

THE LAW OF STORMS.

AT one time it was a just reproach, not only to ourselves, but to our continental brethren, that the laws which regulate the succession of atmospheric phenomena were very imperfectly known. A want of precise observation, imperfect instruments, and limited data, led to crude theories; and till the closing years of the last century, meteorology could not be said to rank among the sciences. The transition period is of very recent date, and were it not foreign to our present purpose, its development might become an interesting inquiry. In the seventeenth century we would find the master minds of Boyle, Torricelli, and Pascal, opening the portals of the temple. In the eighteenth a goodly phalanx, small in numbers, but renowned in strength, enters the shrine, overturning ancient speculations, and placing pneumatic chemistry upon a sure foundation. About the same time we find the acute astronomer, Halley, watching the return of that most gorgeous meteor by which the illustrious Gassendi transmitted to posterity a name, and accurately describing its fantastic appearance in the polar sky. A few years thereafter another branch is made the subject of special study, and Franklin clothes its truths in language modest and perspicuous. Dalton, with his unwearied observations, profound reasonings, and deep sagacity, links the past with the present century; Wells comes next, following in the footsteps of the immortal Bacon, and giving to us and to future generations investigations beautiful for their simplicity and inductive reasoning. Not to mention others over whose loss we mourn, nor the living—not to gather up a host of continental savants, whose very names are precious—not to dwell upon the past, but to look forward with aspirations to the future—not to seek an exposition of a science so extensive, nor to ramble over a field so wide, but to confine our attention to a special department of meteorology—let us approach the subject of the law of storms.

Though 'the wind bloweth where it listeth,' it nevertheless follows, with singular regularity, a prescribed course. Towards the equator, and for some degrees on either side, the wind is constant—that is, always blowing in the same direction—between the western shores of Africa and the eastern coast of America. In the Pacific Ocean, however, it does not blow without a rival, though we find the same eastern wind blowing from Panama to the Philippines and Australia, and from Sumatra to the eastern

shores of that continent whence we started. In this wide expanse of waters the periodical monsoons are found.

These constant winds, from the facilities which they afford to commerce, have been denominated *trade-winds*; and their steady, gentle zephyrs are delightful. By the mariner who spreads all his canvas, and by the invalid who seeks a more genial clime, these breezes are equally sought for. Far different in character, however, are the Indian *monsoons*. Signalled in the sky by portentous clouds, they make their advent in the awful grandeur of a tropical thunderstorm. The wind blows in gusts, the lightning flashes incessantly, the thunder roars with a sound which cannot be expressed in any language, and rain falls in torrents. The face of nature is entirely changed: but when the swollen streams have subsided, the sky cleared, and the wind steadily set in, there is a delightful freshness around, and luxuriant vegetation covers the ground. The period of the monsoons draws to a close, and retires as it came, amid another display of stormy gusts, rains, and lightnings.

That these constant and periodical winds follow a fixed law, is clearly shown by their regularity. What that law is, we will briefly endeavour to explain. The trade-winds owe their constancy to the united action of the solar rays and the earth's rotation, as has been pointed out by Hadley. The heat imparted by the vertical beams of a tropical sun causes a constantly-ascending aërial current, and this leads to a continued flow of colder particles from the temperate regions to supply their place. But the increased velocity of the surface of the earth towards the equator is ill adapted to these molecules acquiring a corresponding speed: they are unable, in fact, to gain this increased celerity, and in obedience to mechanical principles they assume a westerly motion. The north-east monsoon is similarly explicable, but the south-west monsoon arises from the want of balance produced from the rarefaction of the air over the Asiatic continent when the sun is in northern declination.

Beyond the region of these winds, those which have been termed *variable* or *erratic* are met with; and though their veerings seem capricious, doubtless they, too, follow certain laws. Of these unsteady winds the south-west and the north-east prevail during the greater portion of the year, and by their conflict Professor Dove of Berlin has explained the production of the others. The ascending current produced by the trade-winds diverges at a certain height to either pole, that in the northern hemisphere taking a westerly direction, and, about the 30th parallel of latitude, sinking lower in the atmosphere, giving rise to our south-west winds. The north-east wind, which is frequent in April and May, arises from the flow of particles southward to replace the heated air over the Atlantic, caused by the approach of the sun to the summer solstice.

When these variable winds veer round the compass, it has been remarked by Dove that they usually follow a certain course—namely, from E. to W. by S. in the northern hemisphere, and from E. to W. by N. in the southern hemisphere. This is his law of rotation (*Gesetz der Drehung*), to which, however, there are exceptions. Hence it follows that in northern latitudes the warm wind is generally followed by a colder one on the western side of the compass, and the reverse on the opposite side; and, as a farther consequence, that the thermometer falls while the

barometer rises, and *vice versâ*, during the veerings of the wind round the wind-rose.

Though these are the winds which characterise the regions of our globe, there are others which occasionally blow in certain parallels. To these it is our intention to draw particular attention—we refer specially to the *hurricane* and *typhoon*. In many respects they are similar, but the geographical boundaries of the typhoon are more limited than those of the hurricane. Both are revolving, progressive, and impetuous tempests; but the typhoon is met with only in the Chinese seas between lat. 10° and 30° N., and from the coast of China to long. 150° E.

Like 'coming events' which 'cast their shadows before,' these awful storms are indicated by signs of strange and unwelcome appearance. The air is sultry, and in the lower regions deceptively calm, while in the horizon a bank of vapour is seen rising.

——— 'Deep in a cloudy speck
Compressed, the mighty tempest brooding dwells.'

Above, the clouds scud on; perchance a singularly-luminous spot appears in the zenith—the storm's eye, or *el ojo* of the Spaniard; and if at sea, there is a preternatural aspect in the horizon, as if a dark and lofty wall encompassed the observer, and that not far off; there is a universal gloom, in which the whole of nature participates, and from which the animal creation shrinks. Now a deep sound is heard, and the voice of the gale exceeds that of the thunder; lightnings flash; the wind strengthens till few can withstand its horizontal force; rain falls in torrents, and at sea it is mingled with spray. The noble ship heaves upon the billows, lying-to or scudding before the storm, and becoming unmanageable; the sea is agitated peculiarly, like a boiling caldron, rising and falling without an onward motion. On land the strongest trees are prostrated, and the works of human art totter and fall. Meanwhile the barometer has been rapidly falling; but when the centre of the gale has passed, the mercury remounts the tube. The wind veers round the compass, and lulls itself to rest. But the duties of the wearied mariner are not over; the ship still labours in a heavy sea, and strains from the violence of the rolling; some repair the rigging, others the tattered sails, while the carpenter perchance works upon a broken rudder, or fits a jury-mast. 'They that go down to the sea in ships, that do business in great waters—these see the works of Jehovah, and his wonders in the deep.'

At the beginning of the present century, attention was drawn by Colonel Capper* to the gyratory phenomena of the hurricane, and about the same time Dove† was studying the law of rotation of variable winds in temperate climates. The interesting investigations of our countryman do not seem to have impressed the minds of those who were in a position to pursue the inquiry. At length, after an interval of several years, the subject was taken up by Mr Redfield,‡ in America, and has been carried down to the present

* Observations on Winds and Monsoons, Illustrated with Chart. 4to. London: 1801.

† Poggendorff's Annalen der Physik, &c.

‡ Silliman's American Journal of Science—*passim*.

time with praiseworthy zeal and great ability. The rotative character and progressive motion of several Atlantic storms led him to the happy generalisation, *that these tempests are whirlstorms blowing in a determined direction, and advancing along a curved axis from the equator to the pole.* While Mr Redfield was thus pursuing this interesting investigation, our countryman, Lieutenant-Colonel Reid, was similarly occupied. A destructive hurricane which traversed the western Atlantic in 1831 led him to direct his attention to these awful visitations, and since then he has been accumulating facts in support of theory. Before noticing, however, the excellent treatise which Colonel Reid has recently published, let us glance at the labours of his predecessor and coadjutor:—

A West Indian hurricane which blew at St Thomas on the 12th of August 1830, at midnight, and after sweeping along the coast of Florida died away to the south of Newfoundland, afforded Mr Redfield interesting materials for a valuable memoir, 'On the Prevailing Storms of the Atlantic Coast of the North American States.' This hurricane, and one which followed it on the 22d, were very remarkable tempests. The former blew to the north-west of San Domingo on the 13th, reached the Bahamas on the following day, and the coast of Florida on the 15th. There its track made a sharp turn, and assuming a north-easterly direction, the hurricane passed Charleston in South Carolina, and blew to the south of New York on the 17th. With accelerated speed it reached Nova Scotia upon the 18th, and was south of St Pierre on the following day. With a projection before us, we have measured its path over a space of 3000 miles. Along this track it moved at the rate of about 500 miles per diem, enduring violently for twelve hours, and in a milder degree for a longer period, at the different places over which it passed. The hurricane of the 22d moved within the track of the one just described. It appeared to the north of Turk's Island, and passed north-east of the great Bahama bank on the 23d, between which day and the 24th it curved in a north-easterly direction, and on the 26th it blew south of Halifax, and east of New York.

In the same month of the following year another hurricane, more awful in its devastations than either of those mentioned, blew in the same seas—furnishing Mr Redfield with elements for a second memoir and chart. This hurricane, which began in the Barbadoes on the 10th, transforming that island into a desert, passed to America, destroying property valued at half a million, and causing the death of 5000 individuals. In the Barbadoes no fewer than 1477 persons perished within seven hours! It advanced to St Vincent at the rate of ten nautical miles per hour, preceded by a cloud in the north of singularly threatening aspect and olive-green colour. At that island serious injuries were sustained, and many trees at the northern extremity of an extensive forest were *killed*, apparently by electricity, without being blown down. It crossed over Cuba on the 14th, and reached New Orleans on the 16th, having moved over 2300 miles, at the rate of 383 miles daily.

So graphic is the description of this remarkable tempest from a Bridgetown paper, that we do not hesitate to place it before our readers.* At

* Colonel Reid—Attempt to Develop the Law of Storms, 1838.

the Barbadoes, ' after midnight the continued flashing of the lightning was awfully grand, and a gale blew fiercely from the north and north-east; but at one A. M. on the 11th of August, the tempestuous rage of the wind increased; the storm, which at one time blew from the north-east, suddenly shifted from that quarter, and burst from the north-west and intermediate points. The upper regions were from this time illuminated by incessant lightning, but the quivering sheet of blaze was surpassed in brilliancy by the darts of the electric fire which were exploded in every direction. A little after two, the astounding roar of the hurricane which rushed from the north-west cannot be described by language. About three, the wind occasionally abated, but intervening gusts proceeded from the south-west, the west, and west-north-west, with accumulated fury.

' The lightning also having ceased for a few moments only at a time, the blackness in which the town was enveloped was inexpressibly awful. Fiery meteors were presently seen falling from the heavens—one in particular, of a globular form, and a deep-red hue, was observed by the writer to descend perpendicularly from a vast height. It evidently fell by its specific gravity, and was not shot or propelled by any extraneous force. On approaching the earth with accelerated motion, it assumed a dazzling whiteness and an elongated form, and dashing to the ground, it splashed around in the same manner as melted metal would have done, and was instantly extinct. A few minutes after the appearance of this phenomenon, the deafening noise of the wind sank to a distant roar, and the lightning, which from midnight had flashed and darted forkedly with few and but momentary intermissions, now, for a space of nearly half a minute, played frightfully between the clouds and the earth. The vast body of vapour appeared to touch the houses, and issued downwards flaming blazes, which were nimbly returned from the earth upward.

