

ART. LVII.—*Further Light on the Circulation of the Atmosphere in the Southern Hemisphere.*

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Plate LV.

HAVING been favoured by J. L. Barthorp, Esq., an experienced officer of the New Zealand Shipping Company's steamers trading between England and New Zealand, with extracts from the logs of twelve voyages between the Cape of Good Hope and New Zealand, and of eleven voyages between New Zealand and Cape Horn, during the years 1891 to 1898, I have learned so many interesting facts from the ships' logs regarding the circulation of the atmosphere in these southern oceans that they appear to me worthy of record for general information.

These voyages have been made between the south latitudes of 35° and 57° , those to Cape Horn being, of course, more southerly than those from the Cape of Good Hope, though in both a somewhat southerly course has been pursued, both to shorten the distances by great-circle sailing and also to benefit as far as possible by the usual westerly counter-trade winds. It will be seen, however, by the logs that this latter advantage is not always obtained, easterly winds being not infrequently experienced. These easterly winds are sometimes experienced with a high barometer, indicating an anti-cyclonic circulation very much farther south than has generally been supposed to be the case. Strong indications indeed are given that there is a second belt of anticyclones between the latitudes of 60° and 70° south, in addition to the well-known belt of anticyclones usually lying between the latitudes of 20° and 40° south, and that between these two anticyclonic belts cyclones move eastwards, their northern parts giving the westerly strong winds usually felt; but occasionally, as the ship goes far south and the cyclone travels northwards, the southerly part of the circulation is felt, with low barometer and east winds.

The rate of eastward travel of these cyclones appears to correspond generally with that of the steamers, averaging ten to twelve knots an hour; so that a vessel may voyage eastwards for many days in the comparatively fine weather of the intervals between the following cyclones, or in the stormy weather within one of them; but occasionally the cyclones travel much

faster, as in the voyage of 1897, in which a cyclone and its following anticyclone overtook the ship.

Our Australasian experience has shown us that the neutral line between the anticyclones and the cyclones south of them is variable within wide limits, and that occasionally the centres of southern cyclones reach as far north as 47° or further, and the northern boundaries of anticyclones occasionally are displaced as far south as about 47° ; yet an anticyclone lying altogether south of latitude 56° was to me at least a new fact.

It is no doubt possible that such southerly displacements of the regular anticyclone belt normally lying in about latitude 35° may occasionally occur. We notice that in the voyage of the "Aorangi," leaving Wellington on the 22nd December, 1893, an anticyclone extended for about fifteen hundred miles south-eastward from Wellington, the south-east extremity being in latitude 56° ; but in the voyage of the 6th July, 1893, we notice the ship passed the northern edge of an anticyclone, in latitude $56\frac{1}{4}^{\circ}$, to the west and south of Cape Horn. I feel constrained to regard this very far south anticyclone, and probably many others observed in these voyages in far southern latitudes, as belonging to a different category from those to which we are accustomed in these latitudes, and to indicate, as above mentioned, a second belt of anticyclones lying south of the parallels of 50° to 55° south. The observations of the limited number of explorers in antarctic regions concur in noting very low barometer readings in the summer in latitudes between 65° and 75° south, and hitherto it has been supposed that a mean low barometer was to be found in all the belt between that very far southern belt and the vicinity of the ordinary anticyclone belt between 30° and 40° south. Now it would seem, however, that the atmospheric circulation is sometimes, if not always, more complicated than had been supposed, and that between the "lows" found in about latitude 45° and those found in about latitude 70° there are generally to be found intermediate "highs," in about latitude 60° . If "highs" and "lows" be viewed, as I believe them truly to be, as positions in which there are descending or ascending parts of atmospheric vertical circulations, then it would seem that over these southern oceans there is usually an intermediate vertical circulation between the descending currents, about latitude 35° , and the ascending currents, about latitude 70° , which produces the normally high and low barometric indications in those latitudes respectively, and that this intermediate vertical circulation is indicated by the high barometer with easterly winds frequently noted in latitudes as far south as 56° or 57° .

This seems to be the chief item of instruction to be gained:

from a study of these logs of twenty-three voyages in the Southern Ocean during the last eight years. There are, however, other facts which have considerable value, such as the ordinary rate of eastward progress of the cyclonic storms, which, as I before mentioned, is about ten or twelve knots an hour, although it is occasionally accelerated or retarded, and sometimes is deflected northwards or southwards by the influence, I believe, mainly of anticyclones.

On only one occasion (in April, 1892) is the fact mentioned that observations had been made on the temperatures of the air and the sea in the vicinity of icebergs. Mr. Barthorp, however, informs me that such observations have been regularly made, and with the disappointing result that no reliable information evidencing the proximity of an iceberg is to be obtained by thermometrical observations, but that in the dark, and in foggy and thick weather, the only means available to safeguard a ship against dangerous collisions with icebergs is to keep always a most vigilant look-out.

