading wind simply commences the rotation, without entering into the body of the storm, or taking any fresh air into it, so that a cyclone in progressing from one extremity of the partial vacuum to the other, leaves only as much air behind it as it takes up before it into its rotation, which leaves the partial vacuum in a measure intact, the effects of which and the previous rotatory momentum acquired by the air of the position, soon causes a second rotation to commence and to follow the first preceding cyclone, which it may eventually overtake or even pass by laterally, for the path of the progression of the second consecutive cyclone may not be on the exact track of the first preceding it, as the differences in the time of their commencement may allow some new local pressure to arise, or the effect of the earth's rotation may considerably alter the position of the belt of the partial vacuum.

The Incidental Phenomena of Rotatory Storms— Or those attending its continuance, may be enumerated as colored skies, moaning and roaring noises, pyramidical, cross and chopping seas, and low temperature.

The colored appearances of the skies are clearly due to the refraction of light caused by the large quantity of partially condensed vapour that as mist pervades the atmosphere, arising from the intermingling of the air currents of the different strata. These colored appearances, from the effects of refraction being even observable beyond the range of rotatory storms, are to be seen from great distances, so that they thus become one of the premonitary signs of its proximity or approach. The color most frequently observed within the range of a cyclone is usually red, while blue and green are the more distant effects.

The moaning noises which are generally heard at a distance, but which increase to a roar within the influence of the storm, are partly due to the oscillation of the vortex and partly to the reverberatory effect of the rotating air surrounding it, which becomes as it were a separate strata, both from being of a different density, and from being greatly imbued with moisture, so as to form banks of mist around the vortex, which, like the clouds, reverberate the noises of the storm, and these are also much augmented by the greater sonorosity of the less dense air of the partial vacuum itself,—similar in its effects to that of our chimneys, which, from holding rarified air of small density, gives out hollow moaning noises during a gale.

The pyramidical, cross, and chopping seas depend on the peculiar properties of liquids, which, from their fluid nature, are very susceptible of the smallest influences, as their adhesiveness causes the smallest force imparted to one particle, or to a portion, to be communicated and transmitted to the particles or portions of the surface before it (as owing to the incompressibility of liquids force cannot be transmitted below), causing what is known as its undulatory motion, by which the impression of a force is retained for a considerable time, and sent to a great distance with but small lateral movement or translation of the particles themselves;—we see, for instance, that a pebble, when thrown into still water, causes a series of these undulating waves to spread in circles from the spot or centre of contact, the waves increasing in extent, but losing in height as they recede from the centre. In this, however, there is no actual movement at all of the water immediately struck by the pebble, as the surrounding water to which force is imparted cannot quit the central point to move off in the radial directions, in which they are impressed, as they would leave a void, so that their motion or flow is here also restrained by the great force of atmospheric pressure: and in this force we see the cause of the inability of a shot to penetrate water when projected with great violence or rate of motion, as from a gun, for whatever tends suddenly to cause a break in the surface of the water, is opposed by the full pressure of the atmosphere, which is communicated to the water, so that it re-acts as an elastic bed, and causes the shot for instance to glance off.

But though this property of liquids prevents any such sudden impact as tends to break its surface, still force may be gradually imparted to water by the constant action of the wind in one direction as to cause great undulations of even 50 or 60 feet in height, and that without being affected by differences of pressure ; for these undulations, however great, must still be considered as the level surface of the water, as their depressions and elevations are only so far affected by atmospheric pressure as is equal to the difference of their height in the atmospheric column, which may be considered as nil while the pressure due to their differences of height is counterbalanced by the force that occasions them, or the *vis viva* or living force the undulating waves have acquired. Now these undulations must clearly always bear a strict proportion in their extent to their height, and require time for their full development, but still the constant and great action of the wind in a storm, while it increases the undulations, yet as it catches and breaks their elevations, so it partially moves the surface of the water or rather the upper particles of the undulating waves, and causes a smaller undulation over them, so that these particles, secondarily influenced, having thus a proportional greater degree of motion or flow imparted to them, may be observed as a rolling wave moving over the undulations, and is the storm wave, usually called a 'frightful sea.' As the effect of a force in producing any kind of movement must always be in the direction that it is imparted, it follows that both the undulations and the sea, caused or raised by a rototary storm, must move (as parallel) with the radii of the circle of rotation, having even a tendency towards the vortex in accordance with the nature of these storms, so that at the vortex, from the meeting of these undulations from all directions, we have the pyrimidical seas, which, though they are a good indication of the position of the centre, are still, from their irregular inclination and tendency, most dangerous, and are to be avoided, as no skill or precaution will prevent their breaking over, while their own pressure, together with that of the atmosphere added to it, makes their force irresistible, as on their breaking over, the level of the sea is affected or destroyed. At the head of the hurricane circles, which occupies the position of the vortex as the storm progresses, it is the sudden rush and great violence of the storm in opposition to the direction, both of the great undulation and storm wave raised in the preceding body of the storm that renders the sea cross and so confused, that it may well be said to 'defy description,' as mentioned in the accounts of those who have been so fortunate as to escape its perils. The chopping seas, or what may properly be so called, occur only in confined or in shallow seas, and are occasioned by the breaking of the great undulations in striking below.

Low Temperature.—This is an invariable accompaniment of a cyclone, for the weather or the wind is always described as being 'intensely cold.' This is due to the isolation of the air of the revolving storm, with reference to the air of the surrounding atmosphere, as none or very little of the comparatively warmer air, at the earth's surface of the neighboring regions, enters or mixes with that of the storm, the separated air of which, rising at the vortex, first parts with its moisture (which readily absorbes and holds caloric), and then rising to the upper strata, moves to the extremity or circumference of the storm, and having parted with its caloric by radiation, in this its passage, as the upper strata to the range, it then descends, being drawn back again into the rotation with the low temperature, which we may say it has thus acquired or been reduced to in the upper strata: and were the loss of caloric even a matter of time, the continuous exposure of air to the effects of radiation in its frequent vertical circuits would soon, it is evident, reduce the temperature of the air, and which would also become the more remarkable from the contrast when experienced after an occasional warm spell of air that may be taken up before the storm, as it progresses, or which may enter with the leading wind.

Cessation of Rotatory Storms.—This must evidently result on the extinction of the partial vacuum of the vortex, which is the life of the storm, and this can only result from the introduction of new or fresh air to supply the deficiency, and which can only be effected by a gradual withdrawal of a portion of the dense air of the leading wind as it circulates round the vortex, yielding a gradual and small supply of air, which springs into the vortex from its greater elasticity. This supply of air, however, is generally a slow process and a matter of time, for the leading wind, although it has commenced the rotation, still it has not a continuous entry into the body of the storm, for it has its own regular circuits to complete, and it is only on the progressing of the storm to a position of great density and the entrance of the leading wind as a squall, that a portion of air is obtained for supplying the deficiency of the vortex, and this, in fact, is the explanation of the experience, that squalls accompanied with rain generally precede the break-up of these storms.

Forecasting of the Weather.—With delicate instruments to inform us of the state of the atmosphere, together with our knowledge of the many natural indications that precede a change of the weather, we are frequently enabled to pronounce correctly upon the expected change. In doing this, we may reasonably be said to have acquired a fore-knowledge of the weather; but as this fore-knowledge is necessarily limited to a short previous notice of the occurrence of a change, it has never come to acquire any special importance, but from its occasional failures, has come to be a subject of jest and ridicule, for there was wanting those links that our reason required that could connect the event with its preceding effects. With our increasing knowledge, however, of the atmosphere and of the nature and causes of its movements, together with our extended means of information in the aid of Electric Telegraph, the importance of this fore-knowledge promises, in the practical results of the forecasts of Admiral Fitz-Roy, soon to be recognised if it is not so already. Beyond this, it is to be hoped that the time will soon arrive when, from our being able to watch the grand movements of our atmosphere, we shall be able to ascertain the commencement of the disturbances of the great currents of circulation, so that we may know where or in what position to expect a deficiency of air, and so be early prepared for the occurrence of a rotatory storm—the most destructive of all the phenomena of our atmosphere.