' The moment after this singular alternation of lightning, the hurricane again burst from the western points with violence prodigious beyond description, hurling before it thousands of missiles, the fragments of every unsheltered structure of human art. The strongest houses were caused to vibrate to their foundations, and the surface of the very earth trembled as the destroyer raged over it. No thunder was at any time distinctly heard. The horrible roar and yelling of the wind; the noise of the ocean, whose frightful waves threatened the town with the destruction of all that the other elements might spare; the clattering of tiles; the falling of roofs and walls; and the combination of a thousand other sounds, formed a hideous and appalling din. No adequate idea of the sensations which then distracted and confounded the faculties can properly be conveyed to those who were distant from the scene of terror.

' After five o'clock the storm, now and then for a few moments abating, made clearly audible the falling of tiles and building materials which by the last gust had probably been carried to a lofty height. As soon as dawn rendered outward objects visible, the writer proceeded to the wharf. The rain was driven with such force as to injure the skin. The prospect was majestic beyond description. The gigantic waves rolling onwards seemed as if they would defy all obstruction; yet as they broke over the careenage they seemed to be lost, the surface of it being entirely covered with floating wrecks of every description. It was an undulating body of lumber—

shingles, staves, barrels, trusses of hay, and every kind of merchandise of a buoyant nature. Two vessels only were afloat within the pier, but numbers could be seen which had been capsized, or thrown on their beam-ends in shallow water. On reaching the summit of the cathedral tower, a grand but distressing picture of ruin presented itself around. The whole face of the country was laid waste—no signs of vegetation were apparent except here and there small patches of a sickly green. The surface of the ground appeared as if fire had run through the land, scorching and burning up the productions of the earth. The few remaining trees, stripped of the boughs and foliage, wore a cold and wintry aspect, and the numerous seats in the environs of Bridgetown, formerly concealed amid thick groves, were now exposed and in ruins.'

Returning to the labours of Mr Redfield, we now find him deducing from a number of observations the grand phenomena of these rotary winds, and establishing the principal directions of the hurricane.* In another paper † he furnishes practical rules to the seaman, notices the peculiarity of rotation and progression in the southern hemisphere, and gives projections of several tempests anterior to 1836.

We now arrive at the time when Colonel Reid published his first work on the 'Law of Storms,' but upon it we will not dwell. We may venture, however, to sketch an outline of the volume. After some preliminary matter he describes in his fifth chapter three hurricanes of 1837, and gives charts of their course. The first of these is the Barbadoes storm of July 26th, which blew in the Gulf of Florida on the 30th, and assuming a north-easterly direction, passed over the eastern coast of the United States; the second is the Antigua tempest of the 31st of the same month; and the third, that of the 12th of August. In the sixth and seventh chapters he describes the storms of southern latitudes, and the Chinese typhoons. In the eighth he gives an interesting account of the rotary gale of the 3d of October 1780, and of 'the great hurricane' of the 10th of the same month. The former of these crossed Jamaica and Cuba, and died away to the south of Newfoundland. The other began upon the night of the 10th at the Barbadoes, where it raged with exceeding fury. It is calculated that upwards of 4000 persons perished by this storm, and that property worth considerably above a million was destroyed. Three British ships of war, having a complement of 376 guns, were wrecked. Leaving the Barbadoes, this hurricane chiefly affected St Lucia, St Vincent, and Martinique; while Antigua on the north, and Grenada on the south of its track, felt it but slightly. Having passed over Haiti, the storm became northerly at Turk's Island, and bent to the north-east, blowing somewhat out of the ordinary region of West Indian hurricanes. The concluding chapters contain valuable information of a miscellaneous character, with the practical application of the law of rotation to the purposes of navigation.

At the time when Colonel Reid communicated the results of his early labours in this new field of investigation, he saw the importance of tracing the tracks of tempests in the Indian Ocean, and suggested to the Court of Directors of the East India Company that steps should be taken to accom-

* Blunt's Coast Pilot, twelfth edition.

† United States Navigation Magazine.

plish this object. Instructions were accordingly transmitted to our possessions in the East; and Mr Piddington of Calcutta entered upon the task of collating the logs and projecting the hurricanes, the records of which were transmitted to him; and no one can over-estimate the value of the Horn-Book which he has since then published. It is with pleasure we find that this valuable work has recently been translated into the French language by M. Bousquet of the Mauritius.* Having mentioned the work of Mr Piddington, it behoves us also to refer to the labours of Mr Thom,† in the same quarter of our globe; but of them more hereafter.

Having thus rapidly noticed the labours of meteorologists in this interesting inquiry, we beg to call the reader's attention to the second and most recent work of Colonel Reid.‡ And in passing its chapters individually in review, we feel that we address the landsman disadvantageously. The practical character of the volume in its application to navigation has led the author to use technicalities which may sometimes puzzle those who are not familiar with seafaring terms. In this, however, the benefit more than compensates for the evil, as he speaks home to the mariner in his own language, and the frequent appeal to the log-book of the ship has somewhat required a rigid adherence to the sententious and often terse expressions of the original.

The first and second chapters embody the principles of revolving gales, and the attending barometric oscillations. In both hemispheres these devastating tempests are characterised by a double motion, and in the early stage of their passage over a particular spot by a falling barometer. They are vast whirlwinds advancing towards the poles obliquely, but blowing in opposite directions in the two hemispheres, though following a determinate course in each. Beginning to blow about the 15th degree of northern latitude, the tropical hurricane advances along an axis directed to the north-west, till it approaches the 25th or 30th parallel. It then changes its direction to the north-east, slackening its speed while making the detour, and moving on obliquely, it is lost about the 55th degree of latitude. Looking at projections of these hurricanes in the Western Atlantic, the eye observes a striking resemblance to the parabolic curve, its focus being near the Bermudas. A remarkable exception to this, the ordinary course of the West Indian hurricane, took place in 1847. Upon the 10th of October a rotary gale was encountered in lat. 12° N., and long. 54° W., about a degree north of Tobago, and eight to the east of that island. It crossed Tobago on the night of the 11th—12th, passed on to Margarita in lat. 11°, and advancing to Venezuela and La Guyra, was lost.§ Similar instances have been met with among the typhoons of China; but in no case has the whirlstorm crossed the equator. 'It is not probable,' says Colonel Reid, 'that storms would continue to move on towards the equator and pass it; they would either subside, or change their direction. We cannot conceive a rotary storm

* *Lois des Tempêtes, ou Guide du Navigateur.*

† *Nature and Course of Storms in the Indian Ocean.* 8vo.

‡ *The Progress of the Development of the Law of Storms, and of Variable Winds.* London: 1849.

§ *Progress of the Development of the Law of Storms*, p. 172.

to pass the equator without subsiding, since the mode of revolution would be reversed.'

Turning now to the Indian Ocean in southern parallels, we find the analogy preserved, but the direction of the wind reversed. Blowing as before from the east, the hurricane advances at first to the south-west, and if followed through its progressive path, it will be found recurving and moving towards the south pole obliquely by the south-east. As the West Indies was found to be the focus of northern hurricanes, so in the southern hemisphere the focus of the storm is met with about the Mauritius and Rodriguez Islands to the east of Madagascar. This is well shown in the work of Thom already alluded to, and in the projections of rotary gales in the Physical Atlas.

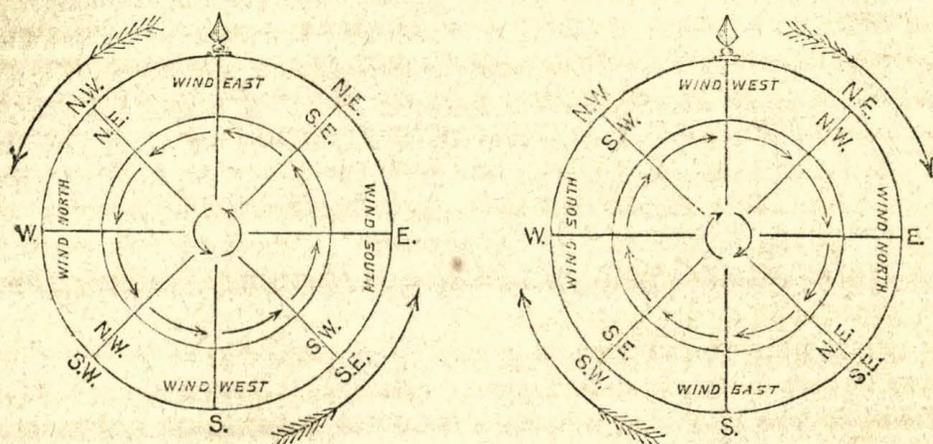
The rate at which hurricanes move along this parabolic curve is variable. The same storm even acquires different velocities. The motion is a compound one, and its speed is the mean velocity of progression and rotation. Mr Piddington calculates the progressive movement at from three to thirty-nine miles an hour in the Bay of Bengal, and from seven to twenty-four miles in the China Seas. The first hurricane of August 1830 in the West Indies advanced at the rate of 500 miles per diem; the Barbadoes storm of 1831 moved over 2300 miles at the rate of 383 miles daily; the Rodriguez hurricane of 1843, so well described by Mr Thom, progressed at the rate of about 220 miles near the equator, and only 50 miles as it approached the tropic of Capricorn; the Malabar storm of April 1847 advanced at the rate of about 13 miles an hour, slackening to 9 miles in the same time; and to furnish another illustration, the tempest of November 28, 1838, described by Mr Milne, passed over our own country at the rate of about 20 miles an hour.

It must not be overlooked that the rate of progression of a hurricane is by no means the actual velocity of the wind. Although it may be traversing the globe at ten miles an hour, the wind, meanwhile, is sweeping round at from fifty to a hundred miles in the same time. Just in proportion to this rotary velocity will be the force or horizontal pressure of the wind; and this will be greatest when the direction of the wind in the whirl coincides with the axis of progression, and feeblest at the opposite quarter.

Having thus noticed the onward motion of the hurricane, let us consider its rotary movements. We have described the storm as a great whirlwind, revolving by fixed laws. In the northern hemisphere the direction of the wind is from east-by-north to west, and from west-by-south to east, or contrary to the movement of a watch-handle—the reverse of what takes place south of the equator. In the southern hemisphere the rotation is from east-by-south to west, and from west-by-north to east. This is a great principle to be borne in mind in tracing the path of a rotary gale.

As a consequence of this law of rotation, we find that in the northern hemisphere, with the needle pointing to the pole, the wind is east; that it blows from the north at the western cardinal point, from the west at the south, and from the south at the east—the same order being preserved through the intermediate points of the compass. In the southern hemisphere the resemblance is found, but inverted. Thus the wind is west in the north, south in the west, east in the south, and north in the east. The direction of the wind, supposing the whirl to be circular, is thus eight

points, or 90 degrees, from the points of the mariner's compass. This will be better understood by referring to the following diagram:—



Were the hurricane stationary, or could one keep ahead of its progression, the wind would always blow from the same point of the compass, and the direction at any place would depend upon the bearing of that locality to the centre or vortex of the whirlwind. The onward motion, however, leads to those veerings of the wind which, with a falling barometer, characterise the hurricane. We find this noticed by Sir Gilbert Blane* in the Barbadoes storm of 1780. 'A ship,' says he, 'that arrived at Barbadoes six days after, had a gale of wind about the time of the hurricane, which was not particularly violent, and was remarkable only for this—that the wind blew from all round the compass; a circumstance which distinguishes the hurricane from all other gales within the tropics.'

To illustrate this veering of the wind, let us adopt the example given by Colonel Reid of a hurricane approaching the Barbadoes. Suppose the axis of the tempest crossing that island from the eastward. At first the approach of the storm will be indicated by north-easterly winds, gradually blowing due east; as the centre of the storm passes, the wind will blow apparently from all directions in a brief space of time; but soon it will set in from the south, going off at south-by-west. The diagram on the following page will illustrate what we have said, and also the veerings of the wind to the south of the equator, to be immediately referred to.

