Practical Rules.

In the preceding pages we have sought to reduce to certain principles the behaviour of the vane and the barometer, under the influence of the different classes of storms which may occur in the temperate and torrid zones, and have indicated their variations, which are due to the Law of Gyration. We may now pass on to the solution of the following problem, viz. what are the indications which the instruments will give of the approach of a storm. Ships' barometers are certainly costly instruments, and are liable to breakage at the moment of danger*; but aneroid barometers can be got for a moderate price (50*s.* to 60*s.*), and may be fastened up, like a clock, to the cabin bulk-head. There is no doubt that, by a general use of these instruments, whose accuracy is quite sufficient for the purpose, danger might often be escaped, as the warning they give is so timely that it will often be possible to reach a safe harbour or to postpone putting to sea. The weather-scale (words), which is printed on most barometers, may lead to error; so that I shall give briefly the rules for the variation of the instrument.

1. Region of the Trade-winds.

The permanent wind of the torrid zone, NE. in the

* Thom recommends the sympiesometer which is described in the Edinburgh Journal of Science, No. 20, as particularly accurate in its indications.

northern, SE. in the southern, hemisphere, is divided by the intermediate zone of Calms into two parts. This zone does not fall exactly on the equator, but a little to the northward of it, so that the SE. Trade-wind extends as a S. wind a few degrees above the equator into the northern hemisphere. The breadth of this zone is greater in summer than in winter (*vide* Tables, pp. 20–24).

In the zone of the Trade-winds the level of the barometer varies very slightly in the yearly period, but on the outer edge of that zone stands about one or two tenths of an inch higher than on its inner edge; so that the barometer gradually falls to this extent as the ship approaches the equator. In the diurnal period it changes very regularly, reaching a maximum at about 9 A.M. and P.M., and a minimum after 3 A.M. and P.M. This variation, however, hardly extends above a tenth of an inch (p. 42).

In the centre of a cyclone the fall of the barometer is often an inch*; so that it follows at once that a sudden and rapid fall of the barometer indicates the approach of a cyclone.

The path of a hurricane divides that portion of the earth's surface, over which it is circling, into two regions, in

* In addition to the instances recorded above, we have the following notices of the fall of the barometer in certain localities:—

Ship *Duke of York*	at	Kedgeree	in 1833, 2·70 in.
„ *Howqua*	„	Timor Sea	„ 1844, 2·20
„ *John O'Gaunt*	„	China Sea	„ 1846, 2·15
Brig *Freak*	„	Bay of Bengal	„ 1840, 2·05
Ship *Exmouth*	„	South Indian Ocean	„ 1846, 2·00
		Havannah	„ 1846, 1·95
Ship *London*	„	Bay of Bengal	„ 1832, 1·90
„ *Anna*	„	China Sea	„ 1846, 1·85
		The Mauritius	„ 1824, 1·70
Ship *Neptune*	„	China Sea	„ 1809, 1·55
Port Louis	„	The Mauritius	„ 1819, 1·50
Brig *Mary*	„	West Indies	„ 1837, 1·50

(Piddington, *Horn-Book*, p. 264.)

which the shift of the wind, as observed at a stationary point, is different. In the right hand* semicircle, on either hemisphere, it is 'with the hands of a watch' N., E., S., W., N.; in the left hand semicircle it is 'against the hands of a watch' N., W., S., E., N. This shows us that if a captain finds it necessary to lay his ship to, he must take great care to find out which is the proper tack. The right tack, in all cases, is that which will allow the ship, when the wind shifts, to come up with it. This would be the starboard tack in the right hand semicircle (starboard tacks taut; if the wind be ENE., course of ship N.), and the port tack in the left hand semicircle (port tacks taut; if the wind be NNE., course of ship E.). If the ship were on the wrong tack in the respective semicircles, she would have to fall off in order to follow the wind as it shifts, and meanwhile be in a very perilous position, unable to offer any resistance, as her yards would be taken aback, even though she were under bare poles.

If we go on and draw through the centre of the cyclone a line perpendicular to the direction of its advance, we shall divide the two semicircles into four quadrants. It is easily seen that the most dangerous quadrant of the two, which lie in front of the observer at the centre, must be that in which the wind is blowing towards the path of the storm. This will be the right hand quadrant on the northern, the left hand on the southern hemisphere. In these two quadrants a ship cannot get farther away from the centre by sailing with the wind free. There is then nothing else for the captain to do but to heave-to on the proper tack, viz. the starboard tack on the northern, the port tack on the southern,

* *Right hand* and *left hand* refer to an observer, placed at the centre of the cyclone circle, and looking forwards along the direction in which the storm is advancing.

hemisphere. If, however, the ship is in a locality in which the direction of the path of the cyclone is pretty certain, and finds herself, judging from the direction of the wind at the beginning of the storm, in such a position in the most dangerous quadrant, that the centre of the cyclone must pass very close to her, she will not run any greater risk by scudding before the wind and crossing the path of the cyclone, and then sailing out of the circle on the same course, than she would have run if she had been hove-to.

In the left hand quadrant of the northern hemisphere, the right hand of the southern, a ship can get farther away from the centre by sailing before the wind. If the hurricane is too violent to allow of scudding, or the ship is so far from the centre that she has nothing to fear, and would be taken too much out of her course by scudding, she may be placed on the port tack in the northern hemisphere and on the starboard tack in the southern.

The two other quadrants of the circle, those behind the centre, are the least dangerous quadrants, as the centre of the cyclone is moving, of itself, away from ships situated therein.

The cyclones of the Atlantic Ocean advance usually from SE. towards NW. within the torrid zone. Accordingly, if the wind shifts from ENE. through E. towards ESE., &c., the ship is lying on the right hand (i. e. NE.) side of the cyclone, and ought to steer towards the NE. in order to get away from the centre. This is impossible; so she must heave-to on the starboard tack, and lie successively towards N., NNE., NE., &c.

If the ship be hove-to, and finds that the wind is keeping in the N.E. point and increasing, and that the barometer is falling rapidly, the captain may be quite sure that he is close to the track of the centre of the cyclone, which is coming upon him from the SE.; so that, after the lull, he may expect the hurricane to blow from the SW., and the barometer to rise rapidly. In such a case the ship ought to run before the wind towards SW., when she will soon find the barometer falling less rapidly, and the wind getting round towards N.; she must, however, hold on for some time longer on her southerly course.

If the wind shifts 'against the sun' from NNE. through N. towards NNW., &c., the ship must be lying on the left hand side of the path of the cyclone in its advance from SE. towards NW., and should hold a SW. course. If this be from any reason impracticable, she must heave-to on the port tack, and lie successively towards E., ENE., NE., &c.