Conclusion.—It has been shown that our vast atmosphere, though apparently much complicated in its minor movement, has four great ærial currents that are the prime movers of its whole circulation ; and it has been demonstrated that these great currents result almost altogether from the effects of the earth's diurnal rotation.

At the equator, where direct centrifugal force has an evident tendency always to maintain the atmosphere at a higher elevation than that due to the power of gravity and the levelling effects of fluidity, there must result a constant overflow of air over both the tropics (or over one side alone, depending on other influences). That centrifugal force and not convection is the cause of this overflow, we cannot fail to be convinced, when we note the fact that the position of overflow is ever constant at the equator, although the isothermal line of greatest temperature is at times most remote from it, being at either tropic.

Since a constant overflow at the equator cannot always exist, without a constant source of supply, the air is partly drawn from both north and south of the equator, and at the earth's surface, by what may be considered as the mechanical draught of the action of direct centrifugal force, while it is partly sent by the action of what has been termed indirect centrifugal force, which acts by its effects on the individual particles of air, which are partly retained from their greater density acquired from low temperature at the earth's surface, along which they move as the trades.

Now we can clearly understand how the overflow from the equator by its small density acquired from high temperature would cause it to flow over the tropics as their upper current, while from their momenta they would continue onward, till they arrived at such a position where their momenta, with reference to the rate of the earth's rotation of such position, would have rendered them true westerly currents, as, in fact, they do become over the temperate regions: here, from the superior pressure of the atmosphere, occasioned by another cause, these currents are steadily caused to descend and to turn back again to supply the trades.

At the polar circles, or between 70° and 80° of latitude of both north and south, where the earth's rotation is sufficiently rapid to occasion indirect centrifugal force, the air is first caused to move along the earth's surface, as from the poles, and then as the current advances partly from the increasing effect of the indirect centrifugal force and partly from the momentum the air has already acquired, it continues in a right or straight line, and so it necessarily rises from the earth's surface, as it flies off tangentially to the outer strata of the atmosphere. These now upper currents of air, in moving towards the equator, move so far only till their very inertia, with reference to the earth's rotation, render them true easterly currents, and so arrest their further movement towards the equator. As this also occurs in the temperate regions, in close proximity to the two upper currents from the equator moving in opposite directions and with opposite tendencies, it occasions an accumulation of air, and, consequently, of pressure over those regions which causes the return of the upper currents from the equator back to the trades.

These easterly currents from the poles, as well as the westerly currents from the equator, while continually circulating in the upper strata of the atmosphere, at times descend on the temperate regions as the well known gales, and while frequently alternating with each other they are both of them laterally influenced by other causes, as an occasional insufficiency of the supplying current of the trades, or by a partial want caused by the polar emanations, thus giving occasion to the many fitful changes that characterise the climate of the temperate regions, from whence we have the proverbial '*inconstancy of the winds*' of those cooler regions of the world.

That air is affected by centrifugal force, be that force however small, we have indeed the clearest evidence, for air from its gaseous nature is certainly free to be acted upon by the smallest influence, as it is unrestrained either by gravity or by the retarding effects of friction, for we see that in its movements from one zone to another, according to the direction of its movement, the air either keeps its inertia intact, or that it retains its momentum, or the rate of motion of the position that it has left: from this we may conclude, *not* that gravity has a less proportional hold upon gaseous air, with respect to its density, than it has on liquids, but that it is deprived, from absence of friction, of the power of imparting motion to the ambient air; while liquids, from their inherent attraction of adhesion, attach their particles to one another as a portion of a mass, so that the earth's attraction affects the whole as a body, while friction restrains each particle to its own position.

The particles of liquids thus deprived of individuality can only undulate as a wave, or at most move in portions when actuated by other forces.

But though air has no actual friction within itself, yet in moving over the earth's surface, or over the sea, from contact and from the effect of the lessened densities that result behind sheltering objects, as the waves for instance, which occasion small rotations of the air, as may be seen in the crests of the waves—from these constant small deflections of its original direction of motion, the air soon comes to acquire the same rate of motion as the earth in its rotation or gravity may so be said to have resumed its small hold on the particles of the air in motion, and which thus gives to the trades, for example, their peculiar curve.

In the use of terms to express the intensities of air in motion, the inconvenience of their indiscriminate application has been alluded to, especially of the term gale, which, according to its first acceptation, should only apply as a distinguishing name to the great easterly and westerly currents of the temperate regions, for we distinguish the known superior intensities of these gales themselves similarly as the other winds and currents of the atmosphere, as the trades for instance, by the familiar designations of gentle, moderate, full, high, great, &c., while their steadiness of direction, it is evident, would ill describe those of a rotatory storm, so that correctly we should confine its use to its original application,—as the withdrawal of this word gale, from its so general use as expressing intensity alone, will occasion some uncertainty in terms and designations generally ; it would be as well here to alter what is known as Captain Beaufort's notation to meet these views.

0 For calm.
1 „ Light air.
2 „ Light breeze.
3 „ Gentle breeze.
4 „ Moderate breeze.
5 „ Good or fine breeze.
6 „ Fresh or brisk breeze.
7 „ Strong breeze or wind.
8 „ Great or stiff wind.

(With these intensities a vessel according to her build would make from the same number of knots per hour, to one, two, or three even in excess.)

9 „ High wind,—or moderate gale (if such).
10 „ Storm,—full gale,—or cyclone (if such).
11 „ Frightful storm,—tempest,—or hurricane.
12 „ Hurricane blasts as of head of hurricane circles.

Purely local terms as tornado, typhoon, &c., should clearly be dispensed with as foreign to our language, or if used, the nature of the wind, if known, should also be referred to, or the appearances described,—for a typhoon is but a cyclone, and a tornado but a thunderstorm.

Of the phenomena of our atmosphere, the rotatory movements of air, as cyclones and hurricanes, has been shown to be the natural results of the action of known physical forces, occasioned by possible occurring causes; we may now, with the knowledge we have acquired of the nature of these storms, proceed to deduce the rules or directions by which their dangers are to be practically avoided ; and to make these as clear and as concise as possible, the simplest method would be to imagine ourselves in a vessel, and in all the different positions it is possible to be with regard to these storms, and then draw our conclusions as to the best way out of them separately.

