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"THE GLACIAL ANTICYCLONES:" A REVIEW[1]

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William H. Hobbs: "The Glacial Anticyclones: the Poles of the Atmospheric Circulation." Univ. of Mich. Studies; Sci. Series, vol. IV, xxiv+198 pp., 53 figs., 3 pls., index, bibliog. Macmillan, New York, 1926.

Essence of Doctor Hobbs' theory of the glacial anticyclone.—1. Many features of the winds, character of the snow, and temperature changes indicate that several fixed anticyclones exist over the Antarctic and Greenland ice domes.

2. Most significant is the centrifugal flow of the cold surface air prevailingly down slope, though deflected by the earth's rotation. Light winds and calms prevail on the central flat regions, but the winds increase in velocity toward the margins, where they may attain great violence. The more or less constant outward sweep of the winds, the "centrifugal broom" carries much of the inland snow from the higher slopes toward the margins or into the sea.

3. The upper currents stream at times toward the anticyclonic centers, carrying with them cirriform clouds, which apparently evaporate in the settling air over the ice domes. The moisture from these clouds as well as the uncondensed water vapor are evidently the material for much, if not most, of the snowfall of the interior. The precipitation of this vapor normally occurs near the chilling surface without the intermediate formation of clouds.

4. The temperature of the lower air closely depends on that of the surface. During periods of calm the snow or ice surface cools the atmosphere to a considerable height. Under the influence of gravity this cold air tends to flow down the slopes, giving rise to the blizzards of the margins, with the downward acceleration of the wind the rate of warming by compression increases and ultimately exceeds the rate of cooling by radiation and conduction. This warming automatically stops the blizzard, and another calm period sets in, during which the cold air again accumulates. Such is the apparent mechanism of much of the weather on the margins of Greenland and Antarctica.

5. The central calm and the downward and outward flow prevails apparently throughout the year and is not often interrupted by passing cyclones. Associated with these permanent glacial anticyclones are permanent cyclones, chiefly the Iceland cyclone and those in the Weddell and Ross seas. Thus it is evident that the general circulation of the atmosphere in high latitudes is complete and intimately related to the location of ice domes and neighboring open seas.

It has long been known that over a cold region air contracts and accumulates then spreads outward at the lower levels, and that cold air slides down a slope. Also, decades ago, explorers on the ice cap of Greenland had noted the down-slope winds. But the credit for first visualizing the circulation over ice caps as wholes, collating a large body of data from diverse sources, and erecting a working hypothesis of the glacial anticyclone belongs to Doctor Hobbs. Promulgated first in 1910 and 1911 and presented in detail in 1915, this was taken nto the field by explorers of the continental ice sheets and was found adequate in its essentials. Doctor Hobbs's book now presents these newer data, relating them to the conclusions gleaned from the older.

The book.—The opening portion of the book is occupied by an appreciative preface by Dr. H. R. Mill, followed by the author's historical sketch of his theory, and a criticism of early views of atmospheric circulation, including Ferrel's.

The body of the work summarizes the early explorations of Greenland and Antarctica, and what might be called the second period of exploration of continental glaciers, all fully referenced. Here is interjected a detailed discussion of the characteristics of the glacial anticyclone. New material from the latest period is then added and correlated with the earlier conclusions.

The glacial anticyclones are now placed in the general atmospheric circulation. Then glacial anticyclones of the past are outlined. Present opinion is criticized and problems for further research are mentioned in conclusion.

This approximately historical treatment places the facts before us, to be sure, while references to further details are abundant. Indeed, this volume has considerable value simply as a reference book to polar exploration during the past 100 years. But, after reading all the details, one gains the impression that the author was more intent on blaming meteorologists for not generally recognizing glacial anticyclones and their importance in the general circulation than on marshalling the facts for the presentation of his theory point by point. The glacial anticyclone has not enjoyed the reception it might have had if Doctor Hobbs had not failed to make his main points clear by befogging them with controversy, overpositiveness, and meteorological errors.

It seems unfortunate that in presenting his theory Doctor Hobbs thought it necessary to discount Ferrel's. The glacial anticyclone is an addition to the group of continental winds, which winds are not involved in discussions, like Ferrel's, of planetary circulation. Ferrel's polar calms and outflowing surface winds are in accord with present knowledge, while observations during the past forty years have apprised us of the details of continental interruptions to the theoretical planetary circulation of the higher latitudes.

A real enthusiast claims more for his theory than the available facts appear to others to warrant. Under the heading "The destructive cyclones of Europe sent out during the stroph of the anticylcone" (p. 153) Doctor Hobbs appears highly speculative:

> The great volume of air which pours out from the Greenland inland ice during the stroph of the anticyclone, at the surface and in the lee of the ice cap, halts abruptly [?] just at the contact with the migrating cyclones along the coast. At higher levels this in its outward movement must certainly pass upward within the adjacent migrating cyclones [ref. to Lockyer], and it must impart to them a vigor which near the ground will increase as they travel.

We wonder if this can be so, and await the illumination that only observations can provide. "The climatic zones which are characteristic of the present age," Doctor Hobbs says, "would appear to be due largely to the existing glacial anticyclones . . ." (p. 54). We can not admit this to be possible without implying that the continental glaciers in high latitudes could be formed if there were no cold zone, though it is true that, once formed, they should lower the temperature further, thereby accentuating, but not creating, zonation.