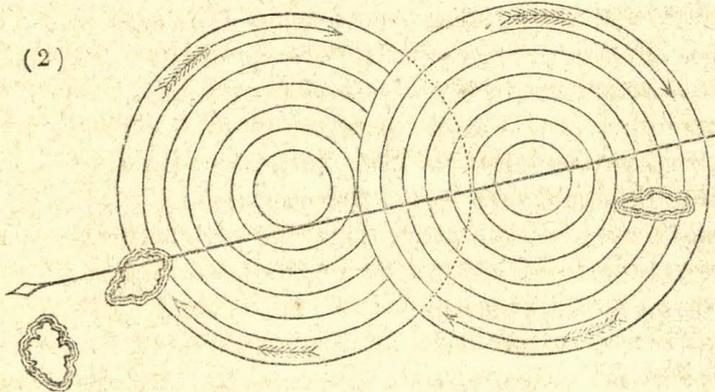
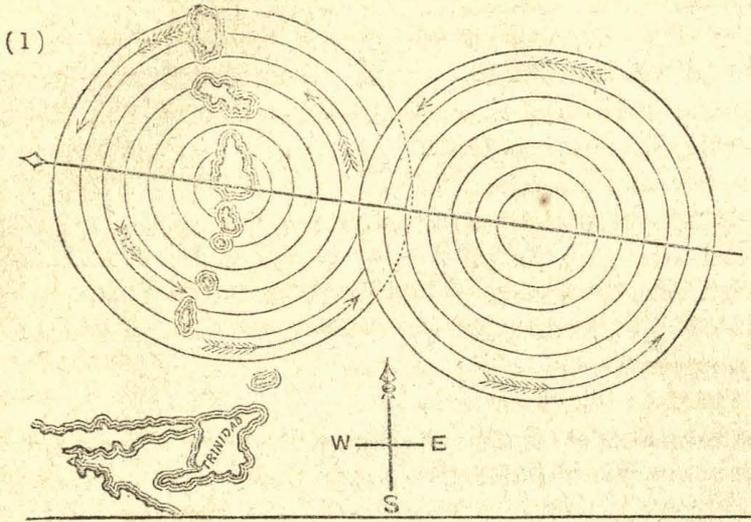
From this it follows, that during the first or western course of the West-Indian hurricane, the direction of the wind at the beginning of the storm is from a northern point, and during the latter portion of the storm from a southern quarter of the compass; and that, in the second stage, or eastern course of the same gale, the hurricane sets in with a southern wind, veering to west on the line of the storm's centre. Upon either side of the central path of the hurricane the veerings will be different, as is easily understood by keeping in mind that the wind is blowing in a whirl. A rotary storm, on approaching our island, will give to those on the right hand of the axis of progression S.E., S., and S.W. winds; while on the opposite side of its track the veering will be from N.E., N., and N.W. Let us take another illustration, and with the view of exhibiting the counter-movements of the

* Edinburgh Royal Society Transactions, vol. i. p. 33.

tempest on opposite sides of the equator, let us suppose the hurricane approaching the Mauritius, having passed over Rodriguez Island, 300 miles to the eastward (*vide* diagram No. 2). At the commencement of the

gale the wind will set in from the south, veering by the east to north, at which point it passes off.

The gyral axis of the hurricane, or its axis of revolution, is supposed by Mr Redfield to be inclined forwards in the direction of its motion, the lower part being retarded by the resistance of the surface of the earth; and the lulls and gusts which alternate in the vortex of the storm, he considers may arise from an oscillation of this rotative axis. The dilatation of the whirl, in its progress towards the pole, is another interesting feature to which we would allude. This has been beautifully



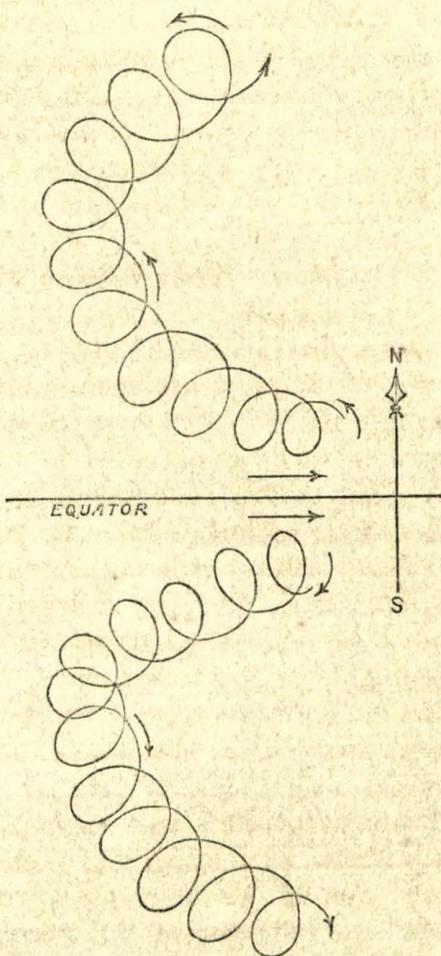
displayed in Colonel Reid's projection of the Bermuda hurricane of the 12th September 1839. At first its diameter was not more than 5° , but when it reached Bermuda, it had expanded to about 8° , and when met with in the 50th parallel of latitude, its dilatation exceeded 13° , including within the whirlwind the whole of Newfoundland and part of Labrador. Six hundred miles is considered by Thom as the largest diameter of a hurricane in the northern part of the Indian Ocean. That of the most violent part of the Malabar storm of April 1847 was not more than 200 miles, while the breadth of the entire whirl was nearly 1500 miles.

We have spoken of the hurricane as moving in *circles* for the sake of expediency: the cycloidal figure, however, would be more correct, the degree of curvature depending upon the rate of progression. This will be better understood by the diagram on the following page, which represents not only the gyrations and the progression of the gale, but the contrary movements of these storms in opposite hemispheres.

In explanation of the barometric oscillations accompanying these winds, Colonel Reid adopts the theory of Redfield, which is as satisfactory as it is simple. We have already mentioned that the mercury falls till the centre

of the hurricane has passed. It is also observed to descend on either side of the central path of the storm in proportion to the distance of the place from the axis of progression. Should the ship steer with the axis of the storm, and at the same rate, the barometer will remain stationary throughout; and the descent of the mercury at any time will depend upon the actual fall attending the passage of the vortex, and the progress the ship has made in relation to the centre of the hurricane. To adopt a familiar illustration in explanation of the fall of the mercury, let a glass vessel be filled with water, and this fluid put into rapid revolution; the liquid will represent the atmosphere, and the motion communicated to it the whirlstorm. Observe the change which has taken place in the level of the water, and watch the effect of sliding the tumbler along a line which may represent the track of the gale. Gradually the surface of the liquid has become depressed, and this is greatest in the centre. So with the atmosphere in the hurricane. Its pressure upon the earth lessens, till the minimum is reached in the vortex of the storm, and the mercury in the tube, which is the equipoise of a similar column of air, falls in proportion. But when the centre of the gale has passed, the mercury remounts in the tube, because a greater quantity of air presses upon its surface. The depression of the mercury is thus owing, as Mr Redfield describes it, 'to the centrifugal tendency or action which pertains to all revolving or rotary movements, and which must operate with great energy and effect upon so extensive a mass of atmosphere as that which constitutes a storm.' In performing this simple experiment, Mr Redfield points out the advantage of producing the rotation of the water by passing the propelling rod round the exterior of the fluid in contact with the side of the vessel, seeing that the impulse given by external force is thus more analogous to that which influences the movements of the hurricane. Instead of a deep and rapid vortex, like that produced by the water leaving the vessel by a hole in the bottom, or by the central application of the force, we shall have a concave depression of the liquid of great regularity. As water is more dense than air, all allowance must be made for an imperfect analogy.

To what limit upwards the rotary movement is conveyed we can only conjecture, but doubtless it depends upon the violence of the gale. Another influence of the depression of the higher strata of our atmosphere caused by the gyrations of the wind must not be forgotten. Colder portions of the air are brought in contact with the warmer and more humid strata, and precipitation of the invisible moisture takes place. Hence arise those



dense masses of clouds and the torrents of rain which accompany the hurricane.

Hurricanes blow with greatest regularity over the sea, for upon land the physical features of the country modify the direction and force of the storm; and it has been remarked, that though the fury of the tempest may prove singularly disastrous upon the ocean, an unusual fall of the barometer may at times be the only inland indication of its proximity and passage. The clouds are borne along, however, and the country is deluged with rain.

Certain seasons have been observed to be more peculiarly liable to their development. Thus in the West Indies the month of August furnishes the most copious records of these visitations, and there the hurricane season may be considered to be from that month to October inclusive. 'From a list of forty-seven hurricanes which have been experienced in the Caribbean Sea and among the West Indian islands, down to August 1848, we find that one occurred in the month of June, four in July, eighteen in August, twelve in September, and twelve in October.* In the Indian Ocean, on the other hand, they are most frequent from December to April.

Colonel Reid's third chapter is perhaps less interesting to the landsman, but it is of great practical utility. It is entitled, 'On heaving-to, and on sailing from a gale's centre.' We have already drawn attention to the fact that, supposing the whirls to be circular, the direction of the wind is eight points from the points of the compass. Hence the bearing of a ship to the centre of the gale may be approximately ascertained, though its distance from the axis cannot be determined. If the barometer is falling and the wind veering, it may be concluded that the hurricane is approaching; but if the mercury is rising, even though the wind should blow briskly, the centre of the storm is receding. In the vortex the wind veers rapidly, and the danger of being taken aback is imminent. It is consequently of the highest moment that, with the assurance a rotary gale is approaching, the seaman should know how to steer away from the centre of the gale. Colonel Reid has clearly illustrated this important part of his subject, and left little to be desired in the way of improvement.

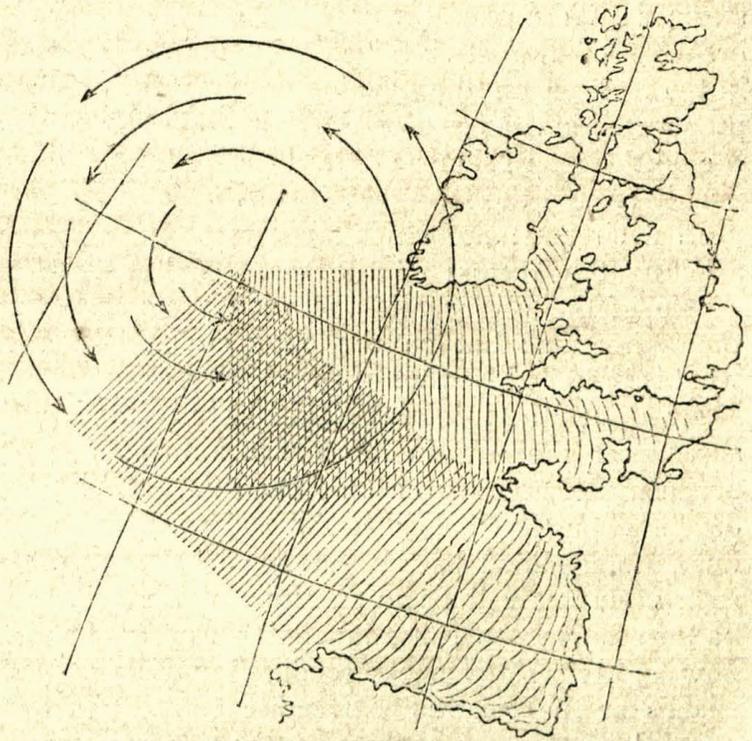
As the sides of a ship have received particular names, so it is well to define the sides of a gyratory storm. Standing at the helm, and looking forward, the right-hand side of the vessel is termed the starboard side, and the opposite one is called the larboard or port side; and the direction in which she is moving, if obliquely, has been termed the starboard and port tack respectively. Suppose now the ship to be advancing in the axis of the storm, that portion to the right is called the right-hand semicircle; and the other to the left, the left-hand semicircle. Practically, it has been found better that the ship should be kept up to the wind than that she should fall off from it. This is gained when the wind blows aft or by the stern in a revolving storm, and the danger is thereby avoided of getting stern-way when the vessel is lying-to and the wind turning by the prow. To quote the words of Colonel Reid:—'If it be desired to lay a ship to in a revolving storm, so that she shall *come up* to the wind, instead of *falling off* from

* Dr D. P. Thomson's Introduction to Meteorology, p. 411. 8vo. 1849.

it, the rule will be, when in the right-hand semicircle, to heave-to upon the *starboard* tack; and when in the left-hand semicircle, to heave-to upon the *port* tack in both hemispheres.' By observing the direction of the veering, and keeping in mind the principles laid down, it will seldom be difficult to determine in which semicircle the ship may be, and consequently the tack to choose. There can be little difficulty experienced, however, if the general rule be borne in mind, to bring the ship up to the wind on the starboard tack north of the equator, and on the port tack south of the line. By these movements the ship will gradually sail away from the storm's centre. Colonel Reid points out the greater danger which exists in steering in the quadrant in the advance of the centre of the storm's track, and he reminds the seaman that not only the direction of the wind, but that of the waves, and, we would add, the position of the land if near a lee-shore, must enter into the calculation of the best course to be taken in these revolving storms. This leads to the fourth chapter—'On the direction of the swell raised by storms.'