First let us imagine ourselves on the right hand side of a cyclone, with respect to its direction of progression, as represented by the large double arrow, (Fig. 9), and as having approached it from a direct or any inclined course: here, although our barometer gives us no indication of its proximity, still we are certain to perceive before us a bank of clouds (or the clouds have what is termed a lowering appearance). These we may perhaps at first have overlooked, supposing them as those of an ordinary thunderstorm ;—as we near the range, however, of the storm, our barometer will be observed (if watched) to rise a little, indicating the compression of air surrounding the cyclone, but as we enter the range itself, it will begin to fall, a sufficient indication for us to infer that we are within the confines of a rotatory storm, and here we will have either a calm with light puffs or a wind having no connection with the cyclone. Now supposing this wind to take us through the range right into the body of the storm; on entering this our barometer will increase its fall, while we experience the power and regular movements of the cyclone circles of the storm, the occasional increasing gusts of which being partly due to the irregular movements or starts of the storm in its progression and partly to the irregular descent of the drawn in air from off the range with their differing momenta. Being now certain as to the nature of the phenomena we have entered, and expecting worse weather before us, as we know our position with regard to the vortex of the storm (from the direction of the wind and our own position as regards the equator), we have next to determine the direction of the progression of the storm. This we may ascertain for ourselves certainly, but at the risk of some danger and of much delay; it were preferable rather to depend on past experience, or on the results of the laborious researches of those eminent meteorologists, who have determined the tracks of many storms in nearly all seas, and added to this, the information we have acquired from the investigation of the nature of these storms, we may risk assuming the probable direction of progression, and act accordingly. Now we know that rotatory storms occurring near the equator are apt to progress towards the west,—that those a little further removed from the equator, as to be well within the influence of the trades, generally move against the direction of those winds, or first from moving towards the poles, they curve gradually to the east,—and that when cyclones occur in the temperate zones, (from their resulting generally from the joint influence of the two leading winds of those positions, namely, the easterly and westerly gales, and from the greater intensity of the latter,) the direction of progression has almost always been found to be towards the east. Now, having assumed the direction of the progression of the storm to be as represented, and judging from the previous indications and direction of the wind, our position as regards it, that we are in or approaching the right lateral quadrant of the cyclone (as divided by the lines M, N and L, I), and knowing for certain our position as regards the vortex from the direction of the storm, and assuming its propable course of progression from our situation as regards the equator, we have to determine what tactics we should adopt, and what course we should steer,—now, we may either scud before the storm, we may heave or lie to, or we may sail right out with the wind on our beam,—and these require to be separately considered,—for to choose between them ever seems to have been a much vexed question.

To scud before the storm, so as to keep parallel with its path of progression, would, it is clear, in no way better our position, except it were our course, and then we would lose were we to keep with the storm, as a vessel sails considerably faster than it progresses, so that it is erroneous to think of ever 'profiting by a storm ;'—to continue scudding right before the storm, so that it took us into the fore-quadrant to C, would put us in danger of the possibility of the storm's progressing over us, or so far over us, as to endanger our falling through the vortex into the head of the hurricane circles; besides, were we mistaken as to the assumed direction of the storm's progression, for supposing it were exactly the opposite way, so, to keep before the wind would lead us directly into the after-quadrant of the storm, where, if we have not the strength of the hurricane circles, we would have the frightful broken seas of that position to encounter.

To heave to in a storm is always objectionable, as it is very dangerous, for the storm in progressing must eventually leave us in some portion of the after quadrant, where we would have to battle with our worst enemy, the uncertain sea, which no skill or management will ever prevent their breaking over us; in fact, to lie to at all (except in confined seas or channels, where we at times have no other resource,) is but trusting ourselves to fate, and we then certainly deserve to suffer, for in all our affairs we must ever help ourselves, even though we may not doubt that many have been and will be in mercy saved. We have then but one course left to keep right out of the storm, taking the wind on our beam and running with the lengths of the undulations and seas, or end on over them, and though these in their appearance ever seem most threatening, still they will generally run clear under our keel. And indeed this is the wisest course which even our prudence tells us is the best, as it leads us direct from danger and all unnecessary risk, for even were we to be mistaken in the direction of the track, and the storm were progressing towards us instead of laterally past us, the fact would before long be evident to us, so that, being now in the fore-quadrant of the storm, we should act accordingly to the altered circumstances of position, which will be presently considered, remarking, however, that all that has been said of the right lateral quadrant applies equally as well to the opposite or the left lateral quadrant of the storm, which we may also unguardedly enter, as similarly we have but little or no premonitory indications to warn us off. So we may say, that as a rule for all lateral positions, we should always keep straight out at right angles to the supposed direction of the storm's progression, and by strictly adhering to this rule, we shall see that we are likely to gain further advantages, especially when we have to encounter contiguous storms, as will be hereafter illustrated and explained.

We may now consider our position as before a cyclone, or as approaching the point c in its fore-quadrant, and from any direction,—if the storm is progressing up a belt of partial vacuum, we shall then certainly have the indication of a low barometer to warn us, and judging from this circumstance, that our position is before the storm, and assuming its probable direction of approach, we may first endeavor, if we have any wind, to move out of the belt of the partial vacuum by striking across it ; but it were preferable to wait the first movements of the cyclone, after we have past the range, as its direction assures us of our position, and then to keep off by scudding directly before the storm, altering our trim for it as it veers, but steadily keeping to its circuit till we find ourselves, from the bearing of our course, that we were on the lateral quadrant of the cyclone, from which, as our starting position, we could always command or weather the storm by keeping away or by going off at right angles to the track with the wind on our beam.

With reference to the after-quadrant of a storm, should our course be such as would take us into it, (although our barometer may not perhaps give us any indication of its proximity, as the storm in progression may have left sufficient air to supply the deficiency,) we, however, would certainly have a rather disagreeable though clear indication of our proximity to the after-quadrant of the storm, in the cross and broken sea, left by the passing of the head of the hurricane circles (as caused by the meeting the old and opposite undulations of the fore-quadrant of the cyclone). With this clear warning before us, and with our knowledge of its cause, it would be far rom wisdom on our part were we to stand further in, for we should certainly run into the violence of the hurricane itself, and it will be bad enough as it is, and as many have experienced, for we often have heard 'of such seas being met with, and with scarcely any wind at all, as were enough to shake the masts out of the vessel.' Here we have the option of two courses left us, either to sail directly back, or in the direction opposite that of the storm's progression, or to stand off at right angles to the track, and round to the lateral quadrant, the starting position, where we should soon make better weather, as it is technically said.

But though the avoidance of a single cyclone, when we are sure of its position and the direction of its progression, requires but ordinary skill and management, yet were we to encounter two contemporaneous rotatory storms (which are of frequent occurrence in the temperate regions), we shall have both what appears to be erroneous indications, and winds that move contrary to their known directions, so that we should certainly be baffled or rendered at least uncertain in our movements, and unless made aware of the existence at the same time of these distinct and separate cyclones, we should most likely, in our endeavors to escape, run into the very danger we would avoid. To illustrate this, let us suppose ourselves at E, as represented in Fig. 10, moving on our course to F, here, being on the track of the cyclone X, with the storm from the south or nearly so, our barometer low, and supposing we even conjectured so far aright, that we were on the margin of a cyclone, but of whose track we are necessarily uncertain, and were to scud before the storm on our course, it being fair, as it is technically called, and having, as we moved out of its influence, first a calm in the range, and then uncertain winds, till at G we suddenly find a storm from the opposite quarter, namely, from the west. From this we might easily be led to imagine that we had passed clean through a cyclone, for we have had a sudden shift of the storm to nearly opposite quarters while we have been through a broken confused sea (caused by the opposing undulations occasioned by the contiguous storms), and with less wind, as of a vortex: so that, were we to act on this supposition, we would naturally hold on to our course, and so run right into the head of the hurricane circles of the progressing storm before us.

Now were we fully to examine the circumstances of the case, (leaving at present out of consideration the fact of the apparent direction of rotation being contrary to the known law of storms for the position,) we would see that we were wrong when we found ourselves on the margin of the rotatory storm X, and as most probably on its fore-quadrant (from the indications), in preferring to keep our course to adhering to the direction or rule to seek the starting point of the lateral quadrant, where we would have clearly ascertained the existence of the first storm and our position as regards it, while we would as well have determined its nature and its track, so that were we to move round to H and start off on our course, then, were we to find the wind change from east to west or north, with a confused and heavy sea, we would then certainly be assured that we were entering the confines of a second rotatory storm before us: and here from our having an exact knowledge of our position, and the confidence which such knowledge imparts, we may easily avoid this new danger, either by keeping off to the south-west and so gradually round to our course again, or we may in preference even sail with this second contemporaneous storm, and then scud right round, as the probabilities are that we should then have a fair wind to continue our course.

