

hills separated by valleys, there is rarely any difference in their height. The more I observe the contours and elevations of hills, I am the more convinced of the correspondence of their angles, and of their resemblance to the channels and banks of rivers. It was the repeated observation of this surprising regularity and resemblance that first suggested the idea of the theory of the earth which I am now supporting. When to this are added the parallelism of the strata, and the shells so universally incorporated with different materials, no subject of this nature can admit of a greater degree of probability.

P R O O F S

OF THE

THEORY OF THE EARTH.

ARTICLE XIV.

Of Regular Winds.

IN our climates, nothing can appear to be more capricious and irregular than the force and direction of the winds. But there are some countries where this irregularity is not so great, and others where the wind blows constantly in the same direction, and with nearly the same degree of force.

Though the motions of the air depend on many causes; yet there are some more constant and powerful than others. But it is difficult to estimate their precise effects, because these are often modified by secondary causes.

The heat of the sun is the most powerful cause of winds: It produces a considerable and successive

successive rarefaction in the different parts of the atmosphere, and gives rise to an east-wind, which blows constantly between the Tropics, where the rarefaction is greatest.

The force of the sun's attraction upon the atmosphere, and even that of the moon, are inconsiderable, when compared with the cause just mentioned. This force, it is true, produces a motion in the air similar to that of the tides in the sea: But, though the air is elastic, and 800 times lighter than water, the motion produced by attraction cannot exceed what is excited in the waters of the ocean by the same cause; for the action of gravity being proportioned to the quantity of matter, it must elevate a sea of water, of air, or of quicksilver, nearly to the same height. Hence the influence of the planets upon the air must be inconsiderable*; and, though it must occasion a slight motion from east to west, this motion becomes altogether insensible when compared with that produced by the heat of the sun: But as the rarefaction is always greatest when the sun is in the zenith, the current of air must follow the course of the sun, and produce a constant wind from east to west. At sea, this wind blows perpetually in the Torrid Zone, and at land, in most

* See *Reflections sur la Cause Generale des Vents*, par M. D'Alcembert.

places

places between the Tropics. It is this wind which we perceive when the sun rises; and, in general, east winds are more frequent, and more violent, than west winds. The general wind, from east to west, extends even beyond the Tropics. It blows so constantly in the Pacific ocean, that the ships coming from Acapulco to the Philippines, perform their voyage, which is more than 2700 leagues, without the least danger, and almost without the necessity of being directed. In the Atlantic, between Africa and Brasil, this wind is equally constant. It is likewise felt between the Philippines and Africa; but there it is less constant, on account of the obstacles it meets with from the numerous islands in that sea; for it blows, during the months of January, February, March and April, between the Mozambique coast and India; but it gives place to other winds during the rest of the year: And, though it is less perceptible on the coasts than on the open sea, and still less in the interior parts of continents than on the coasts, yet, in some places, it blows almost perpetually, as on the east coasts of Brasil, of Loango in Africa, &c.

This wind is constant under the Line; and, therefore, in going from Europe to America, mariners direct their course southward, along the coasts of Spain and Africa, till they come within 20 degrees of the Equator, where they fall in with the east, or trade-wind, which carries

ries them directly to the coast of America. By means of the same wind, the voyage from Acapulco to the Philippines is performed in two months; but the return from the Philippines to Acapulco is much more difficult, and requires a longer time. About 28 or 30 degrees on this side of the Line, the west wind is equally constant; and, for this reason, the vessels returning from the West Indies to Europe, observe not the same route as in going out. Those from New Spain run north along the coast till they arrive at the Havannah, in the island of Cuba; and from thence they proceed northward till they fall in with the west wind, which carries them to the Azores, and then to Spain. In the same manner, vessels returning by the South Sea from the Philippines or China, to Peru or Mexico, sail north as far as Japan; and, under that latitude, they proceed till they arrive at a certain distance from California; and from thence, following the coast of New Spain, they reach Acapulco. These east winds blow not always from the same point; but, in general, they blow from the south-east, from April to September, and from the north-east from November to April.