Drop a pebble in the water, and watch the ripple. It was an amusement in our youth, and we do not enjoy it the less now. Analogous to this would be the swell raised by the storm, if the force was equally applied on every side at the same time. The sea, however, is deeply agitated in the direction of the wind, and its undulations roll on to an extraordinary distance.

The wind veers and the swell advances as a tangent to the whirlwind; but this is not the same series of undulations as the last, which are hastening to a neighbouring shore, or to break over an adjoining reef. It veers again, and a third series of undulations is propagated. Thus the wind changes and the hurricane progresses, producing a succession of undulations all moving on in the direction of their primitive impulse.



But what is the consequence?—cross seas and dreadful waves. In the preceding diagram, which represents a rotary gale setting in to the southwest of Ireland, two series of undulations are represented, one rolling on to the Bay of Biscay, and the other to the coast of England; the cross sea is indicated by the cross lines.

The waves of the Barbadoes hurricane of 1831 were propagated to the southern shores of the Bermudas, although the gale itself was not experienced there. So in the Bay of Bengal a rotary tempest, though not

felt at Ceylon, has been indicated at Trincomalee by a heavy swell rolling in from the north-east. The same storm would propagate a swell in the direction of Madras before the wind rounded to Trincomalee. This occurred in the Mazulipitam hurricane of May 1843. The *Orpheus* was then lying at Ennore, to the north of Madras, when there were brisk winds from the land, and a heavy sea at the same time setting in from the eastward. The swell may be met with in the track of the hurricane some days before the storm sets in, as is well illustrated by Colonel Reid in the following narrative, and it will be most violent in that direction:—

'I was in Bermuda,' says Colonel Reid, 'when the hurricane of 1839 occurred, and distinctly heard the sea breaking loudly against the south shores on the morning of the 9th September, full three days before the storm reached the islands, as recorded in tables of the state of the weather kept at the Central Signal Station. At that time the hurricane was still within the tropic, and distant 10 degrees of latitude. As the storm approached, the swell increased, breaking against the southern shores with louder roar and great grandeur, until the evening of the 12th September, when the whirlwind storm reaching the Bermudas set in there. When the storm had passed the Bermudas, the southern shore became calm, and the northern reefs, in their turn, presented a white line of surge, caused by the undulations rolled back from the storm in its progress towards Nova Scotia and Newfoundland. The breaking of the sea against Bermuda was heard, though not recorded in the register, on the evening of the 8th.' While this swell was being propagated in the track of the hurricane, the sea was rolling on towards the north-eastern shores of Haiti and Cuba. The water of the ocean seemed muddy around the Bermuda islands a day before the arrival of this tempest, a circumstance which appears to have been caused by undulations affecting the bottom of the sea. It has been observed that near the centre of the rotary gale the wind veers faster than the waves change their direction; but on the outer circuit of the storm the change in the wind is preceded by that of the swell.

Mr Milne * and Colonel Reid † have pointed out how a storm-wave may accompany the gale in its course, moving onward like a tidal wave, and producing temporary oceanic currents. The elevation of this wave will depend upon the diminished atmospheric pressure, and the impulse of the hurricane modified by the rotation of the wind. The effect produced by such a current will be an elevation of the tide; and should a spring-tide be then flowing, to cause inundations of flat lands. Mr Milne has shown how an Atlantic tempest produced unusually high tides in the British islands at the close of November 1838. At Plymouth the piers were covered by the sea; at Swansea the tide rose seven feet two inches above its proper level; Newry, to the north of Dublin, was flooded by the highest tide remembered; and in Scotland the wave rolled on to the Orkneys, rising above the quays. In the Bay of Bengal most destructive inundations have followed rotary storms. The Coringa hurricane of November 1839 affords a painful example. That storm, which Colonel Reid has

* Edinburgh Royal Society Transactions, vol. xiv. p. 486.

† The Law of Storms, second edition; Progress of the Development of the Law of Storms, chap. vi.

described in his sixth chapter, blew on the 12th over the Andaman islands, and reached Coringa on the 16th, where it set in with north-easterly winds, veering to east, and passing off to the southward. A loss of more than 20,000 lives has been recorded. 'There is nothing to be seen,' says an observer, 'in every direction but dead bodies and drowned cattle. Sixty native vessels which were in the roads laden with paddy have disappeared, and it is not known what is become of them. All over the country was nothing but like the sea. You can have an idea of it when I tell you that I can see from my house a Choolia sloop lying quite near to the white pagoda of Onagalo, which is four or five miles from Coringa in the interior of the land.' The swell produced rolled on to Calcutta, producing dangerous cross-seas at the head of the bay.

In the fifth chapter Colonel Reid illustrates 'simultaneous storms on opposite sides of the equator' by two remarkable storms of 1843, described at considerable length by Mr Piddington. By a singular coincidence, both were raging on the same meridian at the same time, and within 5 degrees of the equator. The northern gale has been termed the *Fazzulbarry's storm*. They exhibited in an interesting manner the westerly direction of the wind in rotary gales on the aspect next the equator. By their united influence a strong westerly gale blew between the storms, as was experienced by the *Fyzul Carreem* on crossing the equator on the 29th of November. The *Imric* seems to have been in the very centre of the northern hurricane on the morning of the 2d December, for then there was a lull, though 'the weather looked dismal, with continued flashings of vivid lightning and loud peals of thunder'—the wind had been blowing from the west. This interval of repose was fortunately turned to good account in preparing for the approaching tempest; and scarcely was the canvas secured when the storm again burst upon them from the south and south-west; the barometer falling to 29.25 inches. The words of the commander of this ship are interesting—'It is impossible for me to describe the sea that we had to contend with. It had been blowing a gale, and no ordinary one, from N.N.E. round to the S.S.W. for the last three days; and every way we looked a mountain of water appeared coming towards us. Shortly after noon on the 2d the barometer started up to 29.80, but the gale continued without any abatement till midnight.' The *Futtle Rozack*, Captain Rundle, which crossed the equator on the 20th of November on a southern track, met with 'a long southerly swell just perceptible' on the 21st; and on the evening of that day there were precursors of a storm. The stars shone sickly with unusual scintillations, and there was lightning of a peculiar character in the offing—lightning which gradually illuminated the western horizon with a sudden dark-red glare, flickering for a few moments, and gradually disappearing.

So graphic is the description of the phenomena by Captain Rundle, that we willingly extract the following from the log:—Upon the 23d the barometer was 'considerably fallen, with an exceedingly long swell from the southward, and at 7 a high N.N.W. sea meeting the southern swell, created an exceedingly turbulent sea. In the squalls the sea has a strange appearance, the two seas dashing their crests against each other, shoot up to a surprising height, and being caught by the west wind, it is driven in dense

foam as high as our tops. The whole horizon has the appearance of ponderous breakers.

'At 8, barometer still falling. Has there been a gale? Much electricity by the appearance of the clouds; current fifty-nine miles N.E. by E. $\frac{1}{4}$ E. P.M.—Breeze decreasing to $1\frac{1}{2}$ knots, winds west to south, and at times calm. Making preparations for bad weather, appearances being suspicious. Midnight, squally, rain, and calms; dark, dismal appearances all round, and increasing southerly swell.

'November 24th.—Dark and gloomy winds variable from S.E. to S.W., noon lat. $5^{\circ} 32'$ S., long. $84^{\circ} 49'$ E. Barometer 5 A.M. 29.57; at 9, 29.63; at noon, 29.64. I do not like this gloomy weather: with wind lulling and then coming on again with a warning noise, there either has been or will be bad weather. At 4 calm; at 5 severe squalls from S.S.W.; tremendous high sea from the southward; ship rolling dreadfully at intervals. Barometer at 8 P.M. 29.63.

'25th.—A.M. Wind south, veering to the S.W. and *vice versa*; strong gusts from S. to S.W. with a high cross-sea, occasioned by a short northerly sea meeting the long south swell. Noon, strong gale at intervals, but decreases as the wind hauls to S.W., increasing to southward. Ship under close-reefed main-topsail and foresail; lat. $5^{\circ} 42'$ S., long. $85^{\circ} 3'$ E., standing to the E.S.E. Barometer at 6 A.M. 29.64, at noon 29.63.

'P.M.—Strong gales S.W. by S., mostly from S.W., attended with violent squalls. The rain water exceedingly cold, the sea water very warm, much more so than usual. Mountainous sea from the southward. Lofty scud above the lower strata of clouds flying quickly *to the southward* at 7, breaks in the clouds, stars visible, but very dull. Barometer at 10, 29.61. Midnight, wind in severe gusts succeeded by lulls of a very few minutes' duration. Clouds, low stratus not perhaps at 100 yards' height, flying before the wind; breaks at times in the clouds, stars visible, with lofty scud flying with inconceivable rapidity *to the southward*.

'26th.—A.M. Laid-to under close-reefed main-topsail. Wind S. to S.W.; squalls with rain; exceedingly turbulent sea; noon lat. $5^{\circ} 30'$ S., long. $86^{\circ} 23'$ E.; barometer 6 A.M. 29.62; at noon, 29.63. P.M.—Fresh gale with furious squalls, and rain as cold as ice; edging away to E.S.E. and S.E. by E. under two close-reefed topsails; wind S.W., and at intervals W.S.W. and W. At 8, ropes and gear on deck brilliantly spangled by small luminous sparks from the sea, which, when examined, appeared to be fragments of medusæ. Again visible to the W.S. westward the sullen red glare and flickering lightning; midnight squally, sea presenting flashes of phosphoric light in all directions. Barometer at 9 P.M. 29.63; clouds, low stratus and ponderous nimbi.

'27th.—A.M. Increasing gale west; and at 2, N.W. to noon, very high sea; at 1, wind *shifted* from W.S.W. to N.W., creating a tremendous sea; 10 A.M. struck by a heavy sea, which laid the ship on her beam ends—lost main-topmast; scudded before the wind to the S.E. under bare poles. Barometer falling rapidly; noon lat. by dead-reckoning $6^{\circ} 38'$ S., long. $86^{\circ} 53'$ E.; barometer $5\frac{1}{2}$ A.M. 29.63, at 10^h 29.53, at 11^h 29.47, at 11 $\frac{1}{2}$ ^h 29.44, at noon 29.43, and thermometer 80° ; clouds throughout exceedingly low stratus.

'P.M.—Wind N.W. to 10 P.M. when N.; course S.E. to 10, and then

south; three feet water in the hold, and most of the crew sick; vessel making only four knots per hour before the wind, and labouring excessively. At 6, barometer rising very fast, and at midnight falling again, with dark gloomy threatening weather all round. Barometer at 2 P.M. 29·46, at 4^h 29·47, at 5^h 29·56, at 6^h 29·62, at 7^h 29·63, at 9^h 29·61, at 9½^h 29·58, at 10½^h 29·62, at 11^h 29·50, at midnight 29·49 inches.

