

March 10, 1892.

The LORD KELVIN, President, followed by the Treasurer, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The Bakerian Lecture was read by the President on behalf of the Author as follows:—

BAKERIAN LECTURE.—“On the Grand Currents of Atmospheric Circulation.” By JAMES THOMSON, LL.D., F.R.S., Emeritus Professor of Civil Engineering and Mechanics in the University of Glasgow. Received March 10, 1892.

[PLATE I.]

(Abstract.)

In this paper a historical sketch is given of the progress of observational and theoretical researches into the nature and causes of the Trade Winds and other great and persistent currents of atmospheric circulation. Mention is made of the fanciful attempts at explanation by Dr. Martin Lister and by Dr. Garden in papers submitted to the Royal Society a little more than 200 years ago, and which are to be found recorded in the ‘Philosophical Transactions.’ These papers give evidence of the scanty and crude condition of knowledge and speculation on the subject in the early years of the Royal Society; but yet they may probably have had a beneficial effect in instigating Edmund Halley, the astronomer, to communicate to the Royal Society, in 1686, a paper on the “Trade Winds and Monsoons,”* bringing together a systematized collection of observational results, accompanied by theoretical considerations. That paper constituted an important step in the development of the science of the subject, even though his theory, in one of its most important parts, that which relates to the east to west motion of the trade winds, which he attributed to the diurnal revolution round the equatorial zone of the maximum of accumulation of heating effect, turns out to be fundamentally untenable.

Halley’s paper was followed, forty-nine years later, by one more

* ‘Phil. Trans.’ No. 183, p. 153.

important still, by George Hadley, submitted to the Royal Society in 1735.* This George Hadley was a brother of the John Hadley who invented the instrument known as Hadley's quadrant. Hadley's paper is entitled, "Concerning the Cause of the General Trade Winds," and it is right here to notice that he applied the name "general trade wind" not merely to those winds of equatorial regions to which the name trade wind is commonly restricted, but used it as including also the westerly winds known to be prevalent in higher latitudes, and which were taken advantage of in trade by mariners on ocean passages from west to east. Thus, his theory has a much wider scope than the title of his paper would now, according to ordinary nomenclature, appear to indicate. Hadley brought into consideration, for the first time, as an essential element towards the formation of a true theory, the inertial and frictional effects resulting in the atmosphere from the rotation of the earth; and we may with confidence judge that, in that paper, he offered to the world a substantially true theory of a large part of the system of atmospheric circulation in its grandest and most dominant conditions.

The paper gives a full account of Hadley's theory, accompanied by explanatory remarks, bringing into special notice its most important features; and the author quotes the concluding passage of Hadley's paper, which he considers, though somewhat vague, and not entirely correct in expression, is to be regarded as suggesting a very notable and important principle, *videlicet*:—That, in respect to the earth's rotation round its axis, the sum of the forward turning-force-influences applied by the winds to the surface of the earth, land and sea included, must be equal to the sum of all the backward turning-force-influences likewise applied to the earth's surface; so that these force-influences may be such as conjointly to produce no acceleration or retardation in the revolution of the earth round its axis.

During a period of more than a century from the promulgation of Hadley's theory there was little, if any, remarkable progress in the development of new speculation regarding the grand or perennial currents of atmospheric circulation. Hadley's theory seems to have lain dormant for a long time in the pages of the 'Philosophical Transactions,' and to have become but little known, even among men of science. Sketches of the theory, more or less complete, were from time to time put forward in encyclopædias and in works on meteorology and navigation, but usually without due appreciation of its meaning and importance, and often without any reference to his name. On the other hand, progress was gradually being made in the bringing together of information concerning the winds, so far as regards the temporary and local disturbances of the atmosphere; and speculations or theories were advanced as to hurricanes, tornadoes, or cyclones.

* 'Phil. Trans.,' vol. 39, No. 437, for April, May, and June, 1735, p. 58.

A short sketch of such progressive researches is given in the paper.

Also through information derived from observational sources, it came gradually to be accepted, as an established fact, that in the latitudes outside the limits of the trade winds—latitudes extending from about 28° or 30° up to far towards the poles—the wind, while prevailing from the west, as had been previously known, prevails also more from the equator towards the pole than from the pole towards the equator, so that to take the case of the northern hemisphere, for simplicity, the winds of our middle latitudes were found prevalently to blow from south of west.