The east wind, by its constant action, augments the general motion of the sea from east to west. It also produces perpetual currents, some of them running from east to west, and others from east to south east, or north-west, according to the direction of the eminences, or chains

chains of mountains, below the surface: The valleys or intervals between them serve as channels to these sea-rivers. The variable winds which blow sometimes from the east, and sometimes from the south, likewise produce currents, which change their direction with that of the wind.

The winds that blow constantly for some months are commonly succeeded by contrary winds, which oblige the mariner to wait for that which is most favourable to his destination. When these winds change, they often produce, for several days, and sometimes for a month, or even two months, a perfect calm, or dreadful tempests.

These general winds, occasioned by the rarefaction of the atmosphere, are variously combined and modified by different causes, and in different climates. In that part of the Atlantic which lies under the Temperate Zone, the north wind blows almost constantly during the months of October, November, December, and January. These months, therefore, are most favourable for ships going to the Indies, which are carried over the Line by this wind: And it is a well known fact, that vessels which depart from Europe in March, frequently arrive not sooner at Brazil than those which set out in the following October. The north wind reigns almost perpetually, during the winter, off Nova Zembla, and other northern coasts. At Cape de Verd, the

south wind blows, during the month of July, which is the rainy season, or winter, in that climate. At the Cape of Good Hope, the north-west wind blows during the month of September: The same wind blows at Patna in the East Indies, during the months of November, December, and January, and occasions great rains; but the east wind prevails during the other nine months. In the Indian Ocean, between Africa and India, and as far as the Molucca islands, the trade-wind from east to west reigns from January to the beginning of June; the west winds begin in August or September; and, in the interval between June and July, there are dreadful tempests, generally from the north winds; but these winds are more variable on the coasts than in the open seas.

In the kingdom of Guzarat, and upon the neighbouring coasts, the north winds blow from March to September; and, during the other months, the south winds almost always prevail. The Dutch, in returning from Java, set out in January or February, by the assistance of the east wind, which is felt as far as the 18th degree of south latitude; and then they meet with south winds, which carry them to St. Helena*.

Some regular winds are produced by the melting of the snows. This was remarked by the ancient Greeks. During summer, a north-east wind, and a south-east one during winter,

* See Varin. Geogr. cap. 26.

was observed to take place in Thracia, in Macedonia, in the Egean Sea, and even in Egypt and Africa; and winds of the same kind have been remarked in Congo, at Guzarat, and at the extremity of Africa, which are all occasioned by the melting of the snows. Regular winds, which last but a few hours, are also produced by the motion of the tides; and, in many places, as on the coasts of New Spain, of Congo, of Cuba, &c. a wind blows from the land during the night, and from the sea during the day.

The north winds are equally regular within the polar circles; but they become more and more imperceptible as we approach the Equator: This remark is applicable to both poles.

In the Atlantic and Ethiopic ocean, within the tropics, an east wind blows during the whole year, without any considerable variation, except in some small spots, where it changes according to the situation of coasts, and other circumstances: 1st, Near the coast of Africa, and about the 28th degree of north latitude, vessels are certain of finding a fresh gale from the north-east, or north-north-east, which accompanies them to the 10th degree of the same latitude, about 100 leagues from the coast of Guinea; and at the 4th degree of north latitude, they meet with calms and tornado's. 2^d, In going by the Caribbee islands, this wind turns more and more easterly, in proportion as vessels approach the American coast. 3^d, The

limits of these variable winds, in the Atlantic, are more extensive upon the coasts of America than upon those of Africa. Along the coast of Guinea, from Sierra Leona to the island of St. Thomas, an extent of about 500 leagues, there is a perpetual south, or south-west wind. The narrowest part of the Atlantic is from the coast of Guinea to Brasil, where it is not above 500 leagues over. Vessels, however, that depart from Guinea, are obliged to shape their course southward, especially when they set out in the months of July or August, in order to fall in with the south-east winds, which blow constantly during this season*.