In this and many other similar cases much however must always be left to the talent and skill of the navigator, who should draw his conclusions from the circumstances of the position in which he found himself situated, and who should, from his knowledge of their nature, feel his way as it were out of the dangers of these storms.

It may be as well here to caution that in estimating the bearing of the vortex of rotatory storms, we should be careful to allow for the great vorticular inclination of squalls, as they frequently run through the cyclone circles into those of the hurricane, while we should always take into consideration the smaller inclination (Fig. 11) from the constant inward movement of the air from over the range, which will be most apparent in the outer cyclone circles.

Although, as shown, it were advisable always to keep away from rotatory storms with as much sail as it is possible to carry, still it may be unavoidably necessary, in confined seas or narrow channels, to lie or heave to till the storm has progressed past. In doing this, however, we should first endeavor, if possible, to place ourselves so that the centre of the storm should pass between us and either shore, and that we be on the side where we would have most sea room, and this we could do by the rules previously given for the avoidance of these storms, and so, having placed ourselves as we ought into the lateral quadrant, we might lie with our head as direct from the centre as it is possible, or the qualities of our vessel will permit, and there, rather than deaden our way completely, it were even advisable so to proportion the spread of our canvas drawing ahead to that holding us aback, that we should always be forging somewhat ahead, which would be taking us comparatively into finer weather, or into the less intense cyclone circles of the rotating storm, while it would give us a greater command over the vessel itself. In keeping the storm as full on our beam as possible we never need fear being headed by it in its veerings, as, except after passing the centre, the shifting of the storm is never so great or sudden but would allow us to keep our position or bearing as regards it. In this also we run the less chance of being damaged by the sea, as the less or rather the shorter surface we show to the undulations and seas, as regards their direction of motion, the less they are likely to break over us; if cranky, however, we run some risk, certainly, of rolling disagreeably or 'our yards even into the water,' but we would more easily escape being injured from the striking or the breaking over of the seas, for we would rise the more easily with the undulations or waves, as being part of them, and which would so roll clear under us.

What part electricity, the condensation of moisture, and the escape of latent coloric may play in our atmosphere and in the phenomena of cyclones is yet but a matter of conjecture; they most probably compensate the effects of one another, for were the effect of the condensation of moisture to increase the partial vacuum, as is generally supposed, cyclones would be more lasting phenomena; and until our advancing knowledge enables us to determine their exact influences, it were sufficient to consider both electricity and aqueous vapour simple appendages of our atmosphere, as they are more probably the effects or results themselves, rather than the causes of atmospheric disturbances.

That the cessation of rotatory storms may be due to collapse appears possible, as the similar phenomena of whirlwinds apparently conclude from that cause, for after the commencement of rotation the air surrounding the vortex may often be observed from the dust that accompanies it to increase in intensity of rotation, while it spreads from the centre from the effects of centrifugal force. This must clearly produce an excessive diminution of pressure at the centre or vortex, which causes the collapse, and which is evident in the sudden cessation of the rotation, and in the broken or driven in appearance of the dust accompanying the whirlwind.

To avoid the dangers of a gale or tempest, or to move out of their influence and strength, we must singularly adopt the same rule as in avoiding the centre of a rotatory storm, for as gales and tempests are confined to a zone or a belt of latitude, we have but to keep at right angles to its direction either way, to lessen its intensity, as this course, it is evident, would take us out of its influence; but as we may be mistaken as to the nature of the storm, as from its apparent steadiness of direction it may form part of a rotatory storm of large diameter, in appearance as a gale from the west in the temperate zones, we should steer for the equator for both hemispheres, while oppositely with a gale from the east, we should lay our heads towards the Poles. When the trades or monsoons rise in strength or intensity as to become stormy, in desiring to move out of their influence, we should in like manner steer from them as if they formed part of a rotatory storm.

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Fig. 1.