The following table, for the use of the seaman on the northern hemisphere, contains the position in which the ship should be laid, or the course she should hold, for every point from which the wind can possibly blow in the most dangerous quadrant; it also contains the other quadrants, as is easily seen. Nos. 1 to 17 represent all the winds which could be especially dangerous to ships in any Typhoons, which are travelling in the directions between NE. to SW. and SE. to NW.; Nos. 5 to 17 the West India hurricanes within the torrid zone; Nos. 9 to 22 their course from the tropics to about the latitude of the Bermudas; Nos. 15 to 25 their farther course in the temperate zone.

The 2nd column gives the horizontal tangents to the cyclone circle, or the direction of the wind at any point at the commencement of the storm. The 3rd column gives the bearing of the centre with regard to the ship. The 4th gives one series of directions in which the wind may shift, for each of which the 5th column gives the course to be held or the tack on which she must be hove-to. The 6th and 7th columns are related in a similar manner and refer to the most dangerous side of the cyclone.*

NORTHERN HEMISPHERE.

	Direction of Wind at beginning of Storm	Bearing of centre from Ship	Shift of Wind	Corresponding course to be held		Shift of Wind	Course to be adopted
1	NW.	NE.	NW. towards W.	SE.	Or else, heave the ship to on the port tack.	NW. towards N.	Ship to be hove-to on the starboard tack.
2	NW. by N.	NE. by E.	NW. by N. „ W.	SE. by S.		NW. by N. „ N.	
3	NNW.	ENE.	NNW. „ W.	SSE.		NNW. „ N.	
4	N. by W.	E. by N.	N. by W. „ W.	S. by E.		N. by W. „ N.	
5	N.	E.	N. „ W.	S.		N. „ E.	
6	N. by E.	E. by S.	N. by E. „ N.	S. by W.		N. by E. „ E.	
7	NNE.	ESE.	NNE. „ N.	SSW.		NNE. „ E.	
8	NE. by N.	SE. by E.	NE. by N. „ N.	SW. by S.		NE. by N. „ E.	
9	NE.	SE.	NE. „ N.	SW.		NE. „ E.	
10	NE. by E.	SE. by S.	NE. by E. „ N.	SW. by W.		NE. by E. „ E.	
11	ENE.	SSE.	ENE. „ N.	WSW.		ENE. „ E.	
12	E. by N.	S. by E.	E. by N. „ N.	W. by S.		E. by N. „ E.	
13	E.	S.	E. „ N.	W.		E. „ S.	
14	E. by S.	S. by W.	E. by S. „ E.	W. by N.		E. by S. „ S.	
15	ESE.	SSW.	ESE. „ E.	WNW.		ESE. „ S.	
16	SE. by E.	SW. by S.	SE. by E. „ E.	NW. by W.		SE. by E. „ S.	
17	SE.	SW.	SE. „ E.	NW.		SE. „ S.	
18	SE. by S.	SW. by W.	SE. by S. „ E.	NW. by N.		SE. by S. „ S.	
19	SSE.	WSW.	SSE. „ E.	NNW.		SSE. „ S.	
20	S. by E.	W. by S.	S. by E. „ E.	N. by W.		S. by E. „ S.	
21	S.	W.	S. „ E.	N.		S. „ W.	
22	S. by W.	W. by N.	S. by W. „ S.	N. by E.		S. by W. „ W.	
23	SSW.	WNW.	SSW. „ S.	NNE.		SSW. „ W.	
24	SW. by S.	NW. by W.	SW. by S. „ S.	NE. by N.		SW. by S. „ W.	
25	SW.	NW.	SW. „ S.	NE.		SW. „ W.	

Cyclones appear to be less frequent in the south-east trade. If, in that region, the barometer is observed to be falling, while the wind is shifting from SSE. through S., SSW., SW., towards NW., the ship is on the north-west or right hand side of a cyclone which is advancing from

* (James Sedgwick.) The true Principles of the Law of Storms, practically arranged for both Hemispheres. London, 1854, 8vo.

Remarks on Revolving Storms, published by order of the Lords Commissioners of the Admiralty. London, 1853, 8vo.

NE. towards SW., and must therefore hold a NW. course, or else heave-to on the starboard tack. If the barometer continues falling while the wind holds in the SE., and is increasing, the ship is close to the path along which the centre is approaching. In this case the wind will chop

SOUTHERN HEMISPHERE.

	Direction of Wind at beginning of Storm	Bearing of centre from Ship	Shift of Wind	Corresponding course to be held		Shift of Wind	Course to be adopted
1	S.	E.	S. towards W.	N.	Or else, heave the ship to on the starboard tack.	S. towards E.	Ship to be hove-to on the port tack.
2	S. by E.	E. by N.	S. by E. „ S.	N. by W.		S. by E. „ E.	
3	SSE.	ENE.	SSE. „ S.	NNW.		SSE. „ E.	
4	SE. by S.	NE. by E.	SE. by S. „ S.	NW. by N.		SE. by S. „ E.	
5	SE.	NE.	SE. „ S.	NW.		SE. „ E.	
6	SE. by E.	NE. by N.	SE. by E. „ S.	NW. by W.		SE. by E. „ E.	
7	ESE.	NNE.	ESE. „ S.	WNW.		ESE. „ E.	
8	E. by S.	N. by E.	E. by S. „ S.	W. by N.		E. by S. „ E.	
9	E.	N.	E. „ S.	W.		E. „ N.	
10	E. by N.	N. by W.	E. by N. „ E.	W. by S.		E. by N. „ N.	
11	ENE.	NNW.	ENE. „ E.	WSW.		ENE. „ N.	
12	NE. by E.	NW. by N.	NE. by E. „ E.	SW. by W.		NE. by E. „ N.	
13	NE.	NW.	NE. „ E.	SW.		NE. „ N.	
14	NE. by N.	NW. by W.	NE. by N. „ E.	SW. by S.		NE. by N. „ N.	
15	NNE.	WNW.	NNE. „ E.	SSW.		NNE. „ N.	
16	N. by E.	W. by N.	N. by E. „ E.	S. by W.		N. by E. „ N.	
17	N.	W.	N. „ E.	S.		N. „ W.	
18	N. by W.	W. by S.	N. by W. „ N.	S. by E.		N. by W. „ W.	
19	NNW.	WSW.	NNW. „ N.	SSE.		NNW. „ W.	
20	NW. by N.	SW. by W.	NW. by N. „ N.	SE. by S.		NW. by N. „ W.	
21	NW.	SW.	NW. „ N.	SE.		NW. „ W.	

about to NW. after the lull, and the barometer will begin to rise. In this case the ship must run before the wind towards NW., and she will soon find the wind shifting towards S., but must hold on, on a north-west course, for some time longer. If the wind shifts in the opposite direction, from E. through ENE., NE., &c., towards NW., the ship is on the south-east or left hand side of the path of the centre, which is advancing from NE. towards SW., and is therefore in the most dangerous quadrant, so that all that she can do is to heave-to on the port tack.