'28th.—Wind N.E. the whole twenty-four hours. A.M.—Increasing gale, wind *veering suddenly* to N.E. in a furious squall; lost fore-topmast, ship lying-to in much distress. Barometer 29·47 at 1 A.M., 2 A.M. 29·45, at 5 A.M. 29·44, at 6^h 29·43, at 11^h 29·45, at noon 29·49. Lat. by dead reckoning 7° 39' S., double altitude 7° 47'; long. 87° 17' E.

'P.M.—Wind N.E.; tremendous squalls blowing with inconceivable fury; the sea rising in huge pyramids, yet having no velocity, but rising and falling like a boiling caldron. I have never seen the like before. I was in the height of the terrible hurricane of September 1834, in the West Indies; I have been in a typhoon in the China Sea; in gales off Cape Horn, the Cape of Good Hope, and New Holland; but never saw such a confused and strange sea: I have seen much higher seas, and, I am sure, wind *heavier*, but then the sea was regular and the wind steadier.

'10 P.M.—Dreadful squalls and a confused sea; both cutters washed away, and mizen-topmast carried away; blowing still harder, but barometer rising; midnight, tried to set the foresail and scud, but it was blown to pieces. Barometer 2 P.M. 29·49, at 5^h 29·5, at 10^h 29·53, at 11^h 29·54, at midnight 29·56.

'29th.—A.M. Wind N.E. till noon, still blowing fearfully at times. Again tried to scud, and ran S. by W. fifty-eight miles to noon; barometer steadily rising. 10 A.M. good sight for chronometer; 2 A.M. the barometer 29·57, at 7^h 29·57, at 10^h 29·58, at noon 29·59; lat. 9° 47' S., long. 87° 18'.

'Noon—Blowing with inconceivable fury at times, with the sea, I think, more agitated and confused than ever; rising up in monstrous heaps, and falling down again without running in any direction. Noon—laid-to again.

'P.M.—Violent squalls and tremendous high sea; three feet water in the hold; wind N.E. to E. Midnight, more moderate at times. Barometer 2 P.M. 29·60. Clouds during these twenty-four hours exceedingly low; stratus scudding in all directions; upper strata to the southward, lower to the west, at other times apparently to north and east.

'30th.—A.M. Gale abates a little; high sea; ship lying-to with tarpaulins in the mizen-rigging; wind marked N.E. to E.; barometer, noon, 29·61; lat. obs. 10° 48' S., long. 86° 46' E.

'December 1st.—Gale and sea moderating.

'2^d.—Moderate and passing squalls, sea much gone down, repairing damages; winds E. to noon.

'3^d.—At noon quite fine.'

Colonel Reid remarks that the terrific sea of the 28th may have been caused by the southern hurricane alone, but it may have been augmented by the swell rolling from the gale on the other side of the equator, the distance between the storms being only 10 degrees.

In the sixth chapter the 'Storms of the Bay of Bengal' are investigated.

Keeping in view the principles laid down, it will be easily understood why the Birman coast should be a lee-shore while the southern semicircle of the whirlwind is passing from the eastward; and why the coast of India becomes a lee-shore when the opposite half of the rotary gale is impinging upon the land. Practically this is a point of considerable moment, for it is a matter of no little difficulty to be able to steer from a lee-shore in a tempest with a shifting wind. This chapter is illustrated by the narratives of several storms, and there is a good projection of the Madras gale which began on the 22d of October 1842, to the west of the Andaman islands, crossed the southern part of Hindoostan upon the 24th—25th, and expired on the 2d of November near the shores of Arabia. The modifying influence of land upon the rotary character and force of this storm imparts to it considerable interest. The incidents recorded in the logs are often deeply affecting, and the whole narrative may be studied with advantage. The *Seaton*, from Aden to Bombay, weathered the hurricane, but was necessitated to put back in a sadly crippled condition. Had she altered her course when the precursors of the tempest forewarned of the impending danger, she might have proceeded on her voyage, and reached her destination in safety; but being disabled at the beginning, she appears to have drifted round the whirl's centre. On the evening of the 30th October 'the sun went down fiery red and contracted in appearance. His rays, instead of glancing obliquely across the waves, seemed to dip and lose themselves almost perpendicularly in the long heavy swell.' The barometer was then 29·7 inches, and the wind was strengthening, so as to require reefing and stowing of the sails. By this time the hurricane had advanced eastward several degrees from the western shores of India. On the following day the *Seaton* was in N. lat. 14°, and E. long. 61°, when the gale burst in all its fury. Away in an instant went every stitch of canvas, and was lost, and mast after mast yielded to the unseen power, the mizen-mast alone standing. The mercury continued to fall, till in the height of the gale the minimum, 27·6 inches, was read off—two inches and a tenth below the indication on the preceding day! Upon the 1st of November the ship was in the vortex of the whirlwind.

'At daylight the wind lulled a little. At 8 A.M. the hurricane recommenced with redoubled fury. The wind, which before was N. and by W., suddenly shifted to the E.S.E., and settled at E.N.E. Sea breaking over her fore and aft, making a clear sweep of the deck. It is a matter of surprise and congratulation that none of the men were washed from the pumps, which were kept incessantly going during the intervals of the sea. The spray was flying so furiously and thick, that the fore-castle could not be distinguished, and every part of the body that was exposed smarted from its effects.' The rain fell in torrents, and the lightning was awfully vivid, as it darted 'from the intensely dark masses of clouds that pressed down, as it were, on the troubled sea. In the zenith there was an obscure circle of imperfect light, of 10° or 12°—*el ojo*, or storm's eye. 'When the hurricane took off, the scene to leeward was awfully grand: thick masses of the darkest purple-coloured clouds were rolling over each other in inconceivable confusion, tinged and lighted up in different places by intensely vivid lightning. The hoarse roar of the retiring storm, mingled with the hollow groan of continued thunder, as they slowly retreated with

the gale, left an impression on the mind not easily to be forgotten. The respiration of every person on board was affected.'

We will close our sketch of this chapter with an abstract of what befell the transport-ships *Briton* and *Runnymede*, with troops on board for Calcutta, in November 1844. The former was bound from Australia, the latter from this country, and both reached the eastern side of the Bay of Bengal at the same time, encountering together a rotary storm moving from the direction of the Gulf of Siam to the Andaman islands. After enduring severe weather for some days, the gale strengthened to a terrific hurricane on the 10th. There was a lull on the night of the following day, the sympiesometer falling to 27·2 inches; the wind increased in fury, and at 1 A.M. of the 12th the *Briton* struck. When light dawned, the ship was found high and dry in a mangrove swamp, the *Runnymede* lying close to them, upon one of the smaller islands in that group.

Upon the 10th of November, the *Runnymede* lost part of her canvas and smaller masts about 2 P.M., but she lay-to under bare poles, perfectly tight. The rain was pouring down in torrents, and the wind was terrific. By 9 o'clock the main and mizen-masts alone were standing, and an hour later no one could hold on the poop for wind and rain.

'November 11th.—Hurricane equally severe; wind S.E. (barometer 28·0); the gusts so terrific, mixed with drift and rain, that no one could stand on deck; advantage was therefore taken of the lulls to drain the ship out, and clear the wreck. The starboard bower anchor hanging only by the shank painter, and the stock (iron) working into the ship's side, the chain was unshackled, and the anchor cut away. Noon—lat. acct. 11° 6' N., long. 95° 20' E.; no observations since the 7th. Barometer apparently risen a little. Hurricane equally severe in the gusts; the ship perfectly unmanageable from her crippled state, but riding like a sea-bird over a confused sea, *running apparently from every point of the compass*. A large barque, with loss of topmasts and mainyard, drifted ahead of us, and a brig was seen to leeward totally dismasted. At 4 P.M., barometer fell to 27·70, and Cummin's mineral sympiesometer left the index-tube. Hurricane blowing terrifically; the front of the poop to leeward, cabin door, and skylights torn away, and expecting every moment the poop to be torn off her. *The severity of the wind is beyond description. There is nothing to compare to it; for unless present, no one could conceive the destructive power and weight of wind, crushing everything before it as if it were a metallic body!* At 1 P.M. no abatement—every one, sailor and soldier, doing all in his power to keep the ship free of water. Could not stand at the pumps: the water being principally in the between decks, it was baled out by the soldiers as much as possible.

'12th.—Midnight; hurricane equally severe; the gusts most awful, and rudder gone. At 1·30 A.M. felt the ship strike, and considered the destruction of our lives as well as ship sealed; but it pleased Almighty God to decree otherwise, for although the ship filled up to the lower beams with water, she was thrown so high on the reef that the water became smooth, and the bilge pieces keeping her upright, she lay comparatively quiet. Not knowing our position, the ship being bilged, and fearful of her beating over the reef into deep water, let go the larboard bower anchor, and found the water leaving her. All hands fell asleep.

'Daybreak; hurricane breaking; much rain; wind E.S.E. (barometer rising rapidly, until it stood at 29.45). We then, thank God! saw the loom of the shore to leeward, the ship being nearly dry abaft. On its clearing away, we saw inside of us, up among the trees, a large barque with troops on board. One officer and twelve men were sent over the stern to communicate with her. At 7 A.M., the tide now rising, orders were given for the men to land at next low water, and if possible to get something cooked, as no fires could be kept in during the hurricane—the crew and troops merely having biscuit and a glass of spirits during the time it lasted. At 3.30 P.M., the tide having fallen sufficiently to wade on shore, Ensign Dabernt returned on board, and stated the vessel in shore of us to be the *Briton*, from Sydney, with 311 men, 34 women, and 51 children, of H. M. 80th Regiment, under the command of Major Bunbury, with a crew of 36 men, bound for Calcutta, and short of everything.'

The seventh chapter of Colonel Reid's work is devoted to the 'Storms of the Arabian Sea,' the importance of which is considerably increased by our 'overland' communication with the East. It is to be regretted, however, that up to this time our data for collating particular tempests there should be so scanty. The Madras storm of April 1847, in which the steam-ship *Cleopatra* was lost, is described at some length. Of this hurricane Mr Piddington,* Mr Thom,† and Captain Carless,‡ have also published independent narratives.

This whirl-storm seems to have originated over, and to the south of Ceylon, on the 14th of April; and on the following day easterly winds blew at the Observatory of Dodabetta, on the Neilgherry Hills, with a force not exceeding ten lbs. to the square foot. Upon the 16th the vortex of the storm was about a degree west of Cape Comorin, on the 17th it was off Calicut, and on the 18th to the south-west of Goa. The track of the hurricane thus coasted the western shores of India, advancing northwards; but it does not seem to have reached Bombay, for there no tempestuous winds were encountered. Interesting records are preserved of the gradual fall of the barometer, from the exterior circles of this whirlwind to the vortex, even from Madras, distant on the 17th 300 miles, and on the 18th 480 miles from the storm's centre. A strong current flowed along the Malabar coast northwards, and an extraordinary fall of rain took place both at sea and on land. At Tellicherry the rain-gauge measured twenty-nine inches.

To one catastrophe we have already alluded. It was the loss of the H. C. steamship *Cleopatra*, bound for Singapore with convicts. This ill-fated vessel sailed from Bombay on the afternoon of the 14th, heavily laden with coals and provisions, and on that account less able to resist the fury of the wind and waves. Her course was southward, near to and against that of the hurricane, the sea-current of which she probably met on the 16th, when near Mangalore. The adverse winds must now have been increasing. With land to the port quarter, and the axis of the gale to the starboard, with furious winds augmenting in force, and with a tempestuous

* Journal of the Asiatic Society of Bengal.

† Bombay Times.