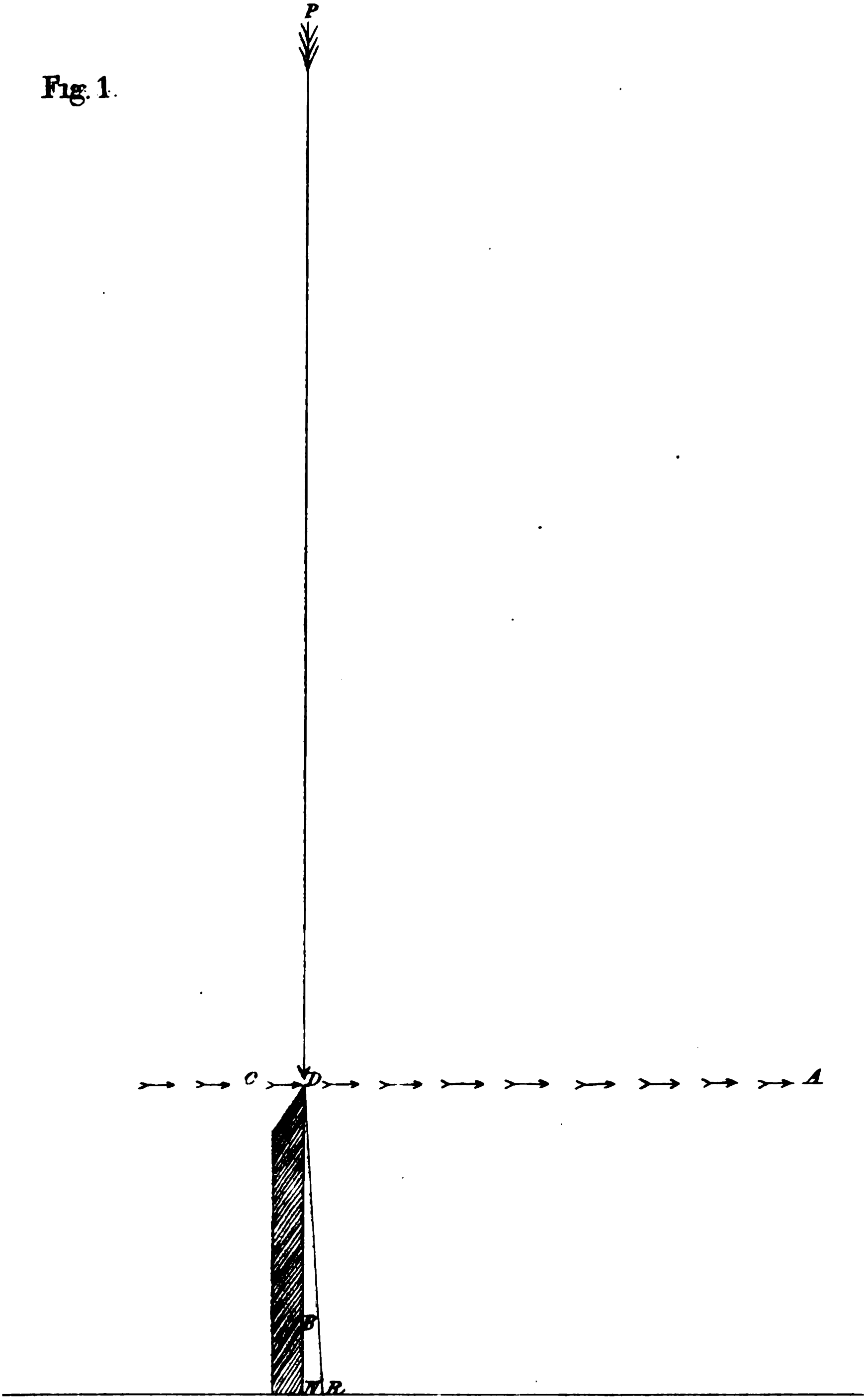


Fig. 2

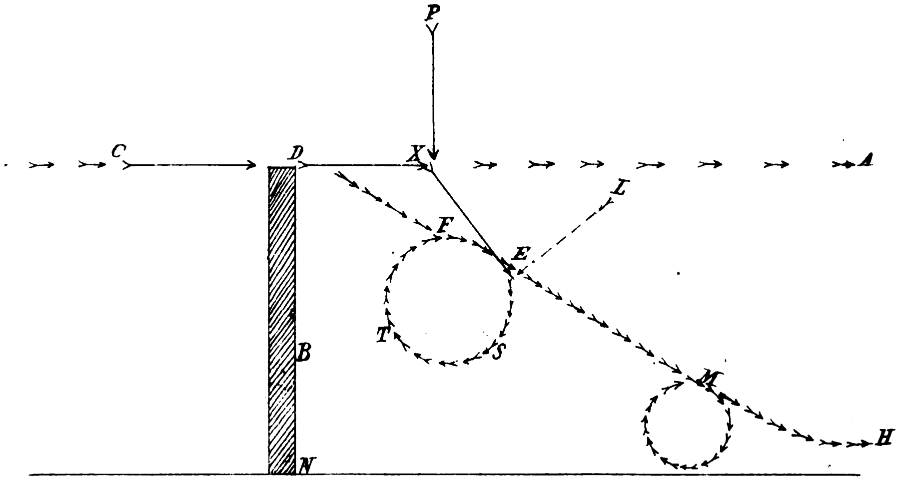


Fig 3.

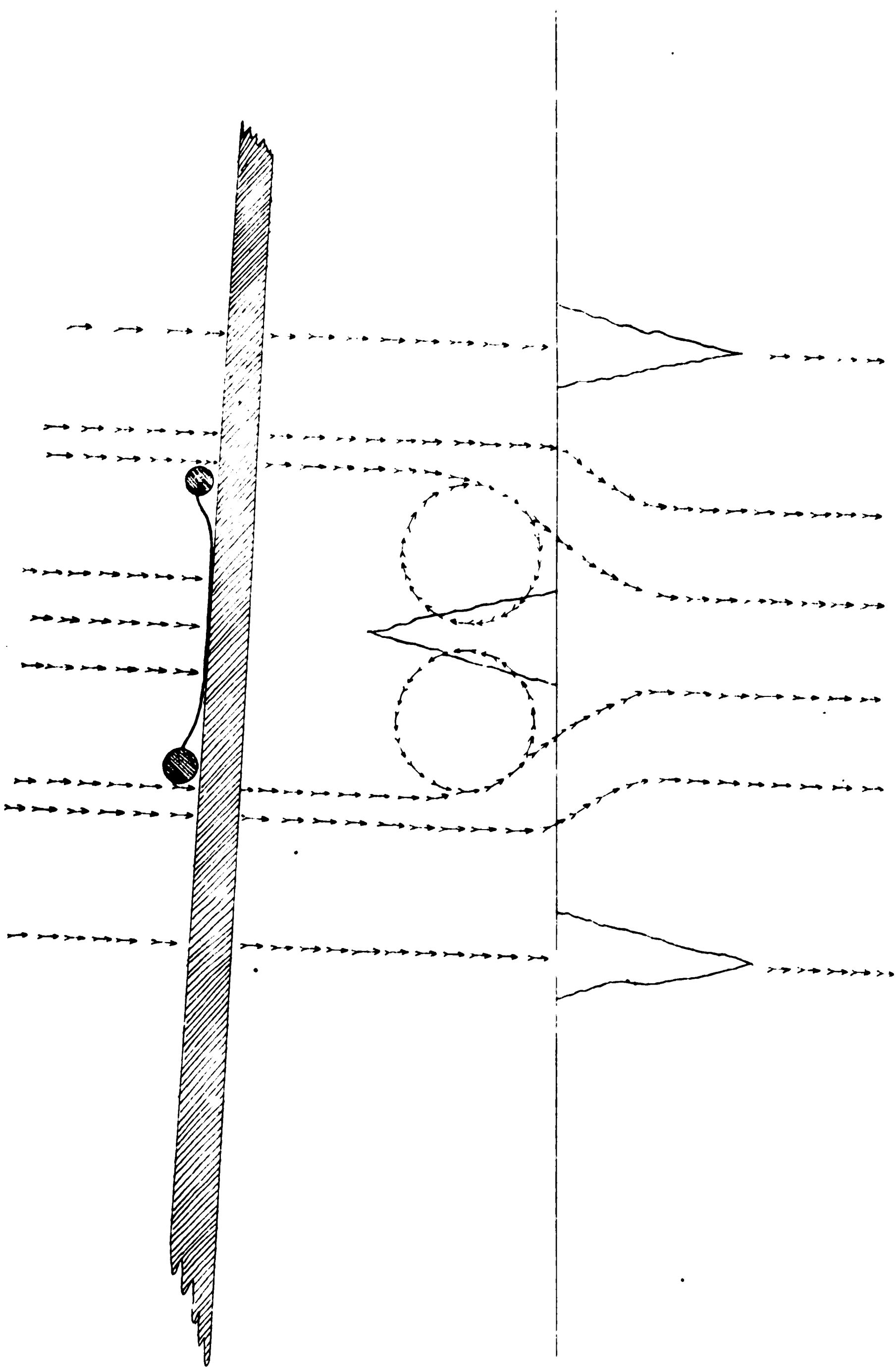


Fig. 4.

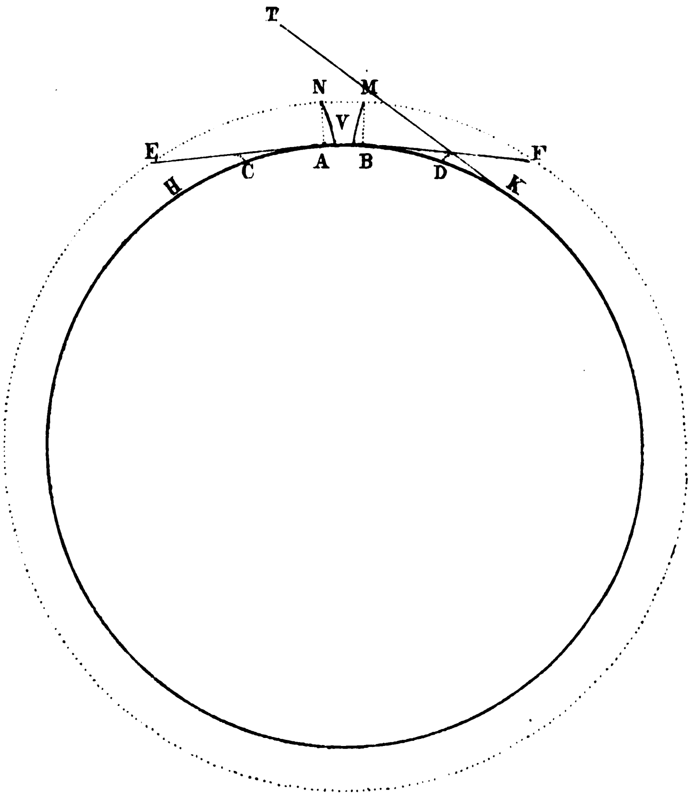


Fig. 5.