The table (p. 291) for the southern hemisphere corresponds to that just given for the northern.

There is one point which must be remembered in the use of these tables, viz. that the shift of the wind within the cyclone is that which would be observed at a stationary point. This may, in many cases, if the ship be itself making considerable way, be converted into a shift in a direction which is exactly opposite to that which would have been observed if the ship had been stationary in either of the cyclone semicircles, or at least may undergo considerable modification. This will always happen if the ship be in the most dangerous quadrant, and be scudding before the wind exactly as fast as the cyclone is advancing, or perhaps be gaining on it. In order to illustrate this, I shall take the case of a ship in the middle of the most dangerous quadrant (enclosed between NW. and NE.) of a cyclone which is advancing from SE. towards NW. on the northern hemisphere. I shall take the diameter of the cyclone at 300 miles, and its rate of advance at 10 knots an hour. She would have the wind E. at the commencement of the hurricane, and this wind would shift towards S. in the course of the storm if it were observed at a stationary point.

If the ship scuds ten knots an hour before the wind, she will find that the wind shifts to NE. in the first twelve hours and that the barometer falls rapidly. She will then cross the path of the cyclone with this wind, and will find that the wind shifts more rapidly half round the compass, to SW., in the course of the next seven hours. Between the fifteenth and sixteenth hour the barometer will reach its lowest level, while the wind is NW., as the ship will be only about thirty miles from the centre. The ship will cross the path of the centre for the second time between the eighteenth and nineteenth hours, but this will be after the centre has passed on, and the storm will end with a S. wind after about thirty hours.

If we suppose the ship in the same place as before, but the rate of advance of the cyclone 1·5 times as great as the rate at which the ship is sailing, and therefore fifteen knots an hour, she will find the wind still holding in the E. and increasing during the first ten hours. In the next four hours the wind will have the normal shift towards SE., and be most violent at this last point, when the barometer is lowest. The cyclone will terminate after about twenty-eight hours, during the last ten of which the wind will have been due S. She will have approached to within ten or fifteen miles of the centre between the fourteenth and fifteenth hours.

A ship which is hove-to in a cyclone, though she may have one or two knots an hour drift, will always have a normal shift of wind, i.e. the shift which would be given by the preceding rules for either semicircle, the right hand or the left hand one. The seaman cannot be too strongly urged to heave-to in the first instance if he is in waters which are liable to these cyclones, and is led by the signs of the weather to expect one. If his ship is once hove-to, he may ascertain accurately his position with regard to the cyclone, and then, either hold on on his former course, or choose any other which may be advisable for him, or, lastly, heave-to on the proper tack.

As regards the period at which these storms are especially prevalent in the different parts of the torrid zone, we may say, as a general rule, that they usually occur when the sun is at its highest altitude, and reach their maximum of frequency at the end of this period; consequently, in September in the West Indies and the

China Seas; in February and March at the Mauritius and in the South Indian Ocean; while in the Bay of Bengal they appear to be most frequent at the change of the Monsoons, i. e. in May and October. In addition to the figures already given, we find in Piddington's 'Horn-Book' (p. 296, third edition, 1860) the following table*:—

TABLE OF AVERAGE NUMBER OF CYCLONES IN DIFFERENT MONTHS OF THE YEAR, AND IN VARIOUS PARTS OF THE WORLD.

For what number of years ascertained	Locality	Authority	Months											
			Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
123	West Indies	Nautical Magazine . .	...	...	...	...	...	1	2	13	10	7	...	...
59	"	U. S. Journal, 1843, p. 3	...	...	...	...	...	1	5	13	13	9	...	...
300	"	Royal Geographical Society	5	7	11	6	5	10	42	96	80	69	17	7
39	Southern Indian Ocean, 1809–1848	Reid, Thom, H. Piddington	9	13	10	8	4	...	...	...	1	1	4	3
24	Mauritius, 1820-1844	Mon. A. Labutte, Trans. Royal Society of Mauritius, 1849 .	9	15	15	8	...	...	...	...	...	...	...	6
25	Bombay	. . . .	1	1	1	5	9	2	4	5	8	12	9	5
46	Bay of Bengal, 1800-1846	H. Piddington . . .	1	...	1	1	7	3	...	1	...	7	6	3
64	China Sea, 1780-1845	H. Piddington, Captain Kirsopp . .	...	...	...	...	1	2	5	5	18	10	6	...

The storms of the temperate zone in the southern hemisphere have more the character of gales than of cyclones, as is shown by the fact that the predominant

* I have quoted from the last edition of the Horn-Book, and the table is more complete than that which is given in Professor Dove's work. My reason for doing so is that I find the following remark on the table in the Horn-Book:—

'In the former editions of this work, I have stated that no cyclones have been known to occur in the month of May in the China Sea; but from a letter from Capt. E. T. F. Kirsopp, commanding the steamer *Juno* at Manilla, I learn that a severe cyclone was experienced in the Bay of Manilla and in the adjacent China Sea as early as May 4, 1850. . . . . The essential matter, however, for us at present is the fact, that severe cyclones may occur in May in the China Sea, and thus upon the appearance of doubtful weather or an uneasy barometer the careful seaman will take due precaution.'

The importance of this fact will be, I hope, sufficient excuse for my adding it to the text. — *Trans.*

change of direction is in accordance with the Law of Gyration. In the '*Ondersoekingen met den Zeethermometer*' ('Experiments with the Marine Thermometer'), we read at p. 109—'The course of the winds in storms is, with few exceptions, from N. through W. towards SSW. Storms which begin with SSE. last longer, and do not change their direction much.'

The barometer stands lower during all storms in the southern hemisphere than when there is no storm, as is shown by the following table:—

Latitude . . .	35°—40°	40°—45°	45°—50°
N.	−0·498	−0·405	−0·490
NNE.	−0·498	−0·482	−0·291
NE.	−0·409	−0·441	−0·456
ENE.	−0·291	−0·449	− ...
E.	−0·350	−0·354	− ...
ESE.	−0·370	−0·295	−0·047
SE.	−0·272	−0·228	− ...
SSE.	−0·413	−0·378	−0·705
S.	−0·252	−0·478	−0·478
SSW.	−0·276	−0·394	−0·456
SW.	−0·315	−0·563	−0·311
WSW.	−0·323	−0·582	−0·378
W.	−0·425	−0·567	−0·478
WNW.	−0·374	−0·689	−0·571
NW.	−0·401	−0·547	−0·456
NNW.	−0·466	−0·433	−0·445
Mean . . .	−0·401	−0·414	−0·427

This shows us that the barometer stands lowest with the equatorial current, as the polar current does not produce so great a depression.

