IX. "On the Normal Circulation and Weight of the Atmosphere in the North and South Atlantic Oceans, so far as it can be proved by a steady Meteorological Registration during five Voyages to India." By Captain HENRY TOYNBEE. Communicated by Major-General SABINE, President. Received June 8, 1865.

Having lately made five voyages to India, leaving England on the 1st of July and returning early in April, I have observed the recurrence of certain facts relating to the weight and circulation of the air in the same part of the world at the same seasons of the year, from personal registration of the barometer, wet- and dry-bulb thermometers, direction and force of the wind, &c., five times daily.

These five voyages have carried us through the Atlantic Oceans from 50° N. to 40° S. lat. in the months of July and August; again returning home, we have passed from 34° S. lat. to 50° N. lat. during the months of February and March each year.

The accompanying diagrams* show the height of the barometer at noon in each degree of latitude; and as we were not in each degree exactly at noon, interpolation has been used: for instance, if in 24° N. lat. at noon the barometer were 30·12 inches, and in 22° N. lat. it were 30·10 inches, it has been called 30·11 inches in 23° N. lat. This plan is not to be trusted, however, on the polar side of the trade-winds, where the barometer is constantly undergoing change, depending upon a series of independent gales, of which something will be said by and by; but it seems to give very correct results in and between the trade-winds, where the height of the barometer had long been noticed to depend chiefly upon the latitude and season of the year

We will first allude to the five diagrams representing the outward passage, the two upper ones lying to the west, or outside the Cape Verde Islands, the three lower ones to the eastward, or between them and Africa.

The first facts they prove are, that the barometer at this season ranges lower to the eastward than to the westward of the Cape Verdes, the N.E. trades extending further south to the westward, and the S.W. monsoon (which at this season blows between the trades) sets in further north, and blows stronger the nearer to Africa.

We are told that the Great Sahara Desert being heated by the sun of the northern summer causes an upward current of air, which draws in the air from the sea to restore equilibrium, just as the heated lands in India during the same season cause a S.W. monsoon in the Bay of Bengal, where a N.E. trade would otherwise prevail. Our barometer diagrams show this by being lower near Africa, and gradually rising as the distance from the demand is increased. Again, in about 13° N. lat., where the S.W. monsoon commences, it is always much more from the west than it is further southward, where the wind draws to the south, and very generally turns