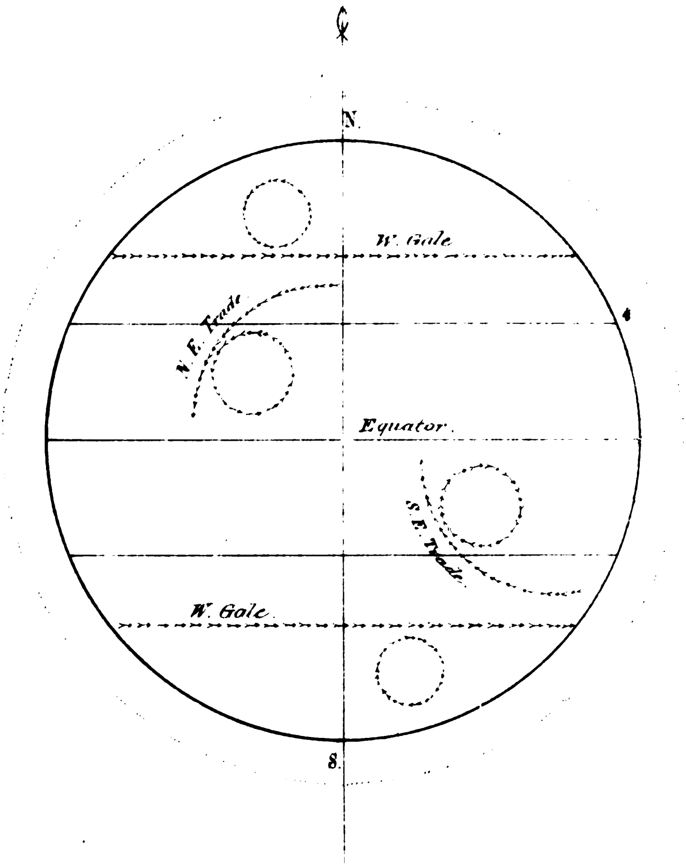


Fig. 6.

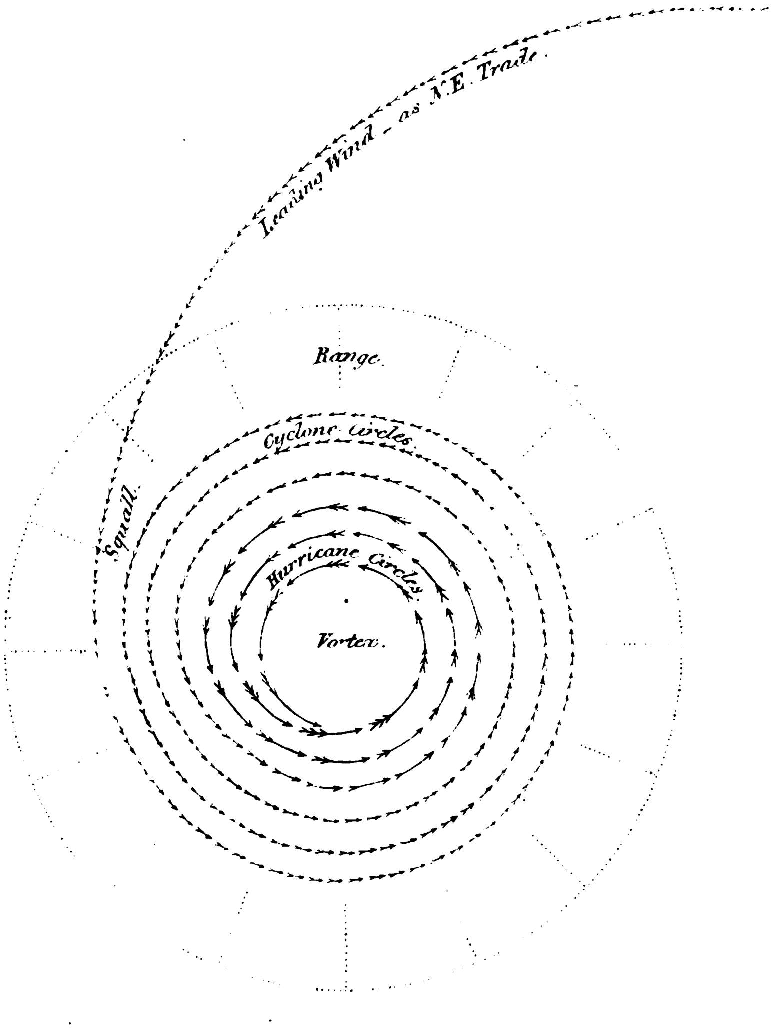

Leading Wind - as N.E. Trade.
Range.
Squall.
Cyclone circles.
Hurricane Circles.
Vortex.

Fig. 7.

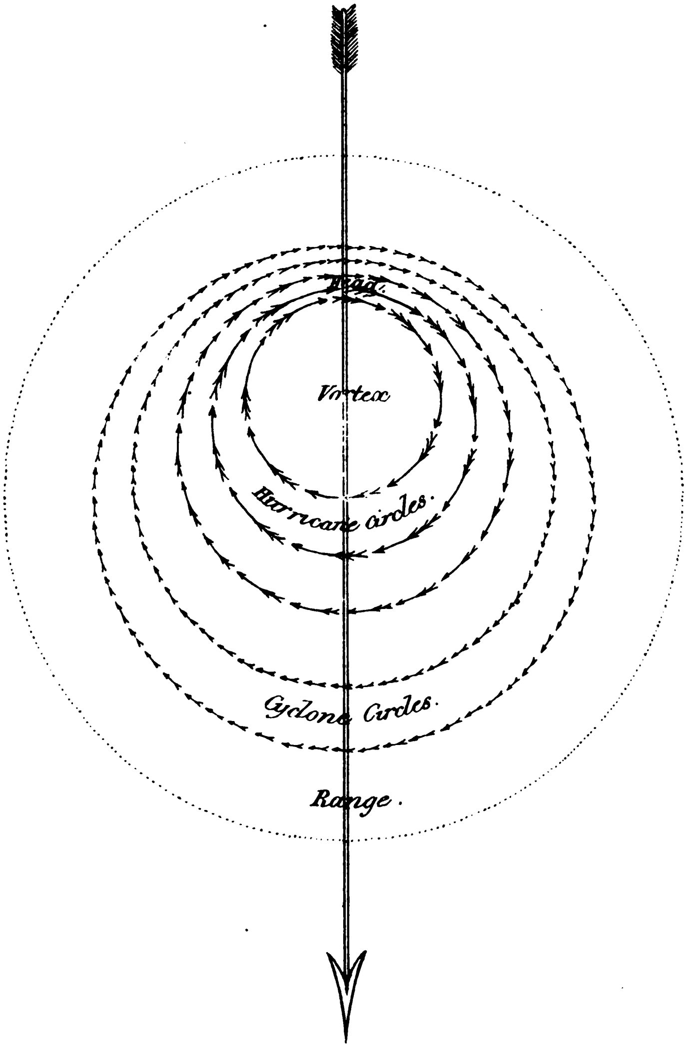


Fig. 8.

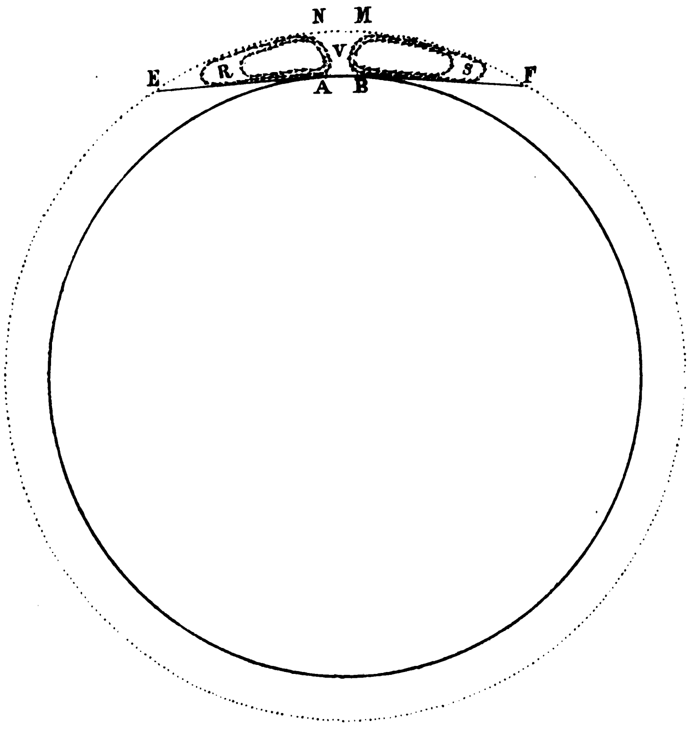


Fig: 9.