Ordinary tornados and thunderstorms occur on each hemisphere at the time at which the sun has his greatest altitude; so that they occur during our summer in the northern, during our winter in the southern, hemisphere. The hurricanes also assume the character of thunderstorms, i. e. they are accompanied by heavy rain and violent electrical explosions. The appearance of the sky, as a cyclone is coming on, is characterised by masses of clouds which are continually changing their form, and frequently by a bank of clouds, in the distance, of extraordinary blackness.

On dry land, in certain regions, the Trombs take the peculiar form of dust whirlwinds, of which Baddeley* has given a very vivid description. The amount of electricity which is excited by the friction of the sand is so great that he was able to obtain from an insulated wire, not only bright sparks, but a continuous discharge of electricity.

As to the motion of the waves in a cyclone, they move out from the centre in directions which are more nearly radii of the circle the farther they are distant from the centre. Consequently, they move from the centre towards the circumference in lines somewhat inclined in the direction in which the storm is rotating. Reid has already drawn special attention to this fact.

Hence we obtain the following differences in this respect between the three classes of storms which we have considered.

1. In a cyclone, the waves move at right angles to the direction of the wind, and the more so the farther they are from the centre.

2. In a heavy gale, they move in the direction of the wind.

3. In the case of a wind which has been stopped by another, they move against the wind. (Seamen then say that two winds are fighting with each other.)

All that we have said hitherto has referred to the torrid zone, properly so called, not to the outer edge of the

* Whirlwinds and Dust-Storms of India, illustrated by numerous Diagrams and Sketches from Nature.

Trade-winds, which shifts up and down with the sun like the belt of Calms. Hence the torrid zone will be bounded in all parts, excepting where the Monsoons are prevalent, by a belt, in which calms are of frequent occurrence, and which is called the sub-tropical zone. This zone forms a complete contrast to that which lies close to the equator. At the latter the air is continually ascending, at the former it is descending. At the equator the barometer is low, at the tropics it is high. At the equator the rain falls in summer, in the sub-tropical zone in winter. At the equator the two winds flow towards each other, in the sub-tropical zone they flow in opposite directions away from the tropics. All stations which belong to the sub-tropical zone are included during the summer in the Trade-wind, on its prolongation backward at that season, and during the winter are outside its area. Such a prolongation in the direction of the poles as that described, is manifested in its most extensive form in the case where a great desert, like that in Northern Africa, prolongs the torrid zone into higher latitudes to a disproportionate extent. Hence, during the summer, northerly winds are prevalent in the Mediterranean, and are known under the name of *Tramontane*, while the *Sirocco* attains as exclusive a predominance in the winter, being the return counter Trade which has descended to the surface of the earth. This is the reason that the seaman finds, at the commencement of the Trade-wind, a more northerly wind on the east side of the Atlantic Ocean than on its west side.

2. District of the Monsoons.

During the summer months in the Indian Ocean, the SE. Trade-wind is prevalent in that part of the torrid zone which is in the southern hemisphere, and the SW. Monsoon in that part which is in the northern.

In the winter months the NE. Trade-wind is felt to the north of the equator, and the NW. Monsoon to the south of it.

In consequence of this alternation, the NE. Trade is termed NE. Monsoon, and the SE. Trade SE. Monsoon.

In spring and autumn, in the so-called 'change months,' there are calms; on the coast, sea and land winds in the daily period. The change from one Monsoon to the other is usually accompanied by a storm, 'the breaking-up of the Monsoon.'

The SW. Monsoon extends much farther to the N. (lat. 30°) in the northern hemisphere than the NW. Monsoon towards the S. in the southern; however, the latter extends also far to the S. on the African coast.

The rainy season is observed, as it is in the region of the Trade-winds, when the sun is highest. It is, therefore, during the SW. Monsoon on the northern, and during the NW. Monsoon on the southern, hemisphere.

There is, however, a difference in the behaviour of the barometer. In the region of the Trade-winds it remains nearly constant throughout the year, in that of the Monsoons it varies regularly. During the SW. Monsoon the barometer stands several tenths of an inch lower than in winter, especially in the northern portion of the district; and similarly in the southern hemisphere, it stands lower during the NW. than during the SE. Monsoon. At the equator this annual variation of the barometer disappears nearly entirely, in consequence of the compensation of the two opposite variations.

The rotations of the storms of the China and Indian Seas are the same as those in the same latitudes in the region of the Trade-winds; however, on the coast of

China, their motion is rather from E. to W. than from SE. to NW. One important distinction is to be observed, that, in the district of the Monsoons, the storms are felt with great violence in the southern hemisphere as well as in the northern.

The rotation of the vane during the Typhoons, although the direction of the rotation of the air itself is quite fixed (contrary to the hands of a watch), is yet, in consequence of the uncertainty of the direction in which the centre may possibly move, less fixed than during the West Indian storms. They take place during the SW. Monsoon, and occur up to November, being most frequent in September.

If the Typhoon move from NE. to SW., on the NW. side of its path, the rotation is N., NE., E., or with the sun; on the SE. side WNW., SW., SSE., or against the sun. On the south coast of China the rotation is generally N., NE., E., SE., as the Typhoons which are passing from E. to W. usually pass to the south of the coast.

According to Thom, the storms are never felt in the Indian Ocean excepting at the time when the NW. Monsoon is prevalent between the equator and the tenth or twelfth degree of south latitude, and are most common just after the winter solstice, when the sun is turning back from the Tropic of Capricorn.

The cyclones are most common in the district between the SE. Trade-wind and the NW. Monsoon, which is called the region of the 'variables.'

The rotatory motion takes place in the direction from E. through S. towards W. and N. The intensity of the cyclone increases regularly towards its centre. At the centre itself there is a dead calm, and the greatest violence of the storm is experienced at the edge of this calm circle. The diameter of this circle is greatest when the storm is just commencing. If the rotatory motion increases in violence, the diameter of this circle is decreased to about ten or twelve English miles.

The advance of the cyclone, up to lat. 20° S., is at the rate of 200 to 220 miles in the twenty-four hours. From that point it becomes less rapid up to the outer edge of the SE. Trade.

The direction of the advance is from lat. 10° S. near the Indian Archipelago, to lat. 28° or 30° on the east coast of Africa; first towards WSW., then towards SW. by S., and lastly towards SSW.

Throughout the whole of the cyclone torrents of rain fall, which are more violent in front of it than behind it. The clouds are dark, massive, and lead-coloured, as the centre is approaching. Electrical explosions are most frequent on that side of the cyclone which is nearest to the equator.

The sea is disturbed irregularly to the distance of 300 or 400 miles during every such storm.

The barometer falls rapidly as the centre of the cyclone approaches, but the lowest level appears to occur a little before it passes.