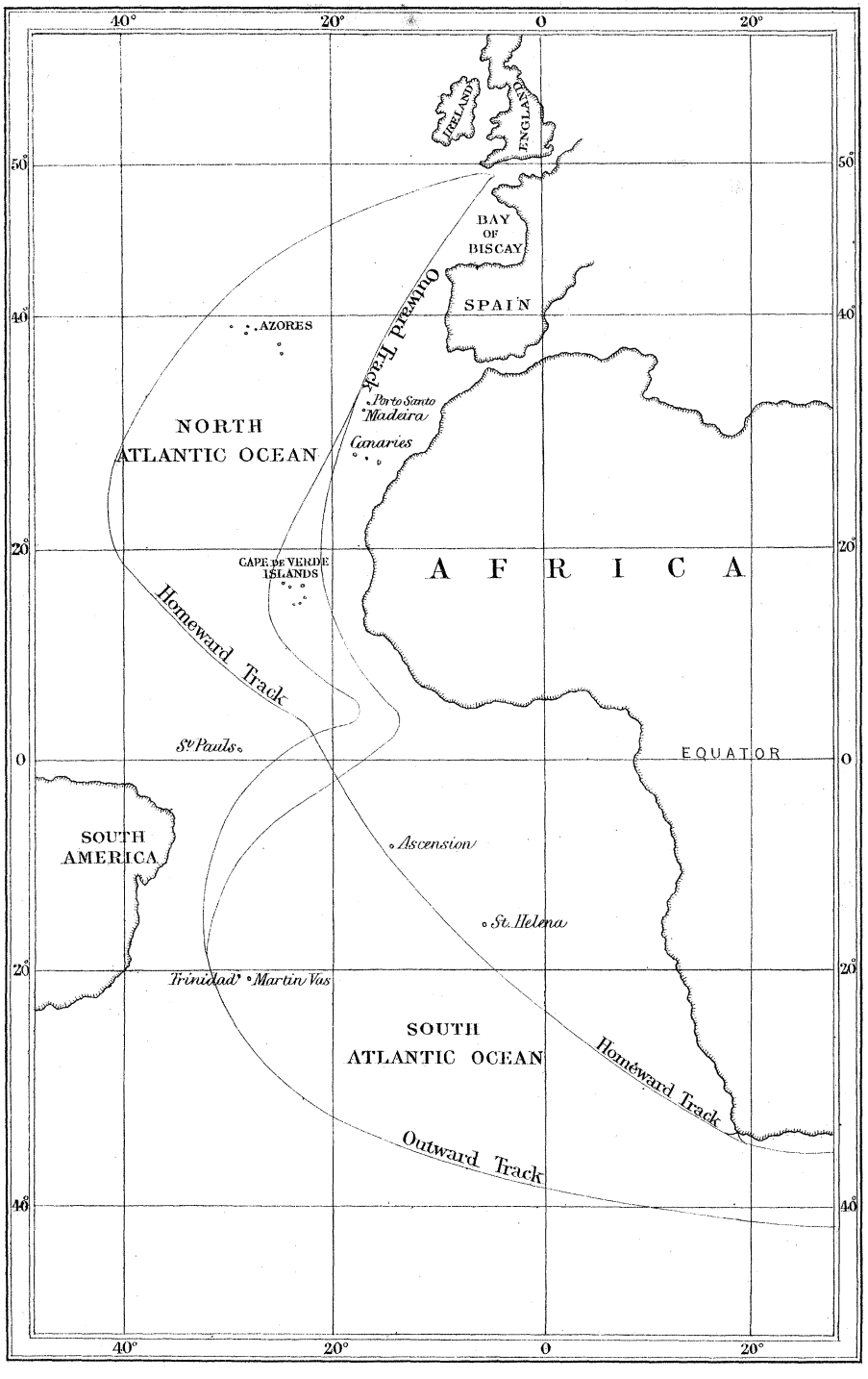
* The Barometric Curves and Track-Chart are preserved for reference in the Archives.

into the S.E. trades without any intervening calm. In fact this heated part of Africa seems at this season to have the power of bringing the N.E. trades to an end in about 17° N. lat. between the islands and the main, instead of 13° N. lat. outside, and of causing an indraft from the westward; it also gradually turns the S.E. trade which blows near Africa into a S.W. wind, which we may suppose finds its way into the upper stratum of air over this heated land. Part of this S.W. monsoon seems to be formed of the damp cloudy air which exists in the doldrums, whilst the rest is evidently formed of clearer air—another evidence that it is part of the S.E. trades.

It would be interesting to treat in a similar way a few logs of American ships leaving in July, and supplied with standard instruments, since they might show how far to the westward the barometer continues to range higher, and we have Maury's works to prove that the N.E. trades do extend nearer to the equator in more western longitudes.

Having thus considered the curves of the outward passage from England with respect to their difference when further east or further west, we will view them in a north and south direction. It will be noticed that the lowest barometer occurs in the belt of doldrums, between the trades; and by comparing the outward with the homeward route it will be seen, as is well known, that this belt is further north in July than in March. It is interesting, however, to see that the lowest barometer travels north or south with the belt of doldrums, showing that its cause must be sought for there, and not in centrifugal force, which might be supposed to fix it at the equator.

