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CORRESPONDENCE

The Editor,

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SIR, *Glacier variation and weather: comments on Professor Hoinkes' paper*

Professor Hoinkes' paper (1968) will give a useful impetus to the study of this subject, in particular to the search for simple relationships between the large-scale atmospheric circulation and the behaviour of glaciers in the various main glacier regions of the Earth.

The late Professor Wagner performed a very useful service in drawing attention to the progressive intensification of the main zonal circulation of the atmosphere from the latter part of the last century to the earlier decades of the present century. He may however have been mistaken in thinking that the relationships between an increase of the mean pressure gradients associated with the prevailing westerlies and variations of "continentality" (i.e. summer–winter temperature difference) and glacier growth and retreat would be simpler than is in fact the case. To understand this and the problems involved, it is necessary to distinguish between the scales of various phenomena. Wagner found evidence of an increase of the strength of the general circulation from the 1880's up to some time about the 1920's, which many other workers have since found represented in the courses followed by various indices of the zonal westerlies of middle latitudes in the Northern Hemisphere. From my own work, it appears also to have affected the trade winds and the Southern-Hemisphere westerlies. This is clearly a large-scale phenomenon, apparently of global dimensions. Changes in the strength of the main zonal wind streams are, however, accompanied by changes in the prevailing positions occupied by the great warm ridges and cold troughs in the upper westerlies, apart from those which are most closely anchored by the effects of the meridional mountain barriers (e.g. the Rocky Mountains) upon the flow of the upper westerlies. Longitude shifts of the warm ridges and cold troughs, corresponding to changes of wavelength downstream from the anchored disturbances, result in some areas experiencing for some time, in the course of a climatic change, temperature changes which are out of phase with the more general experience of the remainder of the latitude zone, or of the world, at the same time.

The relevance of both these points to recent climatic changes and their effects on glaciers is explained in the following paragraphs.

The frequency of westerly weather type (which implies general surface westerly and south-westerly winds) over the British Isles since 1873 has varied in the way shown by Professor Hoinkes—a gradual rise from 1873 to an epoch around the 1920's, when the frequency was 50 per cent greater than in the 1870's, and a subsequent fall to values in the 1960's that are similar to those ruling in the 1870's or earlier. The upward and then downward trend of the frequency of westerly situations in Britain applies to nearly every month of the year and closely parallels changes of the pressure gradient indices for the prevailing zonal westerlies in the middle latitudes over the same period. The same trend is shown by the frequency of Girs' westerly type, affecting the whole northern hemisphere, from 1890 to 1958. Very much the same trend has also been derived by Dr. H. Trenkle of the Deutscher Wetterdienst for the 500 mbar geostrophic wind lats. 50–60° N., longs. 60° W.–60° E. in winter from 1880 to 1963. Dr. Trenkle derived his values of the 500 mbar zonal index between lats. 50° and 60° N. from study of the varying frequency of the different *Grosswetterlagen* of Hess and Brezowsky. Trenkle found that the 500 mbar zonal index increased from low values around 1890 to high values between 1900 and 1925, after which the values fell once more, apart from a brief recovery around 1950: by the 1960's the values were much lower than in 1890. Study of the behaviour of all these different indicators—of the frequency of westerly situations over the British Isles, of south–north differences of mean pressure associated with the prevailing westerlies over the sector between longs. 60° W. and 60° E. and of the frequency of generally zonal westerly flow around the whole Northern Hemisphere—thus produces the same result: a rise and then a recent fall of the strength of the main zonal wind circulation, a trend which is seen as affecting the whole Northern Hemisphere and apparently the whole Earth.

The recent decline of the westerlies has been accompanied by an evident shortening of wavelength in the upper westerlies such that the upper cold trough in the European sector has in the 1960's tended to occupy more western positions than in the earlier part of this century and has often lain over Central Europe in winter and over northern or north-western Europe in summer. (Thus, the years of reduced westerlies in the 1960's have tended to have cold summers and cold winters in north-west Europe—not

the usual expectation when continentality increases!) The amount of meridional (north–south) development of this trough is important and differs in different years. Its position was over north-western Europe, with the axis lying between longs. 0° and 10° E. in the summers of both 1962 and 1965: in 1962 the trough was largely confined to latitudes north of 50° N., and only the Scandinavian glaciers were directly affected, whereas Central Europe had a rather warm summer; but in 1965 the trough axis was well marked as far south as Spain, so that Central Europe not only experienced some of the cold air but also the repeated cyclogenesis characteristic of the forward side of an upper cold trough. Thus the Alpine glaciers were well nourished in the summer of 1965 but not in 1962.

Computations by J. M. Mitchell, U.S. Weather Bureau, of changes in world temperature since 1880 show very much the same trend as the vigour of the westerlies. World temperatures attained a maximum in the early 1940's of the order of 0.5 deg above the temperatures generally prevailing around 1880 and subsequently fell again. The cooling since the early 1940's has been sharpest in the Arctic, where the sea ice has increased again, but by the 1950's the area of cooling showed long extensions into middle latitudes in certain sectors—presumably the sectors affected most by the changed positions of the upper cold troughs. In the 1960's so far, average temperatures over the Arctic and in Britain and Scandinavia, especially in the summers, are believed to be lower than at any time since well back in the last century. In the 1950's Central Europe, like the eastern U.S.A., European Russia and parts of Central Asia, was experiencing higher temperatures than before, i.e. a change of temperature out of phase with that going on over most of the world and notably out of phase with that going on over neighbouring sectors of the northern hemisphere. This presumably means that Central Europe, European Russia and Central Asia were more affected than formerly by upper warm ridges owing to the longitude shift of the waves in the upper westerlies. In view of the cooling tendency of recent years in neighbouring sectors of that same latitude zone, and over most other parts of the world, it may be premature to conclude that the prospects for the Alpine glaciers at the present time are far from favouring fresh growth—though any growth would probably come only after an appropriate lapse of years for increased accumulation at the glacier heads to affect the lower reaches.

In studying the effects of the atmospheric circulation it will be essential to study details of the position and north–south amplitude of the upper cold troughs and ridges, as well as the layout of regions of change of vorticity in the flow of the upper westerlies favouring cyclogenesis. These items are not necessarily revealed by such measures as the zonal index however defined.

Apart from relationships between glacier changes and the general wind circulation, I believe it is necessary to consider the effects of occasional volcanic dust veils such as the great one which covered most of the world in 1963–65 after the eruption of Mount Agung in Bali early in 1963. There is unmistakable evidence of a (doubtless temporary) additional reduction of world temperature for those years amounting to about 0.5 deg at its strongest. It may also be desirable to keep a continuous record of variations of the albedo of glaciers, from month to month and from year to year, in case pollution of the glacier surface by industrial smoke or wind-blown dust should have important consequences in the ablation season.

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REFERENCE

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Sir,

Primary and secondary polygons

During a visit to Iceland in the summer of 1966 a species of patterned ground, possibly hitherto undescribed, was observed. It was discovered on the small summit plateau of the 998 m peak on the Thingeyri peninsula, Vestfirthir, north-west Iceland. A large area of this plateau was covered with large sorted polygons inside each of which several smaller sorted polygons were situated. The primary polygons measured 5–6 ft (1.5–1.8 m) and the secondary polygons 1–2 ft (0.3–0.6 m), respectively, across their internal diameters (Figs. 1 and 2).