3. North Temperate Zone.

In my 'Meteorological Investigations,' 1837, I have stated expressly that the principal characteristic of the climate of the temperate zone is the alternation of two currents of air, of which the one flows from the pole to the equator, the other from the equator to the pole; and in my 'Non-Periodical Variations of Temperature on the Surface of the Earth,' six parts, 1840–59, as well as in the 'Representation of the Phenomena of Temperature by Means of Five-Day Means,' I have proved that these currents move simultaneously in proximity to each other.

Hence, in these localities we can no longer speak of a constant direction of the wind, as in the zone of the Trade-winds, nor of one which changes periodically, as in that of the Monsoons, but only of a mean direction. This mean direction is nearly SW.* in the north, and NW. in the south, temperate zone; inasmuch as the equatorial currents are more prevalent than the polar. In Europe this westerly direction is more southerly in winter than in summer; in America the reverse is the case; and the gradual transition from one of these conditions to the other takes place on the Atlantic Ocean. Violent storms are felt here less frequently in summer than in the winter months, and in the Mediterranean Sea at the transition of one season into the other; whence they are called here 'equinoctial storms.' These storms are either, 1, gales, i. e. ordinary winds whose intensity has been greatly increased, and which cause the vane to rotate with the sun, but through comparatively small arcs; 2, cyclones from the torrid zone, which have changed their path on crossing the outer limit of that zone, and have taken a course from SW. to NE. in the northern, and one from NW. to SE. in the southern, temperate zone; 3, currents, which, by their mutual interference, have checked and then repelled each other; or 4, storms, produced by the sudden intrusion of the cold polar current into the warm equatorial current, a case of which many remarkable instances have been noted. Hence, the barometer during the yearly period neither remains steady nor varies regularly, but is subject to oscillations, which are greater in winter than in summer. The mutual alternation of the currents is indicated by a rotation of the vane with the sun, i.e. S., W., N., E., S. on the northern, and N., W., S., E., N. on the southern, hemisphere. Hence we

* See Note, p. 82.

derive the following general rules for the variations of the meteorological instruments:—

Since the southern current is warm, moist, and rarefied, the northern, on the contrary, cold, dry and dense, we derive the following rules for their alternation; and we must remember that the cold polar current appears first in the lower strata of the atmosphere, while the warmer equatorial current will always have existed for some time in the upper strata before it is felt below. The changes of weather on the west side of the compass are, therefore, simultaneous with the changes of the barometer, while on the east side the indications of the barometer always precede the fall of rain which takes place. If the wind shifts from S. to N. through W., the barometer rises and the thermometer falls. This transition is characterised in winter by heavy falls of snow, in spring by sleet showers, and in summer by thunderstorms, after which the air becomes much cooler. If the wind veers from N. to NE., we have clear weather, the air is dry, the barometer high, and in winter intense cold follows, with great clearness of the atmosphere. As soon as the barometer begins to fall the wind gets round to the E.; the sky, previously deep blue, covers itself with thin whitish clouds, and the snow which falls comes from the S. wind, which has already set in above. If the barometer falls rapidly, the snow turns to rain, and a thaw sets in, when the wind veers farther through SE. and S. towards SW.*

The transition from a clear sky to an overcast one

* The first notice of this transition is to be found in Drebbel, *De Naturâ Elementarum* (concerning the nature of the elements), 1621. 'If we see a thick cloud rising in summer not far from the south-west, we expect, and also find, that a SW. wind will soon blow, then a W., NW., and lastly a NNE. You see also why the E. or SE. wind brings such heavy and continued rain with it in Holland and the adjacent countries. I could very easily explain, on natural grounds, the reasons of all these phenomena.'

usually commences with the appearance of fine streaky cirrus clouds, which gradually change to cirrostratus, and then the uniform coating of cloud is complete. This cirrus represents the equatorial current, seen from beneath, which has already set in above, and marks its progress by the streaks of cloud. The water, on its condensation from the state of vapour, assumes the solid form at once; so that these high clouds are not composed of bubble steam*, but of minute spiculæ of ice, and they give rise to the halos of the sun and moon, which are caused by refraction of the light, and to the so-called rings, mock-suns, and mock-moons.

If these appearances accompany a falling barometer, it is a sure sign that wet weather is coming on.† The reason that the long streaks of the cirrus appear to us as arcs of circles which diverge from one point of the horizon and reunite at the opposite point, is that they are projected on the apparently curved surface of the sky. This apparent curvature of the cirrus differs from the lateral feathery off-shoots of the same clouds, which show that the direction of the upper wind is not quite constant. This latter form of cirrus, consequently, is a less certain sign of rain than the long arched clouds are. There is another form of cirrus, which does not always indicate rain, as the air gets warmed during the day and ascends; if the temperature be high this ascending current sometimes reaches as high as the cirrus above, and then the latter

* *Nebelbläschen* is the word translated 'bubble steam' (*vapeur vesiculaire*, Fr.). It indicates visible steam, as distinguished from vapour, which is invisible. (*Trans.*)

† The hollow winds begin to blow,
The clouds look black, the glass is low;
Last night the sun went pale to bed,
The moon in halos hid her head:
'T will surely rain.

breaks up into small cumuli, which are known in Germany under the names of *Schäfchen*, *Lämmer-Gewölk* in South Germany, *brebis* in France, *fleecy clouds* in England, and were called by the Romans *vellera lanæ*. Howard calls them 'cirro-cumuli.' In the south of Europe they are said to be a sign of rain. In Northern Germany this is not the case, according to my observations.

When the atmosphere is warm and dry, the outlines of distant objects become indistinct and hazy, owing to the dust which is suspended in the air, and the sun appears reddish. If easterly and northerly winds have lasted for a long time in summer, with very dry weather, and a moist wind sets in, its aqueous vapour condenses itself at once on the dust which is in the air, which thus becomes heavy and sinks to the ground. Under these circumstances, the air becomes very clear, and in mountainous countries the mountains appear quite close, and the waterfalls are heard more distinctly. This is considered an infallible sign of rain.

The rain comes, as a general rule, from the west side; so that a clear sunset is a proof that there is no rain coming from that quarter for some time. Hence, this is considered to be a sign of fine weather.

In the evening, when the air ceases to ascend, the clouds sink, and are dissolved in the warm strata below. From this nothing can be augured for the following day. There is an old French proverb:—

Temps, qui se fait beau la nuit,
Dure peu quand le jour luit.*

If the atmosphere is very damp, evaporation cannot go on, and this feeling produces in us the sensation which we designate by sultriness, *drückende Luft*. The direct

* Weather which clears up at night, will not last when the day breaks.

action of the sun is then more felt, and we say the sun is scorching.

If the south wind sets in suddenly in the upper strata in winter, the rain falls at once at that level, and small transparent grains of ice, i.e. rain frozen while falling, reach the ground. We say then that *Glatteis* (glazed frost) is falling, as the rain which soon sets in freezes on the ground and glazes it. We may then expect a SW. storm with a great fall of the barometer.