When a geologist writes a book on winds and weather, it is not surprising to find a number of meteorological errors in it. Ice crystals of cirrus clouds descending over

[1] Presented, in more extended and slightly different form in a symposium on Greenland, at a joint meeting of the American Meteorological Society, Association of American Geographers, and Section E of the American Association for the Advancement of Science, Philadelphia, Pa., Dec. 30, 1926.

the ice caps of Greenland and Antarctica are not likely to melt before vaporizing, as Doctor Hobbs reiterates (pp. 2, 52, 131). Latent heat can not further augment an elevation of air temperature (p. 131). To apply the term "vortex" to an anticyclone (pp. 34, 100, 127) is a misuse of the word. (Cf. "Meteorological Glossary", Brit. M. O. 225 ii, pp. 347–351, 1918.) Likewise, it is a misappropriation of the term "eye" in meteorology to speak of "Eye of glacial anticyclone" (fig. 18). An intense cyclone is said to have an eye when it has a sharply limited central region more or less calm and clear. The author's idea of a limited central area of descent appears to have been gained from an ingenious experiment in which, however, the coloring matter to show the streamlines of descent over a cold dome was restricted to only a central portion of the fluid, thereby giving a fictitious semblance of limited circulation in a form suggestive of a vortex (Pls. II and III, and fig. 18).

Four important points still to be settled are—(1) the relative importance of the general low temperature and of the slope in the strength of the glacial anticyclone, (2) the nature and extent of the upper inflow of air '(3) the alimentation of the ice sheet, and (4) the locations of the permanent large high pressure areas in high latitudes.

1. A snow or ice field at sea-level surrounded by open water would be marked by an anticyclone. But how strong would it be? Doctor Hobbs insists, on the other hand, that the slope of the cold glacial dome is responsible for the anticyclone over it. When we have enough surface and aerological observations, perhaps we can determine to some quantitative degree how much of the wind velocity of the "glacial" anticyclone is due solely to the slope over which and down which the outflowing cold air travels.

2. It seems to the reviewer that Doctor Hobbs' idea of a distinct downdraft in the interior free-air portion of the glacial anticyclone is far too strong for what probably occurs over the exceedingly broad and apparently nearly level expanses of the interiors of Greenland and Antarctica. The amount of air involved in the downward and outward flow along the surface of the ice is small relative to the total air in the troposphere over the dome. It is, therefore, unnecessary to demand a well-defined inward flow and descent. Aerological observations in west Greenland do show a turning of winds with altitude till there is a slight average inward component of motion. But there appears to be no direct flow to the interior, as suggested by Doctor Hobbs, nor anything approaching an upper air cyclone, as some others demand for the formation of the precipitation. All balloon evidence seems to point to the Greenland anticyclone being essentially a ridge of high pressure extending nearly to the top of the troposphere. Cyclones greatly disturb this anticyclone, at times even wiping out the entire southern portion.

3. The point in Doctor Hobbs' theory, that has been open to perhaps the greatest criticism is his claim for anticyclonic alimentation of the ice sheet. Nobody denies there is precipitation in the far interior of the glacial anticlone; that is self-evident from the presence of the glacier and the almost continuously outward-moving drift snow. The sticking point with some critics is, how can precipitation occur in compressionally warmed descending air? In the interior of Antarctica temperatures below −75° F. have been observed, and it is not unlikely that equally low temperatures occur in the interior of Greenland, since Nansen experienced temperatures well under 40° F. below zero there even in September. Therefore, it is readily possible for air that has descended even 4 or 5 kilometers onto the ice dome to yield frost or frost fog precipitation even if this air contained no condensed vapor in the form of cirrus clouds before it descended. Explorers have found this type of precipitation to be common in the cold interiors of Greenland and Antarctica.

It seems likely, however, that on the margins of the ice-dome the precipitation from ascending air is far greater than any frost fog, while in the cold interior, much drier in the absolute sense, the precipitation from ascent may fall behind that from chilling at the surface, the total from the two causes together being greatest at the margins and least in the farthest interior.

4. In the south polar region, the center or centers of highest pressure throughout the year are unquestionably over Antarctica. In the north polar region, however, there is some doubt whether the actual north pole of the air circulation of the globe throughout the year is over Greenland as Doctor Hobbs claims. In winter, there is the well known great extension of the polar high pressure conditions into Asia and North America, while in summer high pressure conditions appear to be restricted to the Arctic Ocean and Greenland, with a reasonable possibility that, in addition to the apparent high pressure center over or near northeast Greenland (Cf. MONTHLY WEATHER REVIEW, 51:260), there may be one in the great unexplored areas north of Alaska and the Yukon. It seems that the general Greenland HIGH is north of the latitudinal middle of Greenland where centered by Doctor Hobbs, being a compromise between the tendencies to high pressure both over Greenland and over the polar basin immediately about the North Pole. (Cf. Buchan's charts, plate 13, in Bartholomew's Atlas of Meterology.)

Conclusion.—These questions will disappear as the facts become better known, and they do not involve the main points of the glacial anticyclone theory, of a more or less pulsatory prevailing outflow of air down the slopes of an ice-cap, with a necessarily compensatory inflow aloft, and the occurrence of precipitation all over the dome. Some of the miscellaneous errors noted will be corrected, and differences with meteorologists can be smoothed out, though it is not to be expected that all others will see so far reaching an importance nor so many ramifications of the theory as its keen and enthusiastic proponent urges. As a full collation of polar wind observations relative to the glacial anticyclonic circulation, Doctor Hobbs' monograph is an outstanding contribution to polar meterology.