‡ Journal of the Geographical Society, 1849; vol xix. p. 76.

sea, the situation was perilous and the dangers were increasing. On the 17th, at eight A. M., she is supposed to have been in lat. $12^{\circ} 5' N.$, 40 miles from land, 50 from the nearest of the Laccadives, and 428 from Bombay: there it is believed she foundered.

We will only refer to what befell another ship, the *Buckinghamshire*, and pass on to the next chapter. This vessel ran parallel with the storm during the greater part of its fury. 'On the 14th,' says Mr Thom, 'she was in the westerly half of the circle, with bad weather, at N. and N.N.W., and as she neared the island of Mincoy the N.E. wind delayed her, until the focus of the gale had passed from between her and the coast of India. On the 17th the gale veered to N.W., enabling her to run 120 miles to the eastward, crossing through its equatorial side, crossing its wake, and getting in between it and the land of India. On the 18th she availed herself of the strong southerly gale on the east side of the vortex, and ran along the coast N.N.W. and N.W. by N. The current and wind being favourable, her speed was eleven to twelve knots an hour. Thus she ran up to the focus, passed ahead of it, with the gale veering from S. by W. to S. and S.E., and in consequence of the jutting out of the coast near Vingorla, she was forced to keep off N.W. by W. at the very time when the vortex was assuming a northerly course, and approximating the land.' The consequences were very disastrous. Instead of lying-to on the 18th, before the wind veered from south to eastward, she pursued her course, was borne into the very centre of the storm, and there dismasted. In the log we find the weather stated to have been that day 'threatening, and all the glasses falling rapidly. At noon, the gale being augmented to an extraordinary degree, kept the ship before it. Barometer, last marked, 28.35 about this time.' The following are the captain's 'remarks:—

'April 19, 1847.—The gale blowing furiously, and veering to the eastward; cut the foresail from the yard, and hauled it on deck; the fore-topsail blew entirely away. At 0.30 P.M. the ship inclined to broach-to; cut away the mizenmast, and kept her before it; blowing a hurricane; blew away the main-topmast, the hurricane increasing, and the foremast bending to its force. About 1 P.M. the foremast fell over starboard; a most furious gust blew away the mainmast near the deck; the quarter boats blew away, the starboard or large cutter flying across the poop. The poop ports having been blown in, the violence of the wind blew down the back-heads, destroying the barometers, and everything in the cabins. The ship covered with spray, and labouring excessively in a tremendous sea—the rapidity of her motion tearing everything on the different decks and in the hold adrift. Men unable to stand on their legs, or to hear one another shout. Two P.M. the wind, which had been for the last half hour indescribably furious, suddenly ceased entirely.

'The sympiesometer in the calm continued to stand at 28.08. The fore and mainmast, which had got under the bottom, were now cut adrift. The ship covered with aquatic birds, thousands of them dying on the deck. About 4 P.M. the wind, that had ceased at E.S.E. or E., began to blow with equal fury at W.N.W. The ship was again enveloped with the sea, and labouring with a violence that nothing could resist; $3\frac{1}{2}$ feet water in the hold. At 9 P.M. the wind abating; sympiesometer 28.96. At midnight, moderate wind at W.; sympiesometer 29.1. Daylight, squally at

W.; commenced rigging a jury-foremast; Chinese at the pumps. At 9 A.M. saw the Vingorla Rocks by N.E. $\frac{1}{2}$ E.; crew at the pumps. Noon, squally at W., with showers.

'20th.—1^h, Set the fore-topmast staysail and a fore-topgallant sail on the jury-foremast, and bore up for Vingorla. 4^h, Westerly breeze and squally. Passing about 2° south of the Vingorla Rocks. 7^h, Light breeze and squally, with showers. S. Vingorla Rock W. $\frac{1}{2}$ N. At 7.30, anchored with the larboard bower in 9 $\frac{1}{2}$ fathoms. 10^h, Burnt blue lights. 12^h, Fresh westerly breezes. 6^h, Turned the men out to the pumps. 8^h, A vessel with only her foremast standing, and steering by a spar over the stern, running into the rocks. 11^h, Fresh W.S.W. breeze, and fine. The stranger firing guns. 12^h, Sent a letter on shore in a water cask.

'21st.—1^h, Moderate westerly wind and squally. 3^h, Moderate W.S.W. breeze and cloudy. (We have been since told that Major-General Morse came down to the beach this afternoon, and offered 200 rupees to any boat that would come off to us; but although the weather was moderate, such was the terror caused by the recent loss of life and property, that there were no volunteers.) 11^h, Variable and squally night; heavy rain. 6^h, Squally, with heavy rain. Filled some casks with rain water, salt water having found its way into the ship's tanks during the hurricane. 10^h, Collecting pieces of beef and pork, and other provisions amongst the coals, the casks having been smashed. 12^h, Fresh breeze, and squally; rigging a jury-mainmast.'

Many of the native craft, or pattamars, were lost in this terrific gale, being driven to sea by the east wind, and brought back again by the west wind, or sunk. In standing up the coast after the tempest, the *Sesostris* passed the wrecks of many boats between Mangalore and Vingorla, and the sea was covered with sad tokens of the desolation.

We now pass from the Arabian Sea to that of China, and in the eighth chapter we have a full account of the typhoons which blow there. These storms are in all respects similar to the West Indian hurricanes, occurring, too, at the same seasons. Of thirty typhoons described by Mr Piddington, one took place in June, four in July, five in August, ten in September, seven in October, and three in November. It is interesting to compare these numbers with those already given, keeping in mind that we have forty-seven in the one case, and only thirty in the other, or, more correctly, twenty-seven, for three blew in November. Thus we find that the same number occurred in the months of June and July; but in August we have eighteen hurricanes and only five typhoons; in September, twelve and ten respectively; and in October, twelve and seven.

Keeping in view the grand practical bearing of these investigations upon the course of vessels falling in with rotary storms, we cannot omit drawing attention to the position of ships sailing to and from Canton, as pointed out by our author. Advancing from the eastward with a north-westerly progression, the typhoon meets the ship sailing northwards to the Chinese port, on the side on which the wind blows westerly. By lying-to till the wind veers to the south-west, not only are the dangers avoided, but a fair wind for the rest of the voyage is obtained. Far different, however, is the position of the vessel leaving Canton for the south or eastward. The

centre of the gale being then about the eighteenth parallel of latitude, the current will set in strongly towards the lee coast of China, or the Island of Hainan, and the wind will be easterly. In the northern half of the storm the port tack leads the ship into the vortex, while the starboard tack will carry her to the lee shore. 'Incidit in Scyllam qui vult vitare Charybdim.' The veering of the wind to the south must in this case be carefully watched, and taken advantage of, to clear the land.

Without describing these typhoons in detail, we would notice one on account of the unusual barometric indications. It was that of November 1837, encountered by the *Ariel*. Upon the 17th, with an increasing gale, the mercury stood at 30·10 inches, and the instrument is said to have been in good order at the time, and to have remained so for eighteen months thereafter. At daylight the wind 'hailed to the north in a tremendous squall. 10 A.M.—Blowing awfully hard, and sea beyond description. Noon, typhoon blowing dreadfully; wind N.W., and sea like pyramids all round; could not look to windward for the wind, rain, and sea blowing on board; the ship frequently lurching; half the main-rigging and oftentimes the bowsprit under water. Barometer fell to 29·80. P.M.—Wind W., a most dreadful typhoon blowing; ship in a most perilous situation.' Shortly after this she was dismasted, and at 6 P.M. the mercury rose to 30·10. The following day it continued mounting, with a strong gale, and on the 19th it reached the maximum of 31·30 inches—a difference of an inch and a-half from the lowest altitude during the storm. This was a very remarkable elevation, and seems to have arisen from the augmented pressure of the atmosphere, when the direction of the wind in the circle coincided with that of the north-east monsoon, which was then blowing hard.

At the close of this chapter, Colonel Reid gives a fine illustration of good seamanship in the case of the *Black Nymph*, Captain J. V. Hall,* which we will quote at length, seeing it shows not only how to escape a rotary storm, but also the value of the barometer as a warner of its approach. We well remember the interest with which we first read the account given by Dr Arnott† of an almost miraculous escape of a noble ship, by watching the falling of the mercury on a beautiful afternoon, and providing against the impending danger; and we have been pleased to observe the feeling of attachment which exists towards that instrument on the part of those who have made it their constant guide in protracted voyages:—

'When three or four days' sail from Macao,' says Captain Hall, 'about noon, I observed a most wild and uncommon-looking halo round the sun. Next day set in with light squalls, smooth water, but strong ripples. The afternoon was remarkably fine; but casting my eye on the barometer, I saw it had fallen considerably since noon. I thought at first some one had meddled with it, though, looking again half an hour afterwards, I was convinced it was falling rapidly. Still the weather seemed very fine, and I thought it strange; but I was inclined to trust to my old friend, which, by its timely warnings, had saved me many a sail and spar before, and at other times had often enabled me to carry on through an uncomfortable-looking night. On this occasion it proved itself worthy of trust, and I should have had cause to regret had I neglected its warning, and trusted to

* Nautical Magazine.

† Elements of Physics, vol. i. p. 350.

appearances only. About 3 P.M., the barometer still falling, though the weather continued fine, I ordered the crew, employed in cleansing the ship and preparing for harbour, to strike topgallant-masts and yards, mizen-top gallant-mast, and jib-boom, the sails and rigging of which I put *below*, and indeed divested the rigging aloft of all top-hammer, and everything that could be spared—secured sails and hatches, close-reefed the topsails, and boats hoisted on board, and well secured.

'Done beforehand, all was done quickly and well. I daresay *Jack* thought it funny work, making all this preparation on a fine afternoon; and some of them looked about, weatherwise, to divine the reason; but in a few hours the most incredulous were satisfied with the prudence of the operations. Quiet succeeded to bustle, and the barometer still falling, I said to myself, Now in reality is coming one of these "typhoons;" and having previously been led to pay some attention to the subject, I looked to its approach with a mingled feeling of apprehension and curiosity.

'Towards evening I observed a bank in the S.E. Night closed in, and the water continued smooth, but the sky looked wildish—the scud coming from the N.E., the wind from the *north*. I was much interested in watching for the *commencement* of the gale, which I now felt sure was coming; and considering the theory to be correct, it would point out my position with respect to its centre.

'That bank in the S.E. must have been the meteor approaching us, the N.E. scud the outer *north-west portion of it*; and when at night a strong gale came on about N. or N.N.W., I felt certain we were on its western and southern verge. It rapidly increased in violence, but I was pleased to see the wind veering to the N.W., as it convinced me that I had put the ship on the right tack—namely, *on the starboard tack*, standing of course to the S.W.

'From 10 A.M. to 3 P.M. it blew with great violence; but the ship being well prepared, rode comparatively easy. The barometer was now very low, the wind about W.N.W.—the centre of the storm passing doubtless to the northward of us, and to which we might have been very near had we in the first part put the ship on the larboard tack, and stood to the N.E., and towards the centre instead of on the starboard tack, and to the S.W. the opposite direction.