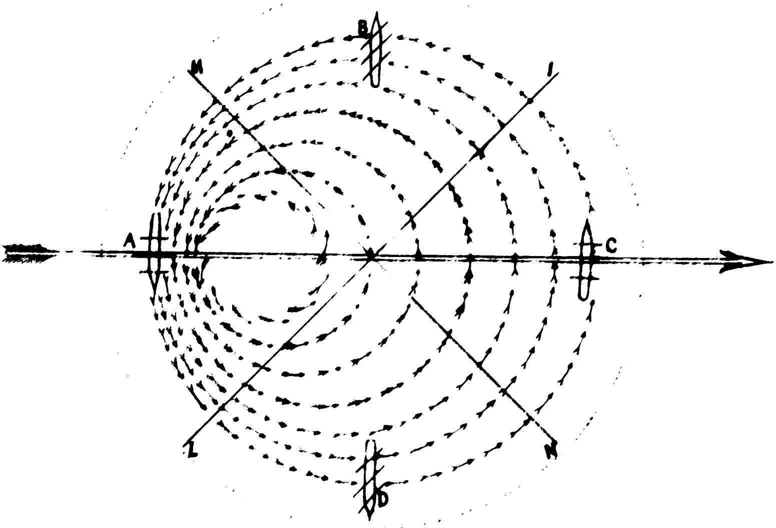


Fig: 10.

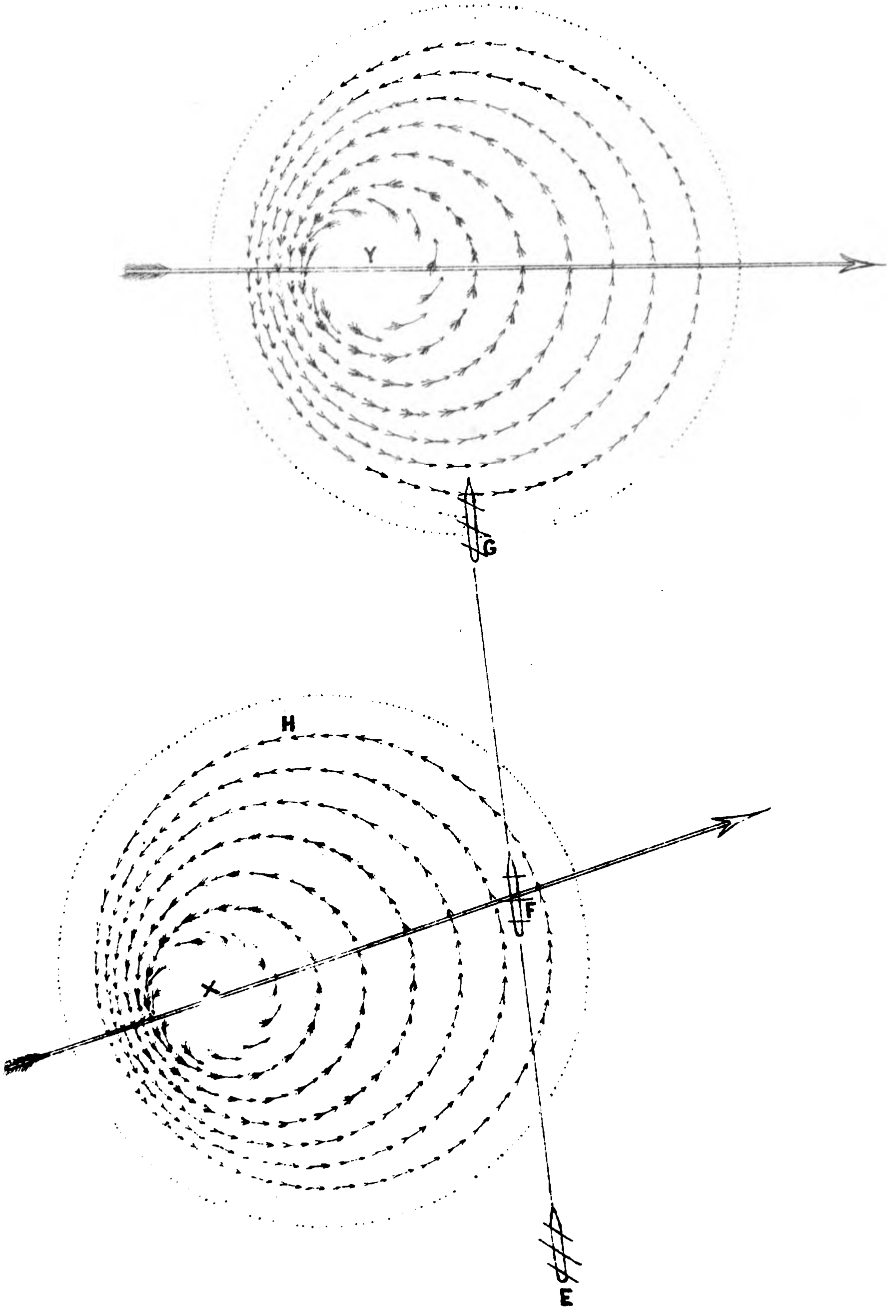
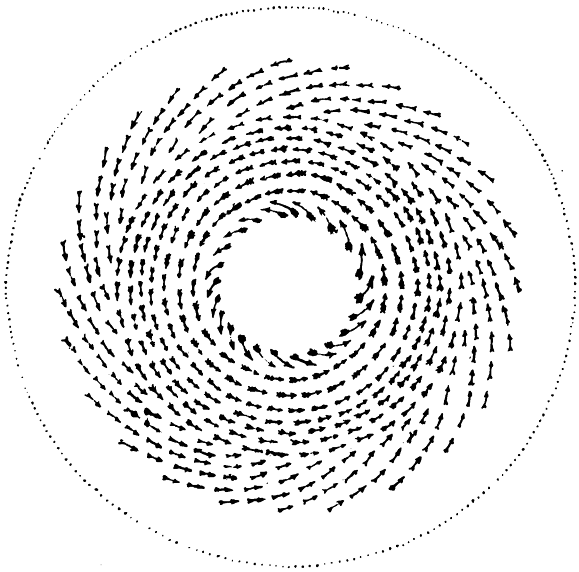