In winter, rain, with a west wind and a rising barometer, turns to snow; snow, with an east wind and a falling barometer, to rain.

In spring, if the wind shifts through W. to N., we may expect the weather to clear up suddenly and night frosts to set in, even though the thermometer, at a little height above the ground, may not fall below the freezing point.

Heavy thunderstorms, which come up with an E. wind while the barometer is falling, do not cool the air. We say that it is still sultry and there will be another thunderstorm. The air does not grow cooler till a thunderstorm comes up from the W. and the barometer begins to rise.

If several thunderstorms come on in succession from the W., each successive storm is usually more northerly than that which has preceded it.

In the case of thunderstorms from the W., the under current is usually more northerly than the upper one; consequently the true thunderclouds (cirro-strati) drive more or less at right angles to the lines of the cirrus above them.

The greater the difference of temperature between the two currents which displace each other, and accordingly the greater contrast there is between their directions, the more likely they are to produce a thundercloud. The winds stop each other's path and produce a calm before the storm comes up. The cold wind then breaks in suddenly, and it is a mistake to say that the thunderstorm has made the wind change.

The winter thunderstorms in Norway are westerly storms, in which the under current is shifting quickly towards N. The barometer rises and cold follows. They are preceded by a thaw, mild weather, heavy rain, and southerly winds.

Our winter thunderstorms in Germany, which are rare, exhibit the same character. There is, however, another type of these storms. This is exhibited when the equatorial current sets in with great violence. In such a case, the thunder and lightning are often so tremendous that we say the sky is bursting open (*der Himmel öffnet sich*). They are followed by a complete spring wind.

The time at which thunderstorms are most common is regulated by the commencement of the rainy season. They are most common in the height of summer in the torrid zone; in mid-winter in the district of the sub-tropical rains at the outer edge of that zone; in spring and autumn in the south of Europe; and in the middle of summer in that part which is north of the Alps, with the exception of Norway. They are, on the whole, rare in the frigid zone, but yet do occur there up to high latitudes. Lastly, they occur in volcanic districts, as secondary results of the rapidly ascending current above a volcano in eruption, and at times at which they are never observed unless under these circumstances.

If bad weather continues for a long time, the vane oscillates between SW. and W., and the barometer fluctuates slightly. This is the true equatorial current.

Thunderstorms in spring lie at a low level, and do not last long; they are usually followed by a return of cold weather. They are at times accompanied by sleet or snow, and they frequently do considerable damage by means of lightning. The lower wool-pack clouds drive with a WNW. wind, the upper cirrus with SSW.

If the barometer rises very quickly, this indicates, not that the southern and northern currents are interfering with each other laterally, but that they have met and mutually stopped each other's way. A severe storm is sure to follow; and if the barometer falls as quickly as it has risen, it shows that the southern current has prevailed, and that the danger is therefore close at hand. In this case, the lettering of a barometer which bears 'very dry' for this level is totally wrong.

If in winter a cold and a warm wind meet each other, and the southerly current has not sufficient force to overcome the resistance of the northerly current which opposes it, the barometer rises to a great height at the line of contact, and a thick fog appears there. This fog often disappears suddenly and reappears again, according as the southerly current gives way a little, and the place of observation comes off the line of contact into the true northerly current, and vice versâ. If severe cold follow such a fog, it shows that the northerly current has finally prevailed.

If the barometer at any place oscillates violently, and the air remains at rest there, the disturbance must lie in a lateral direction. At times in winter the southerly current prevails over a large area, and the barometer is low, the air delightfully mild. Under these circumstances there is a very severe winter, with a high barometer somewhere in the neighbourhood. It is possible that this cold air may force its way, as a storm, into the warm and rarefied air in its neighbourhood, and cause the barometer to rise rapidly.

On the Atlantic Ocean, if the wind veers against the sun, i. e. from NE. through N. to NW., and the barometer be falling rapidly, the ship is probably in a cyclone whose centre lies to the SE. and is moving towards the NE. In this case she must steer NW., in order, if possible, to get away from the centre of the cyclone, where the danger is greatest. If it veer from SE. to S. and SW., and the barometer be falling, the ship is either in an ordinary gale, or in a cyclone whose centre lies to the NW. In the latter case she must steer SE.; and this course is the best for her to take in general, as the ordinary SW. gales usually increase in intensity to the westward.

If the wind continues a gale from the SE., and the barometer keep falling, it is probable that the ship is exactly in the path of a cyclone which is moving from SW. to NE. If the barometer still fall, and the wind keep in the same quarter but increase in violence, the centre is coming closer. If the ship come into the centre of the cyclone, there is a sudden lull when the barometer is at its lowest level. This is the moment of greatest danger, as the storm will recommence from the quarter diametrically opposite, viz. from NW. In these cases the vane gives the tangents to the cyclone. In the West Indies these storms travel from SE. to NW., and the vane therefore shows NE. before the centre has passed and SW. afterwards. As soon as they reach the boundary of the torrid zone they turn at a right angle, and travel from SW. to NE. It is only this portion of the cyclone, on its altered course, which we feel in Europe, and, owing to the increase of its diameter, we are not exposed to its fury until this has been diminished. In these instances a fall of the barometer indicates the increase, a rise the decrease, of danger.

Cyclones of a smaller diameter, known as 'Trombs,' at times do great damage in our forests: their lateral extent is comparatively small; however, in the neighbourhood of the path of their centre they are capable of blowing down trees,* unroofing houses, and lifting heavy articles from the ground. In the progress of such a whirlwind its axis frequently receives a considerable inclination in the way it is moving, in consequence of the resistance presented to the motion of the air by its friction with the ground. It is probable that many of our thunder and hailstorms are to be attributed to this circumstance. The grain of sleet, first formed at a great height in the air, makes several revolutions in the inclined whirlwind, and in its passage through cold and hot strata alternately it obtains the shell of ice, which covers the grain of sleet, like a grain of snow, in the centre, and at last becomes so heavy that it falls to the earth. The characteristic noise which precedes a hailstorm is owing to the rotatory motion of the hailstones before they fall. Such hailstorms, and many severe thunderstorms, present the striking appearance of a long, almost horizontal, column of clouds which is rolling on, and when projected on the sky appears more or less bent. At times the dark bank of clouds covers itself with a number of brighter stripes of grayish clouds, which envelope it, like a waterfall does the cliff over which it falls. The edges of the whirlwind seem to favour the formation of hail, in consequence of the fact that there the circles described by the hailstones are largest, and consequently the difference of temperatures which they have to pass through is greatest. It has been very often observed that the district where hail fell,

* In September 1848, I saw what such a Tromb had done in the forest of Biesenthal near Neustadt-Eberswalde. The track was like a long trough with sloping sides. Along the centre the trees had all been broken off close to the ground, and towards the sides you found them broken off nearer and nearer the top, and many of them twisted together.

whose breadth is never great, has been double, with a district in the middle where it has only rained. The reference of the formation of hail to the whirlwind explains the fact that the boundaries of the hail district are often very clearly marked. The barometer is not much affected by hailstorms: they are local phenomena which it cannot indicate, as it measures the total pressure of the atmosphere, and therefore only gives notice of phenomena which are on a great scale.