The sailor is naturally led to ask how it is that the barometer is lower here, a zone towards which two trade-winds are pouring in an immense body of air along the earth's surface, and in nearly opposite directions; for near the equator the trades draw more north and south. We suppose there can be but one answer, viz. that here the air rises, and forms those two upper currents which rush towards the poles, above and counter to the trade-winds. Maury tells us that the so-called African dust is really South American, and that much more rain falls in the northern than in the southern hemisphere, from which he argues that the air which formed the S.E. trades, having traversed more sea and picked up more moisture, rises in these doldrums, and travels to the N.E. above the N.E. trades; and *vice versâ*, that the N.E. trades travel to the S.E. above the S.E. trades. He does not say how they pass each other, neither can we, but we have strong evidence of a current of air travelling above and in opposite direction to the trade-winds, because we generally see the high clouds travelling in that direction. We have, however, as it were, even seen the air ascending; for on the 15th of March, 1865, in 4° 18′ N. lat. and 20° 33′ W. long., when we had light fleecy clouds passing over us from the N.E., and we lay becalmed and roasting, longing for the trades, my chief officer came and reported to me with a hopeful countenance that he had seen these light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Porto Santo
Madeira
Canaries
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CAPE DE VERDE ISLANDS
AFRICA
Homeward Track
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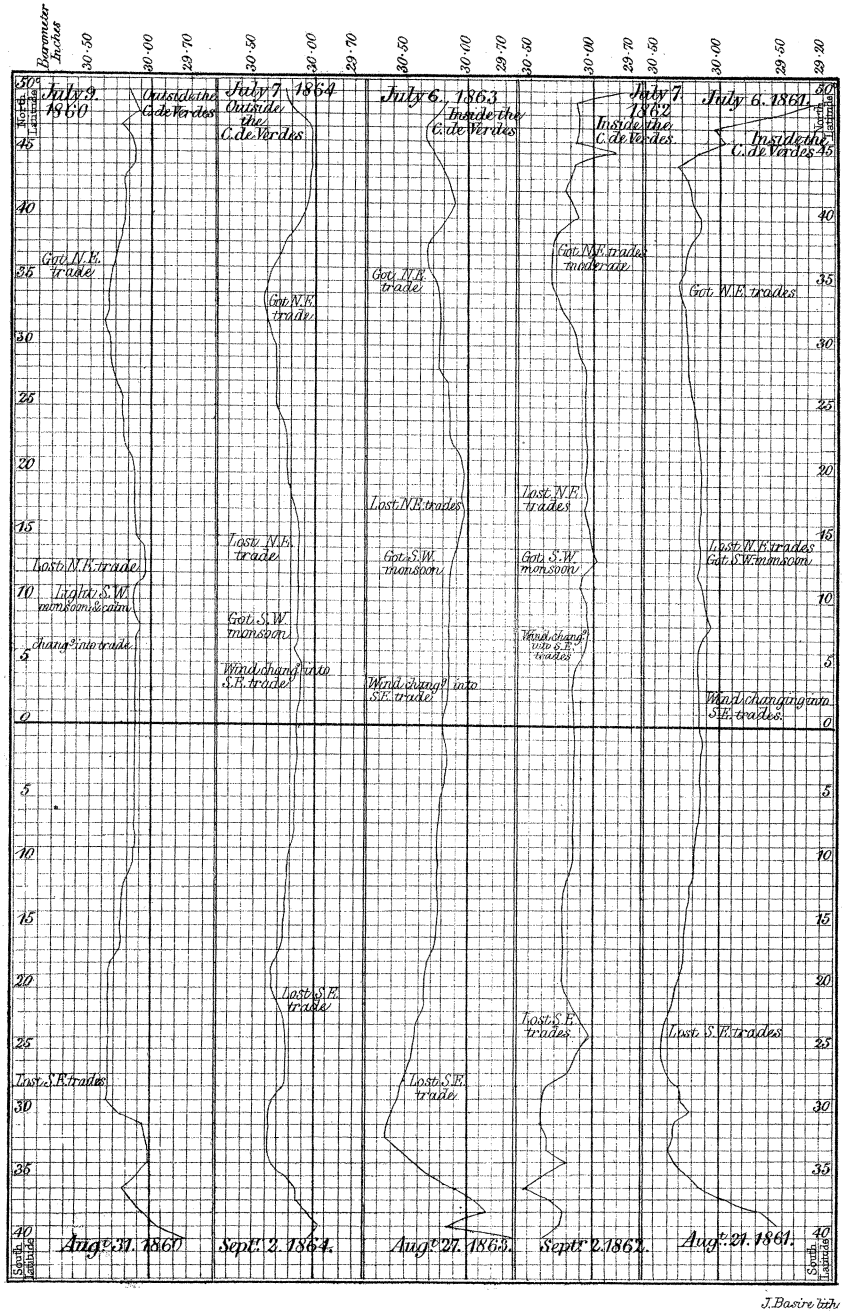
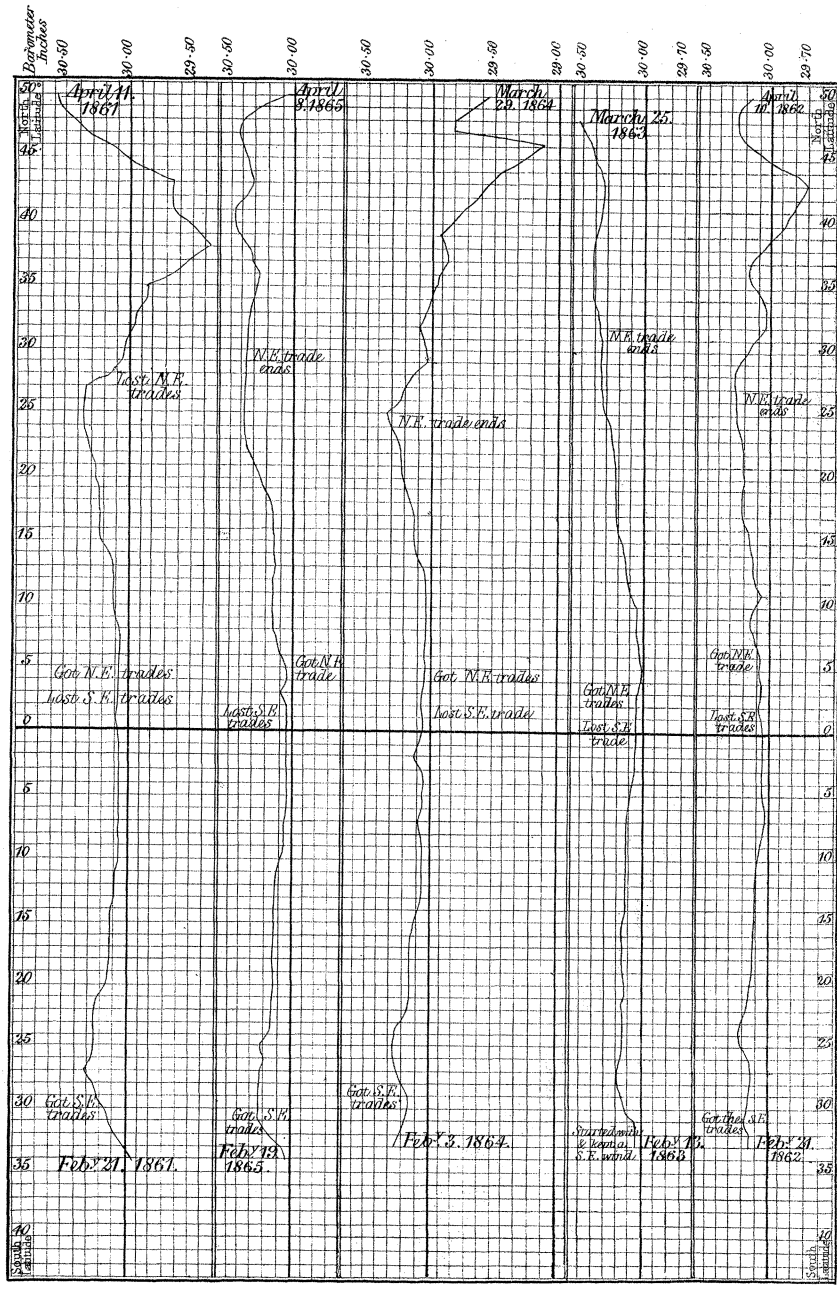