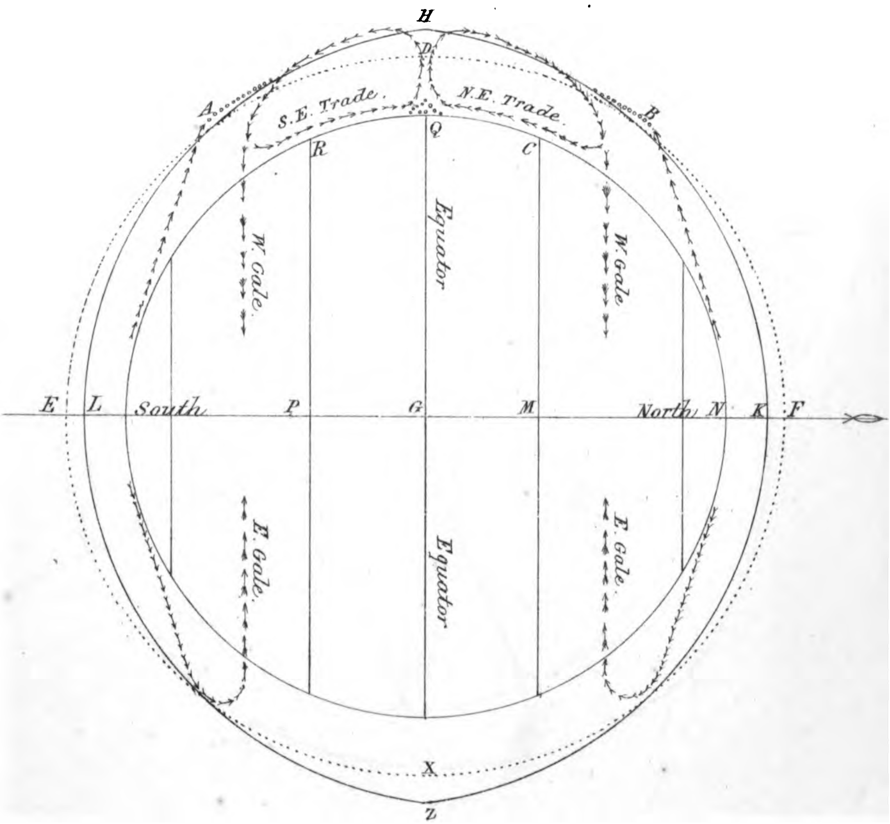
Fig. 11



Wind Chart.

No 1.

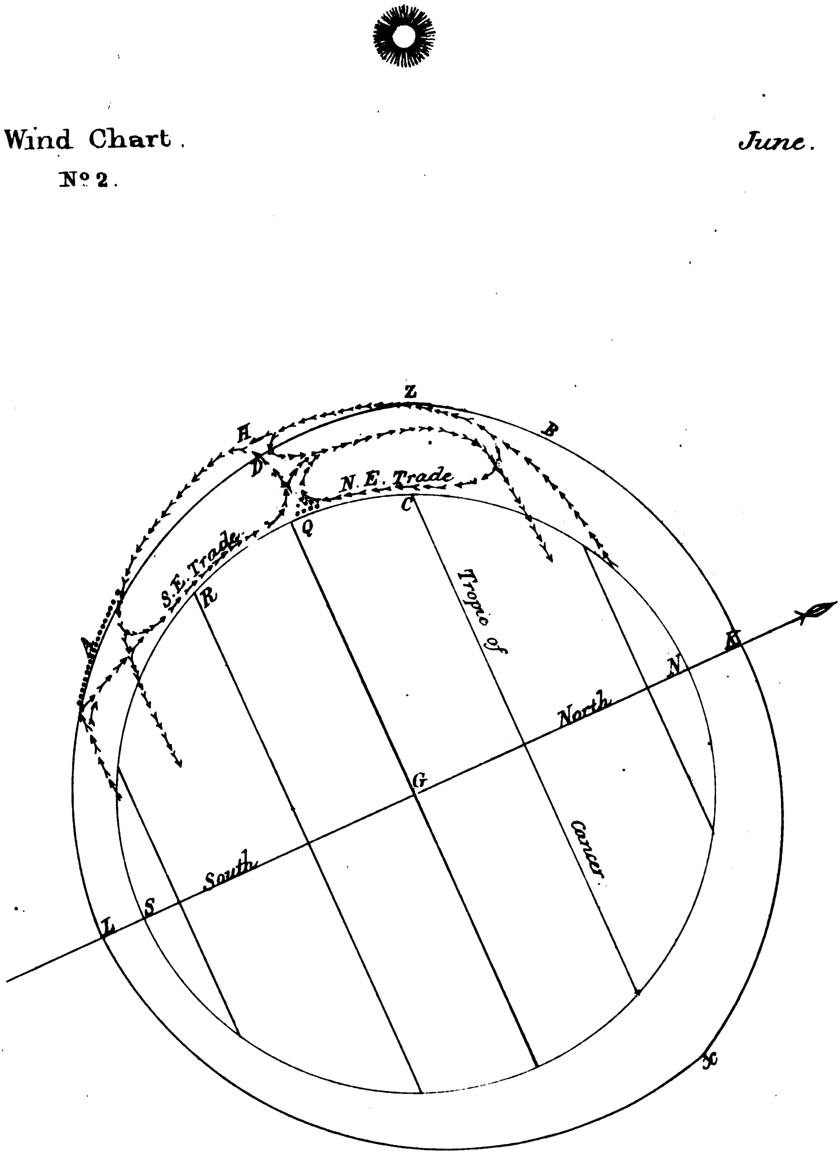
March & September.



Wind Chart.

No. 2.

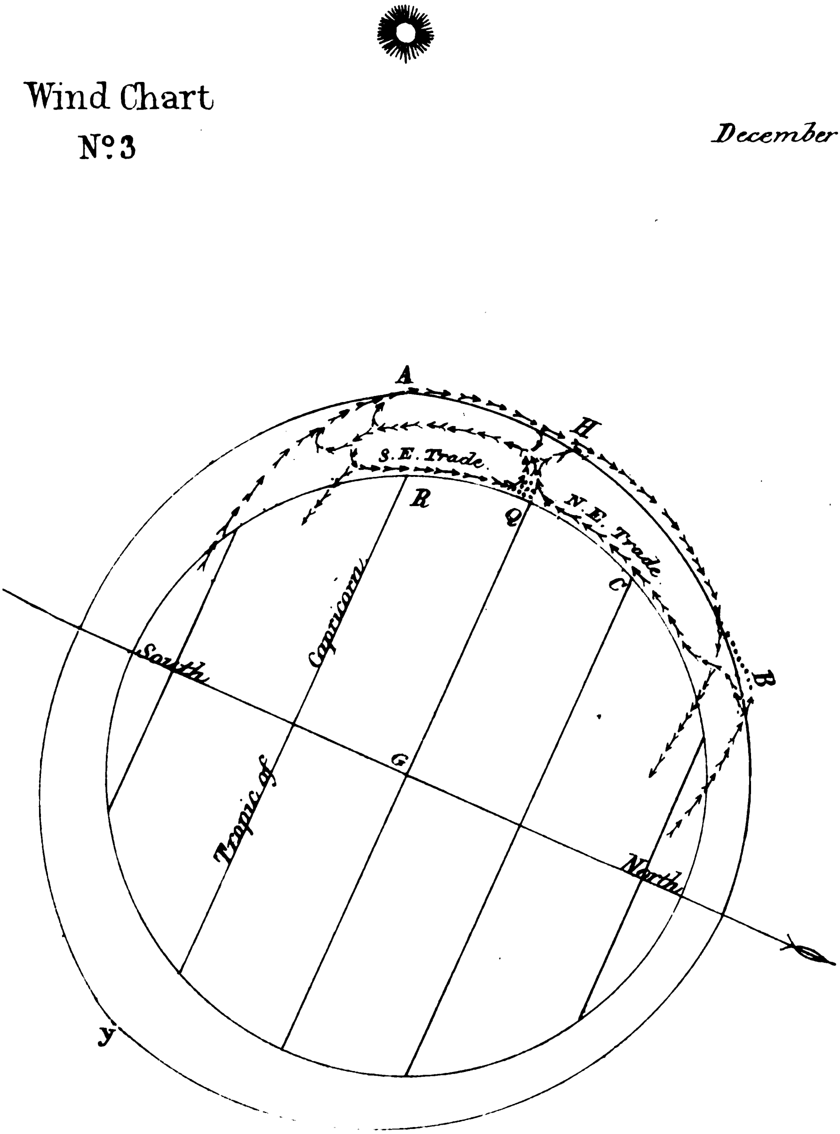
June.



Wind Chart

No. 3

December.



Wind Chart.

No. 4.

June.