The sudden squalls which accompany these thunderstorms are sometimes very dangerous to ships if their upper sails are not reefed. In the year 1850, at Heringsdorf, I witnessed a thunderstorm like this, on a day which was otherwise very fine. It lasted a very short time, and there was only one clap of thunder, like a cannon shot. On the passage to Rügen next day, I saw a ship at the mouth of the harbour of Swinemunde, which had capsized in bright sunshine, so suddenly that the corpse of one of the crew could not be got out of the cabin.

Lettering on barometers loses its value from the fact, that the difference of temperature, and therefore of density between the two currents, is much greater in winter than in summer. Inasmuch as the fluctuations of the barometer in winter are much greater than in summer, it is evident that the scale for winter should have at least double the extent that it has for summer. It is easy to see how such lettering has arisen. Correctly speaking, the highest mark should be NE. wind, or, better, 'polar current;' that in the middle E. or W. wind, or, better, 'transition;' the lowest SW. wind, or, better, 'equatorial current.' The air of the polar current flows from a colder to a warmer climate; so that, as its capacity for the absorption of aqueous vapour is increasing, the effect of this increase is entered on the scale as 'very dry.' At the transition of one current into the other, rain falls, owing to the mixture of the air belonging to the two currents; but at the same time the weather either breaks or clears up for a time, so that this point is marked 'change.' The southern current, as it moves into higher latitudes and comes into contact with a surface whose temperature is continually decreasing, discharges the aqueous vapour which it has absorbed; so that we have at the point corresponding to it 'much rain.' If the southern current forces its way to the northward very rapidly, the contrast between the pressure exerted by the rarefied air of which it consists, still farther diminished by the condensation of its aqueous vapour, and the mean value of the atmospherical pressure, is greatest, and consequently the lowest mark on the barometer is 'stormy.'

From what has been said above, it is easy to see that, as the barometer rises with rain on the W. side, and falls with it on the E. side, of the compass, it is impossible to lay down rules for the weather which do not take the direction of the wind into consideration, as has been attempted by many persons. At times the phenomena of the one side pass into those of the other, without any change or interruption in the form of the discharge having taken place. If after severe cold it begins to snow, and the vane moves from E. to SE., the barometer falls and the cold grows less intense; however, it does not always rise above the freezing point. In this case, when the wind gets round to S., the snow does not turn to rain, and if this S. wind is, in a short time, in its turn displaced, the fall of snow is uninterrupted, but really it consists of two separate formations: one, while the barometer is falling, in consequence of the displacement of a colder by a warmer wind; and the other, while it is rising, from the converse change. The rule that fresh snow brings fresh cold arises from the fact, that snow is more usual with W. than with E. winds. It is also easily seen that snow can never fall when the temperature is very low, since it arises from the contact of two currents whose temperature is different. It is certainly true that some snow falls when the cold is very intense; but in this case it does not take the form of flakes, but rather that of spiculæ of ice, which owe their origin to a stratum of clouds which belongs to a warmer current, lying at a great height in the atmosphere. These needles, passing in their fall through very dry air, cannot increase in size, and hence cannot assume the form of flakes. If the variations of the barometer in summer and winter were of equal extent, or, in other words, were the difference of pressure of the two currents constant, the barometer would, generally speaking, stand lowest during rain. This is, however, not the case as regards the yearly mean; for the depression of the barometer during S. winds below its mean level is greater in winter than in summer, while the usual form of the discharge in winter is that of snow. During the course of one single revolution of the vane, the barometer is lower in rain than in snow.

If in spring, in the centre of Europe, the barometer be high, and the wind easterly, we may expect to have strong S. winds, accompanied by heavy rain, in the south, e.g. in the Mediterranean; since the high level of the barometer is owing to the fact, that the wind blowing from higher latitudes has been prevented from finding a passage to the south by the sirocco, which is blowing in the opposite direction, and which is the upper current returning to the surface of the earth at the outer boundary of the Trade-wind. We further deduce the following fact from the Law of Gyration:—Southerly winds in high latitudes are more westerly; northerly, in low latitudes more easterly: the only winds which can preserve their direction unaltered over a large area are due E. and W. winds.

Rotations of the vane against the sun, which extend beyond S. or E., indicate cyclones; if they only extend from NW. to SW., or from ENE. to NNE., they are often only a return of the vane to its original position, indicating, in the one case, that the equatorial, in the other, that the polar, current continues prevalent.

4. South Temperate Zone.

The regular rotation of the wind in this zone is with the sun, i. e. from S. through E. and N. to W. and S.; and similarly in cyclones, when the ship is on the NE. side of the path which is travelling from NW. to SE., it is from NNE. through N. and NW. to W. and WSW.; and in both cases the barometer falls until the wind reaches NW., and then rises. The only difference is that in a cyclone the temperature does not vary to any extent, while in the case of the alternation of the regular currents it rises while the barometer falls, and vice versâ. If the wind veer from W. through SW. to SE., the barometer in general rises and the thermometer falls. The prevalent wind, when the barometer is highest and the thermometer lowest, is SE., and when the converse conditions are fulfilled, NW., especially in the cold season; the atmosphere also is clear with SE., and thick with NW. If the wind veer from W. through SW. to SE., the weather clears up; if from SE. through NE. and N. to NW., it breaks, and there is rain. If the wind veer against the sun from ENE. through SE. to S., the ship is probably on the SW. side of the path of a cyclone travelling from NW. to SE. The rules for finding the position of the centre and the course to hold have been already given.

The only parts of the earth which I have not considered are the frigid zones. The stormy periods here seem to be the summer, and the transition from winter to summer; the winter itself is, comparatively speaking, a time of calms. In the American polar sea, the barometer stands at its highest level in spring. According to Ross's observations, the permanently low level of the barometer, which was first observed at Cape Horn by Krusenstern, appears to extend far into the antarctic zone. This district of barometrical depression is of far greater extent than that in the vicinity of Iceland. The cold air, lying over the ice-fields, seems to stop the most violent south winds, which accordingly deposit their aqueous vapour in heavy falls of snow in their attempts to force a passage; hence large floes which are rotating are surrounded by a wall of snow. Very little of this snow penetrates to the interior of the floe, while the different points of the circumference come successively into the area where the contest is going on (Scoresby). In the immediate neighbourhood of the pole the rotation of the vane becomes complicated; since the influence of the rotation of the earth on the wind changes as soon as storms pass the pole, from the fact that the velocity of rotation of the surface with which the air comes in contact, which had been previously decreasing, begins to increase again. The dense fogs which arise from the difference of temperature of the sea, and the very cold air lying immediately above it, and the similar fogs which are due to the difference of temperature of the air over the sea and over the ice-floes, are the prevailing form which the condensation of moisture takes in these regions. This form is also not unusual in spring in the N. Atlantic Ocean, owing to masses of ice which are drifting southwards, and is an indication of the proximity of icebergs, especially off Newfoundland.