Assuming that the main cause of high and low barometer readings at the level of the sea is, as I have given strong reasons for believing, downward or upward motions of the air in its vertical circulations, the ships' logs under consideration seem to indicate a normal downward motion between latitude 30° and 40° south, upward about 50° south, and again downward about 60° south, and it would appear that westerly counter-trade winds usually felt at about 40° to 50° south are really the northerly parts of a belt of cyclones, and that when a ship pursues a more southerly course than usual, or when the belts of cyclones and anticyclones are in more northerly latitudes than usual, then easterly winds are experienced, either resulting from the circulation of the southern parts of cyclones or the northern parts of far south anticyclones. This very probable interpretation of the facts observed during the numerous voyages under consideration is, of course, more important to sailing-ships than to steamers; but it may be useful to either, and from a scientific point of view it leads us to conclude that the vertical circulation of the atmosphere between the equator and the poles, although in principle that shown in the diagram attached to my paper on the subject which appeared in the Proceedings of the New Zealand Institute for 1889, is probably somewhat more complicated in southern regions, and of the character indicated in the revised diagram hereto annexed (see Plate LV.).

It may be, however, apart from cyclonic circulation, that there are other special causes producing very low pressure in antarctic regions.

Fig. 1 gives a half-section of the Southern Hemisphere, showing on its edge the probable vertical system of circula-

tion of the atmosphere. The arrows show the directions of air-motion in the successive portions of the great circulation between the equator and the south pole, and also the probable meaning of the high and low mean barometric pressures in these various parts of the circulation, the "highs" corresponding with downward indications of the motion, and the "lows" with upward indications.

Fig. 2 shows on a diagram of half the south polar region, extending as far as the 30th parallel of south latitude, the horizontal circulations of the air corresponding with the vertical circulations shown in fig. 1. The circulations are shown as if they were mathematically circular and equidistant; but we know that in reality they are very irregular, in consequence, no doubt, of the interaction upon one another of the various circulations, of changes in temperature, and of other influences. The diagram illustrates what seems to be the general disposition of the circulations which move eastward round the probable polar anticyclone in alternate belts of cyclones and anticyclones. The arrows show the directions of the winds in the various horizontal circulations. The combinations of the vertical and horizontal motions result in spiral motions.

As regards the origin of cyclones, I have found no fresh light in Mr. Barthorp's logs; but the light I have found on the whole subject has proved to be so different from what I had supposed that it gives no support whatever to the hypothesis, which I ventured to put forward in a former paper, that there is some spot in the antarctic regions which is a specially favourable nursery for the birth of antarctic storms, whence they start on a north-easterly course. These cyclonic storms seem to be an integral part of the atmospheric circulation in the Southern Hemisphere, and I see no reason to doubt my former conclusion that the liberation of latent heat by the condensation of water-vapour and the rotation of the earth are the two main sources of their energy and motion.

With my hypothetic antarctic nursery I must also abandon the idea that the counter-trade winds have anything to do with the eastward motion of the storms, because the counter-trade westerly winds now appear to be themselves only the northerly parts of the cyclonic circulations in latitudes from 40° to 50° south.

The northward or southward deflection which we often observe in tracing the eastward motions of antarctic storms appears to be due to the forms of the anticyclones or land masses they encounter in their progress; and to the same causes we must attribute their frequent deformation from their normal circular or elliptic shape, as by the projection of long arms northward, so often observed here.

P.S.—I should have mentioned that the south polar anticyclone inserted in the diagram (Plate LV.) is at present hypothetical. We have no facts here to guide us; only reason and analogy. The cyclones also surrounding it are evidenced only by very low barometric pressure, and winds in varying directions; and on the eastward rate of progress of these cyclones we have no information.

The evidence for the remainder of the scheme of atmospheric circulation is so strong that it seems to have passed out of the realm of hypothesis into that of established fact in its main features. But it must be borne in mind that the positions in latitude of the belts of "highs" and "lows" fluctuate constantly, and that probably the more northern cyclones may sometimes blend with those farther south in the intervals between anticyclones, and that possibly a similar blending of the more northern anticyclones with those far south of them may sometimes temporarily occur.

NOTES ON THE SHIP'S LOGS.

(1.) *Voyages from Cape of Good Hope to New Zealand.*

25th August, 1891.—The voyage commenced in a tropical storm. The ship soon ran into the anticyclone belt, which was rather more southerly than usual, and in which she experienced some gales, probably caused by the tropical storm on its northern side.

29th February, 1892.—During this voyage easterly winds prevailed, and it would seem that the belts of cyclones and anticyclones were displaced northwards.

22nd May, 1893.—The indications in this voyage were very similar to those in the voyage of February and March, 1892, and lead to the same conclusion: that the high and low belts were abnormally displaced northwards.

5th November, 1893.—The high and low belts were in their usual positions.