Passages outward-bound from England.

J. Basire lith.



Passages homeward bound from the Cape.

J. Basire lith.

fleecy clouds travelling from the N.E. None but those who have experienced these calms can imagine how anxiously wind is looked for: to the N.E. of us there was an arch of clouds in the sky extending from the S.E. to the N.W. points of the horizon, with a calm and low barometer on the south side of it where we were, and (as we found afterwards) the N.E. trade and a higher barometer on its north side; therefore the arch of clouds was probably formed by the condensation of moisture as the air rose, while we lay becalmed at the foot of the inclined plane of still air, up which the N.E. trade was just commencing its ascent.

Travelling south across the equator, it will be noticed how uniformly the barometer rises until we arrive at the southern limit of the S.E. trades; but on referring to the homeward curves in February, it will be noticed how much lower the barometer ranged then than in August. The homeward route through the Atlantic differing much from the outward, does this difference of barometer arise from difference of seasons or difference of longitude? By comparing the routes near the equator, where they come very close to each other, and where the difference of height in the quicksilver is as great as in any other part, I am led to think that it depends upon the different seasons.

Whilst speaking of the homeward route, it is interesting to remark how on leaving the Cape of Good Hope we invariably had a valley, as it were, in the atmosphere, which quickly rose as we sailed to the N.W., even though we may have started in a south-easter, which is the high-barometer wind in these latitudes. I had noticed that after rounding Cape Agulhas with a south-easter and high barometer, the column fell suddenly after rounding the Cape of Good Hope, though the S.E. wind continued; and I suppose that the fall is caused by the air's ascending as it comes in contact with the high land: the curves seem to support this opinion.

It will be noticed that at both seasons of the year there is a heaping-up of the air at the polar end of each trade, in the place where Maury tells us that two upper currents come to the surface of the earth; the one we have already alluded to, which comes from the equator towards the pole, moving above the trades, clouds proving its existence; the other, Maury tells us, rises at the pole, and travels as an upper current, above the strong westerly winds which prevail in high latitudes, towards the equator; it can hardly be expected to have many clouds, he says, as its moisture must have been condensed by cold before rising at the pole, so that it becomes cold dry air.

We may ask what evidence the sailor can give for this theory as deduced from observation.

First, then, from these heaps of air he finds two surface winds blowing in opposite directions: the one moving towards the equator is cool, dry, and heavy, the other moving towards the pole is warm, damp, and light. He may well say, If two surface winds blow in opposite directions from this heap of air, there must be air brought to it by an upper current or

currents to keep up the heaping; but he may naturally ask, how do I know that an upper current comes from the pole? First, because the prevailing surface winds in high latitudes blow towards the pole, which air must return; and secondly, because the trade-winds are composed of cool dry air, which could not have come from the equator: here there is pretty good evidence that two upper currents come to the surface of the earth in these zones where the air is heaped up, and again, that in dipping to the surface by some unknown means they cross each other, as Maury conjectured.

Perhaps a few words may be desirable as to the manner in which the westerly winds which blow in high latitudes appear to draw the air from the heaps above mentioned. Here we will refer to our experience in 40° S. lat., where the normal circulation of the air is less interfered with by the land.