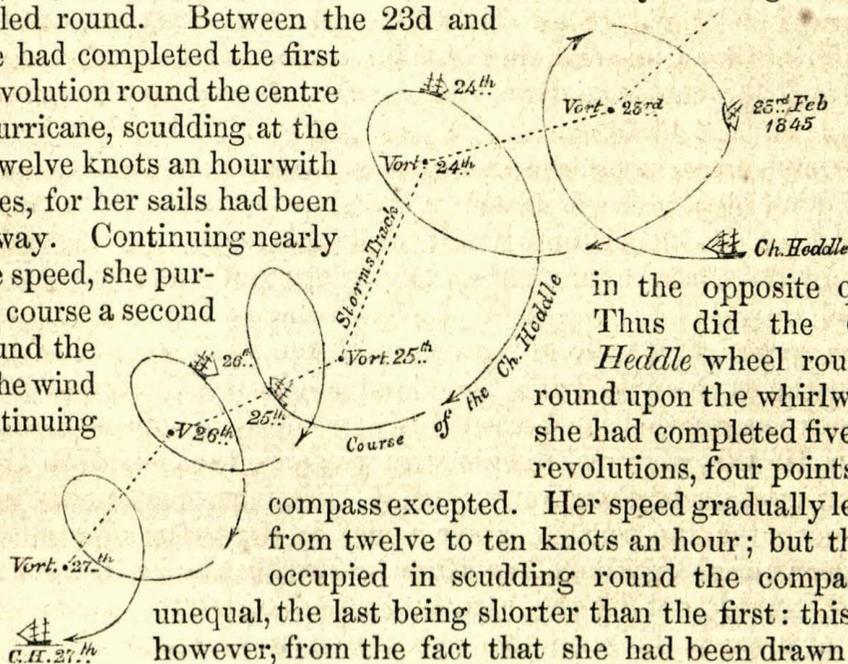
'About 5 P.M. wind at W.S.W. sensibly decreasing—the barometer rising. At 6, fresh gale; made sail to keep ship steady; a very great sea on, and towards midnight it became a moderate gale. The wind having now become S.W. to S.S.W., the ship broke off to S.E. Thinking it a pity to be lying so far out of our course, I wore to N.W., and made sail; but in less than two hours heavy gusts came on, and the barometer began again to fall. I now thought, of course, we were approaching the storm again; and doubtless the theory is not mere speculation. I wore again to the S.E., and to show more clearly how great a difference a very short distance nearer to or farther from these storms makes, the weather rapidly improved. The next morning it was fine and moderate, and the wind became S.E., with a heavy-running westerly swell. Until the afternoon there was a dark, wild appearance in the westward, which seemed to me another proof that it was the meteor which had the day before appeared in the S.E., and whose course had been from S.E. to N.W., passing a little northward of our position.'

In the ninth chapter, which is both deeply interesting and instructive, we have three remarkable 'tropical storms in the southern hemisphere' described. These are the *Heddle*, the *Rodriguez*, and the *Culloden hurricanes*. Although appropriately collected together in this chapter, these tempests have received very full exposition elsewhere by Mr Piddington,* Mr Thom,† and Colonel Reid.‡

The first of them affords us the very curious example of a ship—the *Charles Heddle*—scudding for five days before the wind, while she sailed five times round the vortex of the storm, keeping the wind always in the quarter opposite that in which she was scudding. The log is too long to be quoted, but it is one of the most remarkable documents in the volume.

This ship sailed from the Mauritius on the 21st of February 1845, on a northerly course, and shortly thereafter she encountered the gale. Upon the 22d, at 1 P.M., her course was W.N.W., then N.W., changing to N.N.W., N., N.N.E., and N.E.—the wind constantly veering aft as the brig sailed round. Between the 23d and

24th she had completed the first entire revolution round the centre of the hurricane, scudding at the rate of twelve knots an hour with bare poles, for her sails had been blown away. Continuing nearly the same speed, she pursued her course a second time round the vortex, the wind still continuing



in the opposite quarter. Thus did the *Charles Heddle* wheel round and round upon the whirlwind till she had completed five entire revolutions, four points of the compass excepted. Her speed gradually lessened from twelve to ten knots an hour; but the time occupied in scudding round the compass was unequal, the last being shorter than the first: this arose, however, from the fact that she had been drawn nearer and nearer to the vortex. This will be better understood

by referring to the preceding diagram.

Passing to the *Rodriguez* hurricane, which has received such ample illustration by Mr Thom, we find that it blew upon the 26th of March 1843, near the 11th degree of south latitude, and upon the 90th parallel of east longitude, having commenced three degrees farther north, and seven to the eastward, about two days previously. Several vessels were so unfortunate as to encounter this storm, and ship after ship sought shelter in the Mauritius. Each had its own tale of wo; and all bore testimony to the severity of the tempest as they approached that island in a very crippled state. Upon looking at the projection of this hurricane and that of the Madras storm of 1842, a remarkable resemblance is observed. Both began about the same distance from the equator, although on opposite sides of it, and on the same parallel of longitude—the Rodriguez storm, however, being

* Journal of the Asiatic Society of Bengal.

† Inquiry into the Nature and Course of Hurricanes, &c.

‡ The Law of Storms. 1838.

on a more extensive scale. We are struck, too, by another feature in this rotary gale, to which we have already referred in treating of the motion of the hurricane—at first advancing with gigantic strides, but slackening in its progress as it sped onwards. The course of some of the ships is exceedingly interesting, and the logs of all of them are worthy of careful study. The *Katherine Stewart Forbes*, which was near to the place where the tempest originated, steered parallel to, and upon the southern edge of, the storm during a period of twelve days. Upon the 6th of April, however, she bore into the storm, meeting confused seas and heavy rains; and till the 10th she was more and more involved in the vortex of the gale.

It fails us to tell of the *Margaret*, on the northern margin of the hurricane at one time, and contending with the winds in its very centre at another; or of the *Robin Gray*, the *Broxbournebury*, the *Sea Queen*, the *Velore*, the *Argo*, or of the other ships which were tossed upon the billows in this terrific whirlstorm. Referring the reader to the original for the interesting details, we come to the *Culloden's* hurricane of March 1809, so well described by Colonel Reid in his former work.

This famous tempest raged to the east and south of the Mauritius, while a fleet of merchantmen were under convoy of the *Culloden* and the *Terpsichore*, with four other ships of war. Some of the vessels ran before the wind for days; others sailed into the vortex, and perished; some, by lying-to, soon got out of the danger; while others, by crossing the peaceful area between the two branches of the hurricane, encountered a double storm blowing in opposite directions; and there were some which escaped the gale by cruising beyond the whirls. Four Indiamen, which were last seen on the 15th, must have foundered about the time when the storm recurved towards the south-east. Although Mr Thom regards the two branches of this storm as distinct rotary gales, we consider that Colonel Reid has established their unity.

Passing over the tenth chapter, which is chiefly tabular, but in which our author points out the advantage of studying the extratropical winds, called Variables, not by the regular divisions of time, but by barometric fluctuations, we find him in the eleventh chapter describing the 'gales at Madeira, and in the Mediterranean.' But these need not detain us: we may observe, however, that it is to be regretted that so few rotary storms about the eastern side of the Atlantic and in the Levant should be recorded.

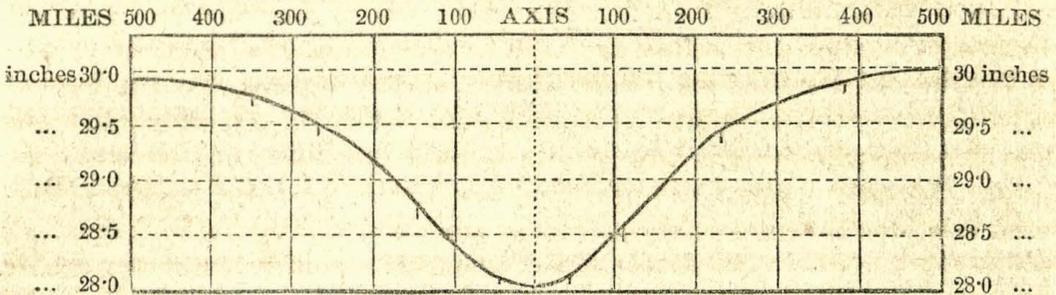
In the twelfth chapter the labours of Mr Redfield* 'On the Northerners of the Gulf of Mexico, and on the influence of contemporaneous gales on atmospheric pressure,' receive ample elucidation. He has made projections of the paths of three rotary gales; one of which blew nearly parallel to the 23d degree of latitude, from longitude 63° W. to Durango, in Mexico, passing over that track in ten days. Probably it passed to the Pacific Ocean, and there recurved, or was spent before it had lost its westerly progression. The second blew in October, same year (1842), to the north-east of Vera Cruz, passed over Florida in lat. 30° N., and was lost on the 10th to the north-east of Bermuda. The third is the *Cuba* hurricane of 1844, which appears to have come from the countries of Honduras, Poyais,

* American Journal of Science and Arts, 3d Series. 1846.

THE LAW OF STORMS.

and Yucatan, and entered the Caribbean Sea on the 3d of October. It crossed Cuba on the 5th, and pursuing a north-easterly direction, swept with extraordinary rapidity the salient points of North America to the east, and Jamaica, the Bermudas, and Newfoundland, to the west of the axis of progression. The loss sustained by this violent gale was estimated at a million sterling; seventy-two ships were wrecked or foundered at the Havanna. At Matanzas, in Cuba, the barometer fell to 28 inches on the 5th, and remounted to 29·8 on the following morning at nine o'clock.

It is interesting to observe the gradual sinking of the barometer towards the gyratory axis of the storm, on both sides its tracks, and over its entire breadth of 1000 miles. This will be more easily understood by referring to the following diagram:—



Mean Barometric Curve across the Centre of the Cuba Hurricane of October 1844, transversely to its path. Vertical Scale one-half.

The ordinary causes of barometric fluctuation—such as the time of day, state of atmospheric temperature and humidity—are here of secondary influence in producing the remarkable depression in, and from, the axis of the storm; the centrifugal force of the revolving wind, as already explained, is the true cause of the sinking of the mercury. During the progression of this hurricane, the pressure did not increase with increase of latitude, and throughout its course the mean barometric curve was very steadily the same. On the posterior side of the storm, however, the return of the mercury to its former position was, at some places, apparently more rapid than its previous reduction—an effect contrary to what has been observed in other gales.

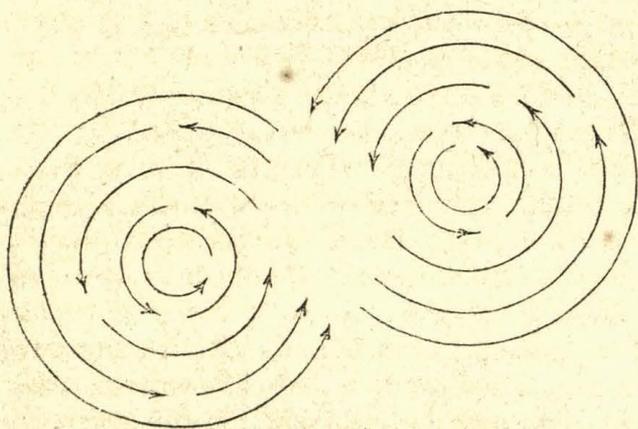
‘Thus,’ says Mr Redfield, ‘during successive days of the storm’s greatest activity, and while passing through 25 degrees of latitude, and near 23 degrees of longitude, we find an extraordinary barometric depression, the intensity of which increases rapidly as we approach towards the axial area of this great progressive whirlwind, coinciding also most remarkably with the progress and intensity of the whirling action. We find, too, that the greatest intensity of the hurricane, and of its influence on the barometer, has no necessary connection or coincidence with the local point of greatest rain or condensation; nor can any such coincidence at all lessen or contravene the known centrifugal force of rotation.’

‘The same law of centrifugal action must tend to produce an accumulation of pressure beyond the verge of the active whirlwind, or at least in the areas or spaces which separate distant storms.’ The latter remark is worthy of attention—the cumulated pressure on the flanks of contemporaneous gales, or of storms rapidly following one another, not only raising the mercury to an unusual height, but influencing the height of the tides.

We have thus followed the development of the law of storms step by

step to the 50th parallel of latitude. We have hitherto found the hurricane blowing with great regularity, preserving in a remarkable manner a prescribed track, rotating with little variation in a determinate way, and the barometer falling and rising again with singular steadiness. But beyond that parallel of latitude we discover certain irregularities accompanying the veering of the wind and the attending phenomena, increasing as we advance towards the pole. To the investigation of the 'Gales of High Northern Latitudes,' the thirteenth chapter is devoted, and to us it is one of especial interest, for the hurricanes which visit our own islands are therein described.