1st April, 1894.—The ship ran into a tropical storm on the third day after leaving the Cape; then she passed south of the normal anticyclone belt, and experienced the gales of the northern part of a cyclone, in which she voyaged for about a week. The belts of "highs" and "lows" were in their normal latitudes in this voyage.

18th August, 1894.—Westerly winds and gales were experienced during the whole voyage, showing that the high and low belts were in their normal latitudes.

29th January, 1896.—The "highs" and "lows" were in their usual positions, but the ship voyaged in fine weather in the interval between two cyclones, the hindermost of which overtook her on the last day of the voyage.

12th October, 1896.—The “highs” and “lows” were normally placed. The ship experienced the effects of the northerly parts of two cyclones, and passed icebergs in latitude 45° , longitude 51° to 76° .

24th June, 1897.—A normal voyage. High and low belts as usual.

24th December, 1897.—A normal voyage. High and low belts as usual.

20th July, 1898.—In this voyage much easterly wind was experienced, and the high and low belts were evidently much displaced. In the early part of the voyage a tropical cyclone seems to have forced the northern belt of anticyclones very far south, nearly joining the counter-trade cyclones through them. In the latter part of the voyage the easterly anticyclone weather seems probably to have been due to a northerly displacement of the southern anticyclonic belt.

5th January, 1899.—The whole voyage was in the northern part of a cyclone, with westerly winds. The centre of the cyclone was nearly reached in latitude 48° , longitude 108° , with barometer down to 28.97° . The positions of the belts were about normal.

(2.) *Voyages from New Zealand to Cape Horn.*

2nd December, 1891.—The voyage for nearly a thousand miles east of Wellington was in an anticyclone, the southern end of which was in about latitude 50° , rather farther south than the normal. The rest of the voyage was in the northern part of the cyclone belt, which was also a little south of the normal.

17th April, 1892.—The whole voyage was in the northern part of a cyclone which travelled at about the same speed as the ship. The centre was very near in latitude 55° , with barometer 28.67° . Icebergs were passed. No thermometrical indications of their vicinity.

6th July, 1893.—After leaving Lyttelton in the easterly winds of an anticyclone displaced southwards in latitude 47° the ship passed in two days, in latitude 50° , into the northern part of a cyclone, in which she travelled for a fortnight, with westerly winds, when, in latitude 52° , she passed into the southerly part of the cyclone, with easterly winds and rising barometer, in latitudes 54° to 56° , showing that the cyclone was moving in a more northerly track than the ship, and that the northern part of the southern anticyclone belt lay in latitude 56° , farther north than usual.

22nd December, 1893.—The early part of the voyage was in the easterly winds and high barometer of a “high” displaced far south; the latter part of the voyage was in the northern part of a cyclone, as usual, but very near its

centre at one time. Many icebergs were passed in latitude 57° , longitude 160° .

18th May, 1894.—Westerly winds nearly all the way. The ship was for a time in the rear part of one cyclone, and was then overtaken by another, the centre of which passed over her with barometer down to 28.64° , in latitude 56° . These cyclones travelled faster than the ship, which was the "Aorangi," doing probably 14 to 15 knots an hour. Icebergs were passed in latitude $55\frac{1}{2}^{\circ}$, longitude $104\frac{1}{2}^{\circ}$.

4th October, 1894.—Westerly winds all the way, in the south edge of an anticyclone at first, then in northerly part of a cyclone which travelled rather faster than the ship.

27th March, 1896.—For about seven hundred and fifty miles east of the Bluff the voyage was in the northerly part of an anticyclone, which was much displaced, probably southwards; then the ship overtook a cyclone moving north-easterly slower than the ship, which passed into its southern part, with easterly winds and rising barometer, near the Horn.

6th January, 1897.—The ship, on leaving New Zealand, experienced gales from north-east to north-west and south-west, with high barometer—probably a detached "high," influenced by "lows" north and south of it. Then the ship ran into the northern part of a cyclone, the centre of which, with winds in all directions and barometer down to 28.51° , was felt in latitude $53\frac{3}{4}^{\circ}$; but the ship travelled at nearly the same rate as the storm, and in its northern part.

28th August, 1897.—It is difficult to interpret the great fluctuations in the usual positions of the high and low belts observed in this voyage. The anticyclone in the usual cyclone belt noted in the first part of the voyage was a northern "high" forced southwards by a tropical "low," as we learn from the New Zealand records. The second "high" noted, nearer the Horn, was more probably a southern anticyclone displaced somewhat northwards. The cyclones felt moved, apparently, faster than the ship, and in diagonal courses.

25th February, 1898.—The voyage was made in the northern part of a cyclone which travelled at the same rate as the ship. Westerly winds all the way.

14th September, 1898.—The first part of the voyage was in the southern part of a cyclone, the latter part in the northern part of an anticyclone, latitude 55° , and which latter must have belonged to the southern belt of "highs." Both the cyclone and the anticyclone were somewhat displaced northwards.

[EDITOR'S NOTE.—The extracts from the logs were too voluminous for publication in this volume.]