This parallel of latitude is subject to a series of gales which commence at N. and end at N.W. or W. As the north wind sets in, the barometer falls, the air becomes warm, damp, and cloudy; the wind gradually draws round to the N.W., after a time rain accompanies the wind, the barometer continues to fall, often fast, until in a heavy shower of rain the wind shifts to the west, when the barometer immediately rises, generally followed by a strong breeze from the westward, which decreases as the quicksilver rises, very often settling down into a calm. After a few hours the north wind sets in again, with a falling barometer, and a repetition of the whole series takes place.

One is naturally led to ask why the trade-wind draws air from this heap in a regular continuous stream, when these gales are fitful. May it not be because in the direction in which the trade moves the meridians diverge and give plenty of room for the flow, whereas the westerly winds have converging meridians which seem to check the progress of the air. These fitful gales have always led me to think that the air was checked in its course. If further south, say in 50° S. lat., the wind continues steady from the west (as Maury leads us to suppose is the case), then this zone of 40° seems to act as a reservoir for the westerly winds, being constantly refilled and steadily drawn off, only the stream into the reservoir is freer than that which runs out.

Now if we consider that these gales are composed of the warm damp air which come to this heap from the equator above the S.E. trades, descending to the surface of the earth and travelling towards the pole, their westing is accounted for by the change in the diameter of the circular route which the air has to describe in accompanying the earth in its revolution. These gales changing from N. to N.W. and W. have been treated as the N.E. quarters of southern hemisphere cyclones; and we read in the 'Nautical Magazine' of a ship's having hove to to allow one of them to pass; but if, as we suppose, they form part of the normal circulation of the air, it seems useless to heave to to avoid them. The source of these gales

being to the north of them is a sufficient reason why the wind does not change to south of west. The polar-wind gales which are experienced in these high latitudes, seem to derive their air from that upper current returning from the pole, part of which sometimes makes its downward way to the surface in high latitudes, especially in spring.

The gales of the southern hemisphere, just remarked upon, have their exact counterpart in the high latitudes of the northern hemisphere, though I have not noticed them to be so constant, perhaps on account of there being much more land in the northern hemisphere. Still all seamen know how, after getting north of the N.E. trades, we look for the wind to come from S., S.W., and W., with warm air and rain.

These curves, and the arguments deduced from them, seem to favour Maury's theory of the circulation of the air; where he supposes two rising currents we have a low barometer, and where he supposes two descending currents we find a high barometer; but they are also suggestive, and a series made with standard instruments for each month in the year might lead to most useful discoveries as to the normal circulation, and its disturbance by the effect of land. How strikingly these curves prove the uniform state of the atmosphere in those parts of the Atlantic between the trades, at the same seasons of the year! especially in contrast with their sudden distortions on the polar side of the trades, where their irregularities resemble the waves of the sea in the same latitudes, which may in fact be called the resultants of these distortions. Similar curves, outward and homeward, deduced from the same logs, between the latitudes of 40° South to 20° North, in the Indian Ocean and Bay of Bengal, would, I think, give interesting results, and I hope some day to work at them.

A track-chart accompanies these remarks, showing the routes inside and outside the Cape Verde Islands, together with a homeward-bound route, thus showing the longitude in which each degree of latitude has been crossed.

X. "On the Sextactic Points of a Plane Curve." By WILLIAM SPOTTISWOODE, M.A., F.R.S., &c. Received June 15, 1865.

(Abstract.)

The beautiful result given by Professor Cayley in the Proceedings of the Royal Society (vol. xiii. p. 553), and deduced, as I understand, by the methods of his memoir "On the Conic of Five-pointic Contact" (Philosophical Transactions, vol. cxlix. p. 371), led me to inquire how far the formulæ of my own memoir "On the Contact of Plane Curves" (Philosophical Transactions, vol. cliii. p. 41) were applicable to the solution of the present problem.

The formulæ in question are as follows: if $U=0$ be the equation of the curve, H its Hessian, and $V=(a, b, c, f, g, h)(x, y, z)^2=0$ that of the conic of five-pointic contact; and if, moreover, α, β, γ being arbitrary constants,