There are too few data for the Pacific Ocean to permit me to enter into a detailed examination of the differences between the phenomena on that and on the Atlantic Ocean. The description of the storm in the harbour of Avarua, in Raratonga, which is given by Williams,* shows that the hurricanes are very violent in those seas. He says: 'The whole island quivered to its centre when the waves broke on the coasts. A vessel belonging to the missionaries was carried over a marsh into a wood of large chestnut trees some hundred yards from the shore. The rain fell in torrents from morning to night.'

The practical rules which have just been given are intended to serve a twofold purpose. Firstly, they will indicate to the seaman the conclusions as to approaching weather, which he may draw from the appearance of the sky and the behaviour of the meteorological instruments, especially of the barometer. Secondly, they will show him which of the phenomena are, as yet, imperfectly explained, and which, therefore, demand a more accurate investigation by means of additional observations. It is very satisfactory to find that practical seamen like Fitzroy, Maury, Van Gogh, Andrau, and Jansen, are taking steps to indicate to the officers of the naval and mercantile service what points it is important, not only for science, but also for themselves, that they should ascertain. By this means central stations, like the Board of Trade, the National Observatory at Washington, and the Meteoro-

* Narrative of Missionary Enterprises in the South Sea Islands.

logical Institute of the Netherlands, have been established, at which the fragmentary materials are registered and worked up into a collected whole.

In my opinion the strictly meteorological element of such investigations has not been brought forward in a sufficiently prominent manner in the instructions furnished by these institutions; and I have, therefore, sought to supply the deficiency by the present work.

The theory which has been here propounded, and which has been developed by me in various treatises since the year 1827, assigns answers to the following problems:—

1. Why the storms of the torrid zone appear more frequently in certain districts than in others.

2. Why they take the form of cyclones; and why the rotation in a cyclone is in a different direction on the northern to what it is on the southern hemisphere.

3. Why they move in fixed directions within the tropics, and turn at a right angle as soon as they cross the boundary of the torrid zone.

4. Why the cyclone increases in diameter and decreases in intensity when this change of path has taken place.

5. Why the form of the storms of the temperate zones presents more variety,* and why in these districts certain

* In what cases these are not to be distinguished (from a local point of view) has already been explained. The following is an important historical example. Macaulay, *History of England*, vol. ii. p. 455, says:—'The weather had indeed served the Protestant cause so well, that some men of more piety than judgement fully believed the ordinary laws of nature to have been suspended for the preservation of the liberty and religion of England. Exactly a hundred years before (they said) the Armada, invincible by man, had been scattered by the wrath of God: civil freedom and Divine truth were again in jeopardy, and again the obedient elements had fought for the good cause. The wind had blown strong from the east while the prince had wished to sail down the Channel, had turned to the south when he wished to enter Torbay, had sunk to a calm during the disembark-

characters of storms are more prevalent at certain seasons and at certain localities than at others.

In conclusion, I wish to draw attention to the fact, that the theory which has been developed in the foregoing pages is only intended to exhibit the principles from which we may deduce, not only the Trade-winds and Monsoons, but also the regular movements of the atmosphere of the regions of changeable winds, when it is not disturbed by storms. According to the explanation which has been given of them, the hurricanes tend to accelerate the earth in its motion round its axis, whereas the constant Trade-wind tends to retard it. The compensating element for the conservation of the earth's rotation, which would otherwise be affected by the great Trade-wind currents, is furnished by the various westerly currents, viz. the predominant equatorial, and consequently westerly current in the temperate zone; the SW. Monsoon of the northern, and the NW. Monsoon of the southern, Indian Ocean; and, lastly, the hurricanes. Despite the destructive action of the last-named movements, they must still be regarded, in the general sense of the term, as agents in the conservation of the vital force in the great organism of the earth. The whole of the phenomena which we have described furnish us with confirmatory proofs, on a great scale, and borrowed from the earth itself, of the great fact that the earth rotates about its axis—a fact whose first discovery is due to the science of astronomy.

In this second edition I have discussed the theories of cthers at greater length than I did in the first. My reason for doing so has not been to bring forward my own theories more prominently, but to show the error of the idea that all atmospherical phenomena may

ation, and as soon as the disembarkation was completed had risen to a storm, and had met the pursuers in the face.'

be discussed according to any one cut-and-dry pattern. There are so many agencies always at work disturbing the equilibrium of the atmosphere—the radiation, whose extent varies from day to day—the infinite variety in the surface of the ground—the ocean currents, and the different forms in which aqueous vapour presents itself—that the Calms ought to excite our astonishment in a much higher degree than the Wind. The atmosphere is eternally striving to attain equilibrium without ever succeeding. The character of the disturbance itself, and the process of restoration of the equilibrium, exhibits in each case a distinct type; so that the problem which presents itself to the meteorologist is to discover the typical form of the phenomenon, which presents in each several case of its occurrence variations of more or less extent from the original type. Generally speaking, the principal types have been distinguished as *Wirbelwind* and *stetiger Sturm*, *hurricane* and *gale*, *ouragan* and *tempête*; but these two forms pass into each other by such insensible gradations, that a gale may become a whirlwind at one point of its course, without being a true cyclone in the strict sense of the word. I have been anxious to show, as clearly as possible, how unjustifiable it is to confound the effects of the Law of Gyration with those of rotatory storms—an error into which many have fallen, and which has not yet disappeared. The reason that many physicists refuse to recognise the existence of cyclones has arisen from the fact, that the disciples of the cyclone theory have thought that they had discovered a cyclone wherever the rotation of the earth about its axis exhibited itself in the rotation of the vane,* and have consequently left blots which

* The influence exerted by the motion of the earth is well described by Herschel in the following words (Meteorology, p. 57):—'To form a right estimate of its importance, it is only necessary to observe, that of all the

their adversaries were not slow to hit. Those who, in exposing such errors as these, willfully shut their ears to Nature when she speaks to them in such unmistakable language as she does in the Typhoons and West India Hurricanes, ignore the problem which it is the business of meteorologists to attempt to solve, viz. to interpret her language, however varied the expressions which she employs may be.

winds which occur over the whole earth, one-half at least, more probably two-thirds, of the average momentum is nothing else than force given out by the globe in its rotation in the Trade currents, and in the act of reabsorption or resumption by it from the anti-Trades.'