In the Mediterranean, the east wind blows from the land in the evening, and the west wind from the sea in the morning. The south wind, which is accompanied with rain, and blows commonly during the latter end of autumn, at Paris, in Burgundy, and Champagne, yields to a mild north-east wind, which produces that fine weather vulgarly called Saint Martin's Summer†.

Doctor Lister alledges, that the east wind, which reigns during the whole year between the tropics is occasioned by the transpiration of the plant called the *sea-lentil*, which abounds in these climates; and that the difference of land-winds is owing to the different situation of trees

* See Phil. Transf. Abridg. vol. ii. p. 129.

† See Traité de eaux de M. Mariotte.

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and forests. This ridiculous whim he assigns as the cause of the winds; and, in his opinion, the wind is strongest at mid-day, because the transpiration from plants is then greatest; and the wind, continues he, blows from east to west, because all plants are, in some measure, sun-flowers, and transpire most from the side opposed to the sun*.

Other authors have assigned the diurnal motion of the earth as the cause of this east wind. This notion is specious: But every man, who has the least knowledge of physics, must allow, that no fluid which surrounds the earth can be affected by its rotation; that the air must move along with the earth itself; and that the rotatory motion is equally imperceptible in the atmosphere as on the surface of the earth.

The principal cause of the winds, as already remarked, is the heat of the sun†; for, whatever rarifies or condenses the air, must produce a wind, or current, in a direction opposite to those places where the rarefaction or condensation is greatest.

The pressure of clouds, exhalations from the earth, the explosion of meteors, rains, &c. likewise produce considerable agitations in the atmosphere. Each of these causes, when variously combined, produce different effects. As it is in vain to attempt a complete theory of the winds, I confine myself to their history.

* See Phil. Transf. No. 156.

† See Halley's Treatise on this subject in the Phil. Transf.

If we had a series of observations upon the direction, the force, and the variations of the winds in the different climates of the earth, and if these observations were sufficiently numerous and exact, we might be enabled to form more complete ideas with regard to the causes of the different changes in the atmosphere.

The winds are more regular at sea than upon land; because their motion is not interrupted. But, upon land, the direction is frequently changed by the interposition of mountains, forests, cities, and other obstacles. Winds are often reflected from mountains with a force nearly equal to that of their original current: These winds are exceedingly irregular, because their direction depends on the contour, the height, and the situation of the mountains from which they rebound. The sea-winds also blow with more force and uniformity, and last longer: The land-winds, however violent, have intermissions, and moments of repose: But, at sea, the current of the air, having no obstacles to contend with, is uniform and perpetual.

At sea, the east winds, and those which come from the Poles, are generally stronger than the west winds, and those that proceed from the Equator. But, at land, the south and west winds are more or less violent, according to the different situation of particular countries. During spring and autumn, the winds, both at sea and land, are more violent than in summer or winter,

ter. For this fact, several reasons may be assigned:

1. In spring and autumn the tides are highest; and, consequently, the winds they excite are most violent during these seasons: 2. The motion produced in the atmosphere by the action of the sun and moon, or the tides of the air, must likewise be greatest about the equinoxes: 3. The melting of the snows in spring, and the condensation of the vapours exhaled in summer by the sun, and which fall down in the autumn in the form of rain, produce, or, at least, augment the force of the winds: 4. The transition from heat to cold, or from cold to heat, must create considerable augmentation and diminution in the volume of the air, which alone is sufficient to raise great winds.

Contrary currents in the atmosphere have often been remarked. We see some clouds moving in one direction, and others, either above or below them, proceeding in a direction perfectly opposite. This contrariety of motion never continues long; because its general cause is the resistance of some large cloud, which reflects the wind in a direction opposite to its natural course, but is soon dissipated.