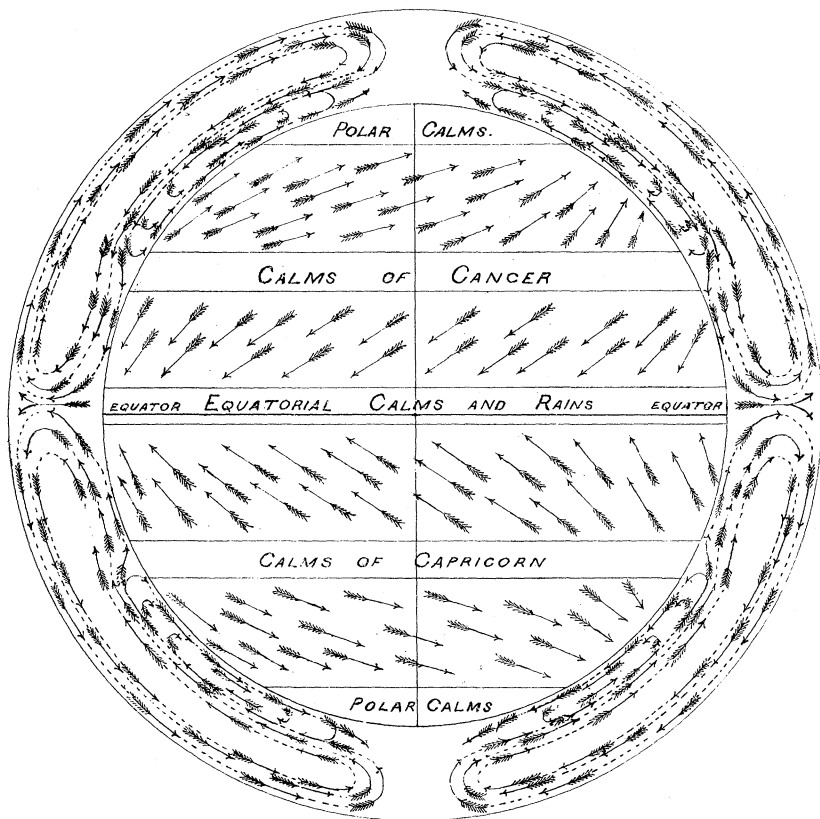
To account for this component from the south in these westerly winds, it came to be very generally supposed among the best writers on the subject that the air departing for the northern hemisphere from the top of the equatorial belt of buoyant air, while flowing northward still in the lofty regions of the atmosphere and over the trade-wind zone; soon becomes a current from the south-west, or from south of west, and continues, after descending to the earth's surface at the northern border of the trade-wind region, still to move forward in continuation of its old course as a current from south of west. But why in the lower regions a poleward motion should be maintained rather than a return flow towards the equator, and how the return from higher to lower latitudes, to compensate for this supposed poleward surface current, should be accomplished, are questions which appear to have been scarcely mooted or to have been left enshrouded in vagueness.

The paper goes on to give an account of the theory which Maury offered in 1855 as an attempt to clear up what he considered “paradoxical” in the theories of others on this subject.

The author of the paper presently reported in abstract (Professor James Thomson), finding Maury's theory untenable, devised a new theory in 1857, and brought it forward at the Dublin meeting of the British Association in that year. In endeavouring to penetrate the mystery as to what the courses of the circulation might be in the middle and higher latitudes, he was, in preliminary ways, fully satisfied that Hadley's theory, in its main features, must be substantially true, and must form the basis of any tenable theory that could be devised. He adopted that theory in all its important features, and superadded further new features, which are told of at length in the paper. His theory, so composed, may be briefly sketched out as follows:—

That at the equator, or near to it, there is a belt of air ascending because of its high temperature and consequent rarefaction:—that its supply of air is maintained by influx from both sides towards the zonal region at its base, which is a region of diminished pressure:—

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that from its upper part currents float away to both sides, northward and southward :—and that these currents continue in the upper regions of the atmosphere each of them advancing towards, and in part to, the high latitudes of its own hemisphere, until, by cooling, its substance becomes less buoyant, and sinks down gradually in various latitudes of that hemisphere, and forms itself into a return current towards the equator, in the lower part of the atmosphere.

That the air of this great cap of atmosphere, covering the middle and higher latitudes, and including portions of the currents just described, having come from the equatorial regions, which were moving absolutely from west to east in the earth's diurnal rotation with a velocity of about 1000 miles per hour, must, on coming into those new regions much nearer to the earth's axis, have greater velocity from west to east than the earth below it in those new regions has. That in the central or polar part of this great revolving cap of air the barometric pressure must be abated in consequence of the centrifugal tendency due to the extra speed of this great whirling cap of atmosphere. That the bottom layers of this great cap of atmosphere, being by friction on the earth's surface retarded as to this extra velocity of rotation eastward, must have a diminished centrifugal tendency as compared with the quicker revolving air above them, and, consequently, tend to flow, and actually do flow, inwards, towards the region of abated barometric pressure at the centre of the revolving cap of air.

That thus, over the middle, or middle and higher latitudes, there are three currents :—

- (1.) A top main current towards the pole.
- (2.) A bottom subordinate current towards the pole.
- (3.) A middle main current in direction from the pole, and constituting the joint return current for both the preceding currents.

And that all these three have a prevailing motion from west to east, in advance of the earth.

That the great return current, flowing in direction from the pole towards the equator, arrives at a certain part of its course at which it ceases to revolve eastward in advance of the earth; and, for the rest of its course to the foot of the equatorial rising belt, it blows along the surface of the earth as the trade wind of the hemisphere in which it is situated.

The description here given of the author's theory, it is to be noticed, is only a brief sketch. The ærial motions which have been described are illustrated by the accompanying diagram (Plate 1). The arrows on the surface of the hemisphere represent the winds at the surface of land or sea, not the currents in the higher regions. The northward and southward motions, and the up and down motions, in the main currents of the atmosphere, are indicated for all heights in

the cross-section forming the outer part of the diagram. A fuller description, with explanations of reasons for the various statements made, would extend beyond the limits suitable for this abstract.

In the paper the author enters into some considerations as to the reasons for or against the views put forward by various persons.

The paper concludes with a sketch of a contemplated experimental apparatus for illustrating the supposed motions in the earth's atmosphere by motions proposed to be brought into play in water placed in a horizontal circular tray, kept revolving round a vertical axis through its centre, and with heat applied round its circumference at bottom, and cold applied, or cooling allowed to proceed, in and around the central part at or near the surface.

Presents, March 10, 1892.

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