Although it is not usual to find hurricanes blowing simultaneously in latitudes not far distant, still it sometimes occurs, and rotary storms have been met with following each other, and even overtaking one another, within a very short interval of time. The consequence of the convergence of the lines of longitude will lead storms, widely separated at their commencement, to approximate as they recede from the equator; and the increased dilatation of the whirl-storm in high latitudes tends to the same result. Bearing in mind the principles laid down, it will be readily understood how storms will either neutralise each other on coming in contact, or modify the force of one of the gales; and this result will follow whether the hurricanes are moving on the same or different parallels of longitude.



If upon the same parallels, the vanguard circles of the second storm will neutralise the rearguard circles of the first; if upon different parallels, the right-hand semicircle of the one will interfere with the left-hand semicircle of the other rotary gale—the wind in all these cases rotating in opposite directions. This will be understood by referring to the annexed diagram.

Turning to the records of remarkable storms which have blown across our islands, by far the most awful was the *great storm* of 1703. Originating, probably, in the vast inland seas embasined by the mountains, and overhung by primeval forests, or over an unpeopled district of North America, it reached the eastern part of that continent, thence it swept the Atlantic Ocean, and increasing in fury, passed over Britain; it crossed France, Holland, Germany, Sweden, the Baltic Sea, Russia, and a great part of Tartary, until it was lost in the Northern Ocean, returning probably to the spot whence it came, thus making a circuit of the globe. It raged with greatest violence on the 27th of November, Old Style—that is, 8th December of our reckoning. The day previous, the wind blew hard from the south-west, and during the continuance of the hurricane veered by west towards the north, when it again shifted to southwards. Though its fury was confined to less than a day and night, a week passed before the stormy winds which heralded and followed this devastating tempest

were lulled to rest, during the whole of which time the force of the wind was that of a strong gale. The destruction by this storm was incalculable. In this country alone, the loss of property was estimated at above four millions sterling. More than a hundred persons lost their lives on land, and 8000 seamen found a watery grave. The Eddystone Lighthouse was swept away, and, by a singular coincidence, Winstanley the architect—who was wont to boast of its stability, and to say he only wished to be in it when it blew a storm—was that night an inmate, and with the fabric perished. In the royal navy twelve ships were cast away, mounting 524 guns, and numbering 1600 men. Faintly to illustrate the impetuosity of the storm, a vessel laden with tin slipped from her moorings off Falmouth, and sped before the gale to the Isle of Wight, at the rate of more than thirty miles an hour.

A rotary gale of great violence visited the shores of England on the 5th December 1822; and another of similar character on the 3d of December in the following year. Upon the 29th of November 1836 a very remarkable hurricane blew in this country. It began on the 23d, off the coast of Newfoundland, reaching Land's End upon the day mentioned at 7.75 P.M.; it blew at Plymouth at 8.5, at Exeter at 9.5, at Poole at 10.5, at Farnham at noon, at London half an hour later; crossing to the continent, it reached Düsseldorf at 2 P.M., Berlin at 6, and Königsberg at 9 o'clock, being lost in Lithuania. The progression of this hurricane was about fifty miles an hour, and the velocity of the wind in the whirl was estimated at 135 miles in the same time. The barometer stood at 29.30 inches at 9 A.M. at London; at noon it fell to 28.82; and by 2 P.M. it had risen to 29.35.

The remarkable storms of November 1838, so well described by Mr Milne,* occupy a prominent place in this chapter. The first of these gales blew upon the 26th, and had its track to the west of Ireland; the second, which was much more severe, passed between Great Britain and Ireland, and crossed Scotland obliquely in a north-easterly direction. It began upon the 28th, but moving much more rapidly than the other, it overtook it in its course about the north of Ireland and S.W. of Scotland, the two neutralising one another to a certain extent at the place of junction; but the latter being the more violent, obtained the mastery. In the southern parts of the kingdom there were distinct indicia of a double storm, each having its own period of arrival and cessation, with barometric oscillation; whilst towards the north these indications became gradually less distinguishable, and were at length significant of one gale only. The first of these gales was met with on the 21st at Gibraltar, the wind veering to due west at night; on the 23d and 24th it blew in the Bay of Biscay; and on the forenoon of the 26th it impinged on the south coast of Cornwall, causing a gale which drove ships from their moorings. There it blew first at E., in the afternoon it veered to S.E., by 11 P.M. it was S., by noon of the following day it was due west, and in the afternoon it veered to the N.W. Its shifting from east to west, as it advanced northward, occurred in regular succession in different places; and the direction of the storm's centre up the Channel was proved by the fact, that while the wind veered from E. to W. by S. in England, it changed in the contrary direction on the coast

* Transactions of the Royal Society of Edinburgh, vol. xiv. pp. 467-487.

of Ireland. It commenced at Cork about 11 A.M. from S.S.E., reached Dublin about 3.5 P.M., and Farnborough at night—the wind veering from the eastward to north and north-west. It reached Cape Wrath on the morning of the 28th. This tempest travelled northwards at the rate of about ten miles an hour. The fall of the barometer on this occasion was well marked. At Edinburgh it fell to 27.7 inches. For more than a week previous to the 25th, both in this country and over a large portion of the continent, both on sea and land, the weather was frosty, with N.E. winds and a rising barometer—a state of weather well calculated to produce this result. 'Its fall on the 25th and 26th,' says Mr Milne, 'was everywhere rapid; but notwithstanding this, there still prevailed in the lower atmospheric regions of Britain on the 26th, and even on the morning of the 27th November, an easterly wind and severe frost, the well-known concomitants of a high and rising barometer, showing clearly that the upper regions of the atmosphere were in a very different state from those parts contiguous to the earth's surface.' Upon the night of the 27th the wind calmed in the south of England, and the barometer rose over the kingdom.

The second storm came also from the southward—probably from Madeira, where a strong gale drove ships from their anchorage. At Lisbon, the same storm blew on the 23d, and at Oporto on the 24th, giving to this tempest a progressive motion of nearly twenty miles an hour: it would reach the British islands on the 28th, and we find that on the morning of that day it set in furiously there—the wind shifting suddenly from a westerly breeze to a strong south-east wind, veering everywhere over the British islands from about S.E. to S.W. It impinged upon the Irish coast near Limerick at 2 A.M., reached Dublin and Liverpool about 1 P.M., Glasgow at 3 P.M., and St Abb's Head, in the east of Scotland, at 6 P.M. By marking the period of the greatest depression of the mercury at different places, and the exact time of the wind's changing from S.E. to S.W. or S.S.W. at the same stations, a similar result is obtained as regards the rate at which this hurricane moved. The track lay to the west of Ireland, and the dilatation of the whirl stretched from the middle of the Atlantic to the eastward of Paris.

A terrific hurricane raged upon our coasts upon the 6th—7th of January 1839, moving progressively about E.N.E. over Ireland and Great Britain, till it reached Gottenburg in Sweden. At Liverpool the wind veered from S.E. to S.W., and blew furiously at due west. The mercury fell to 28.29 inches. At Whitehaven the wind changed from S.W. to N.N.W. Many vessels were lost in this tempest, and in the Mersey alone at least one hundred persons found a watery grave. It blew with extraordinary fury over Ireland, in the central parts of which island stormy petrels were found when the wind had lulled to rest. Upon the eastern coast of England the effects of the storm were apparent: there the progress of the tide-wave was interrupted, as at Saltmarsh on the Ouse, five miles from the Humber, where the course of the river was dry, and at Gainsborough the *bore* did not appear. At Ostend, on the opposite coast, the reverse of this occurred.

Upon the 28th of February 1849, another rotary gale visited our island, its track being up the Irish Channel and across the south of Scotland, to the N.E. At Edinburgh the wind veered gradually from S.S.E. to S., S.W., W., and passed off at N.W. An extraordinary rise of the barometer, fol-

lowed by a sudden and great depression at Greenwich, was the precursor of this storm, the violence of which produced a horizontal pressure of twenty lbs. upon the square foot.

The last of the rotary gales which we shall notice, is the one which visited us upon the 5th—6th of February last year (1850). Its fury must be in the remembrance of all. In Liverpool, where we witnessed its effects, its violence was very great, causing the houses to tremble to their foundations, and leading to sad disasters at sea. It set in from the S.W. with a rapidly-declining barometer, gradually veering to the west, from which quarter its force was most terrific, and passing off towards morning in the N.W. The centre-path of this gale must have been in the Atlantic, considerably west of Ireland, and its track directed towards Scandinavia; consequently we were in the south-east segment of the whirl.

Passing to the fourteenth chapter, we find some good directions for sailing in these rotary gales on North Atlantic voyages. If the storm should be traversing Great Britain, it is clear that the vanguard segment gives a south-easterly and southerly wind, while the other half of the storm gives a westerly and north-westerly wind. If the ship has left port, and is overtaken by the tempest, she must either avail herself promptly of the veering of the wind to pursue her voyage, and clear the land, or lie-to till the gale has passed. If the wind be south-east, and the mercury falling, westerly winds will soon set in, and a ship in port on our eastern coast would soon encounter boisterous weather if she started on her voyage. On the other hand, if, on leaving the English Channel, south-west winds veering to west set in, the gale will soon moderate, and render it unnecessary to return to the port.

By studying the law of storms, and taking advantage of the wind as it hauls round, the passage across the Atlantic may be considerably shortened. On the other hand, by want of knowledge of these laws, the voyage may be protracted, and fraught with danger to ship and crew. Should a rotary gale be blowing up the Atlantic from the tropics, the advantage of the veering of the wind and sailing in curved courses will be greatest to vessels leaving the American port, for they will then fall in with the southern segment of the whirlstorm—the wind blowing from the north, north-west, west, and south-west, upon the larboard side. With ships bound for America the case is very different, for, sailing before the wind, they cross the storm's track in front of the vortex.

Our space forbids that we should notice the fifteenth chapter, on the 'Gales of High Southern Latitudes,' and the concluding chapter must be passed over in silence for a similar reason. There are two passages, however, which we cannot omit calling attention to—the one referring to 'the impolicy as well as inhumanity of sending ships to sea too deeply laden. The overloaded ship, which cannot rise upon the waves in a storm, is in danger of being struck by a weight of many tons of water. Her seams open by degrees. As she becomes leaky she sinks deeper in the water, and then the difficulty of standing to the pumps increases. If the cargo be of greater specific gravity than sea-water, when the ship fills she must go down.' Let the owners of our merchant-marine attend to this. The other regards the importance of the barometer, not only at sea, but in our fishing-

villages. 'It is impossible,' says our author, 'to overrate the value to the seaman of an instrument which will inform him of the changes in the atmospheric pressure over the place of his ship. The barometer is a measure of the atmospheric pressure, and should be regarded as nothing more. But that most valuable instrument has been brought into disrepute with many persons by the makers themselves, from their practice of marking on the face of the instrument indications of the weather not strictly correct. If the index of the barometer were simply divided into inches and parts of inches, the public generally would soon acquire the knowledge of how the instrument measures atmospheric pressure, and how that knowledge assists in forming a judgment on what will be the probable state of the weather.' Alas, the evil which has been inflicted by him who first adopted these arbitrary expressions!

On the cause of storms, we would, with Colonel Reid, in the present state of our knowledge, be silent. The opinion of Espy, that it arises from an ascending current caused by the disengagement of latent heat, and consequent rarefaction of the atmosphere, may be correct, but certainly it does not explain the ordinary phenomena. The hypothesis of Dove, that it arises from the eddy of conflicting winds, is much more plausible, especially when we link with it the suggestion of Sir John Herschel, that there may be a premature diversion downwards of that aërial stream which floats in the higher regions of the atmosphere, from the equator to the poles. Mr Thom has spoken of winds oppositely electrified, but we know not exactly whether electricity is not induced by the friction of the aërial particles, and becomes the consequence rather than the cause.