The winds are more violent in proportion to the elevation of the ground, till it arrive at the ordinary station of the clouds, which is about one-fourth or one-third of a league perpendicular height; and, beyond this, the sky is generally serene, especially in summer, and the wind gradually

gradually diminishes: It is even said to be altogether imperceptible on the tops of the highest mountains. However, as the summits of these mountains are covered with ice and snow, it is natural to think that this region of the air is agitated during the fall of the snows, and that the winds are imperceptible in the summer season only. The light vapours which are raised in summer fall in the form of dews; but, in winter, they are condensed, and fall on the tops of the mountains in the form of snow or ice, which may raise considerable winds at that altitude.

The celerity of a current of air is augmented when its passage is contracted. The same wind, which is but slightly felt in a large open plain, becomes violent in its progress through a narrow pass in a mountain, or between two high houses; and it is most violent at the tops of the buildings or of the mountain, because the air, being compressed by these obstacles, is augmented both in volume and density; and, as its celerity remains the same, its force or momentum must be increased. It is for this reason that the wind appears to be more violent near a church or a tower than at a distance from them. I have often remarked, that the wind reflected from a building standing by itself, is stronger than the direct wind by which it was produced. This effect can be owing to no other cause than the compression of the air against the building from which it rebounds.

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As the density of the air is greatest at the surface of the earth, it is natural to conclude, that the wind must there also be most violent; and this conclusion is, I apprehend, just, when the sky is serene: But, when it is charged with clouds, the action of the wind will be most violent at the height of the clouds, which are denser than air, as they fall in the form of rain or of hail. In computing the force of wind, therefore, we ought to estimate not only its velocity, but likewise the density of the air; for two winds, of equal velocities, may differ greatly in their force, if the densities of the air be unequal. From this remark, we may learn the imperfection of those machines which have been employed for measuring the velocity of the winds.

Particular winds, whether they be direct or reflected, are more violent than those which are general. The interrupted action of land-winds depends on the compression of the air, which renders every blast more violent than if the current were uniform. A uniformly continued stream of air produces not such havoc as the fury of those winds which blow, as it were, by paroxysms. But of this we shall treat more fully in the next article.

The winds, in their various directions, may be considered under general points of view, from which, perhaps, some useful deductions may be drawn. For example, the winds may be divided into Zones. The east wind, which extends

extends 25 or 30 degrees on each side of the Equator, exerts its force round the globe within the Torrid Zone. The north wind blows with equal constancy in both the Frigid Zones. Thus, the east wind occupies the Torrid Zone, and the north wind the Frigid Zones. With regard to the Temperate Zones, the winds peculiar to them may be considered only as currents of air, produced by the combination of the two principal winds, which give rise to all those that come from the eastern points; and the west winds, which are common in the Temperate Zones, both in the Pacific and Atlantic Oceans, may be considered as reflections from the continents of Asia and America, but deriving their origin principally from the east and north winds.

Though we have said, that, generally speaking, the east wind blows round the globe 25 or 30 degrees on each side the Equator; yet it must be acknowledged that, in some places, it extends not so far, and that its direction is not throughout from east to west; for, on this side of the Equator, it is east-north-east, and, beyond the Equator, it is east-south-east; and, the more we recede from the Equator, its direction is the more oblique. The Equator is the line under which the direction of the wind from east to west is most exact. In the Indian Ocean, for example, the general wind from east to west extends not above 15 degrees beyond the Equator. In going from Goa to the Cape of Good Hope,

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this wind is not felt beyond the 12th degree of south latitude, nor is it perceptible on this side of the Equator. But, after arriving at the 12th degree of south latitude, this wind continues to the 28th degree. In the sea which separates Africa from America, there is an interval from the 4th degree of north latitude to the 10th or 11th of south latitude, where this general wind is not perceived. But, beyond the 10th or 11th degree, it extends to the 30th.

There are likewise many deviations in the trade-winds, which have an alternate motion. Some continue for a longer or shorter time; others have a greater or lesser extent; others are more or less regular, and more or less violent. The following, according to Varenus, are the principal phenomena of these winds: ' In the ocean between Africa and India, and as far as the Molucca islands, the east wind commences in January, and continues to the beginning of June. In the month of August, the west wind begins, and continues for three or four months. In the interval between these trade-winds, which is from the end of June to the beginning of August, the sea is infested with violent tempests from the north.

' These winds are subject to the greatest variations near the coasts: Vessels cannot take their departure from the coast of Malabar, and other ports on the west coast of the peninsula of India, to Africa, Arabia, or Persia, but from

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' the month of January to April or May; for,
' at the end of May, and during the months of
' June, July, and August, the tempests from
' the north and north-east are so violent, that
' no ships can keep the seas. But, on the
' other side of this peninsula, in the sea which
' washes the coast of Coromandel, there are no
' tempests of this kind.

' Vessels depart from Java, Ceylon, and several other places, for the Molucca's in September, because the west wind begins then to blow in these regions. However, when 15 degrees south of the Equator, this wind ceases, and they fall in with the trade-wind, which, in this place, blows from the south-east. In the same manner, vessels depart from Cochin for Malacca in March; because, at this time, the west wind begins to blow. Thus the west winds arise at different times, in different parts of the Indian Ocean. The times of departure are different from Java to the Molucca's, from Cochin to Malacca, from Malacca to China, and from China to Japan.

' At Banda, the west winds terminate at the end of March; calm and variable winds occupy the month of April; and the east winds begin with great violence in May. At Ceylon, the west winds commence about the middle of March, and continue to the beginning of October, when the east, or rather east-north-east winds, return. At Madagascar, they have
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' north or north-west winds from the middle
' of April to the end of May; but east and
' south winds in February and March. From
' Madagascar to the Cape of Good Hope, the
' northerly winds prevail during the months of
' March and April. In the gulf of Bengal, after the 20th of April, the south winds blow with violence; and, before this period, the south-west and north-west winds prevail. The westerly winds are also violent in the Chinese sea during the months of June and July. This is, therefore, the most proper season for sailing from China to Japan: But, in returning from Japan to China, February and March are preferable, because the easterly winds then prevail.

' There are some winds which may be considered as peculiar to certain coasts: For example, a south wind blows almost perpetually on the coasts of Chili and Peru. It begins about the 46th degree of south latitude, and extends beyond Panama, which makes the voyage from Lima to Panama more easy and expeditious than the return. The westerly winds blow almost continually on the coasts of Magellan's land, in the neighbourhood of the straits of La Maire. Upon the Malabar coast, they have almost constantly north and north-west winds. The north wind is very frequent on the coast of Guinea. The westerly winds
' reign

' reign upon the coasts of Japan during the months of November and December.'

The periodic, or alternate winds, mentioned above, are peculiar to the sea. But, upon land there are also periodic winds, which return at certain seasons or particular days, or even at stated hours. On the coast of Malabar, for example, an easterly land-wind blows from September to April: It generally commences at midnight, and ends at noon; and it is not perceptible at 12 or 15 leagues from the coast. From noon to midnight, there is a gentle westerly breeze from the sea. Upon the coasts of New Spain in America, and upon those of Congo in Africa, land-winds blow during the night, and sea-winds during the day. Winds blow from all the coasts of Jamaica during the night, which prevents the landing, or sailing of ships, with safety, before the rising of the sun.

In winter, the port of Cochin is inaccessible; neither can any vessel get out; because the winds are so impetuous, that no vessels can keep the sea; and, besides, the west wind, which blows with great fury, drives such a quantity of sand into the mouth of the river, as renders it impossible for ships of any burthen to enter it for six months of the year. But the east wind, which blows during the other six months, drives back the sand into the sea, and opens the mouth of the river. At the straits of Babelmandel, there is a south-east wind, which is regularly succeeded

ceeded by the north-east. At Saint Domingo, there are two different winds that rise regularly every day; the one, which is from the sea, comes from the east, and begins at 10 o'clock before noon; the other, which is a land-wind, from the west, rises at 6 or 7 in the evening, and continues the whole night. Other facts of this kind, collected from voyagers of knowledge and credit, might furnish a complete history of the winds, which would be a work extremely useful both in navigation and physics.