NOTES AND CORRESPONDENCE

On Mathematical and "Natural" Models for the Study of Climate Changes

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In his recent paper Lorenz (1970) makes a plea for the use of mathematical models in the study of climate change, recommending two hypotheses of climate change which can be tested with models. However, a test of climate change hypotheses is available using classical meteorology.

The first hypothesis (Donn and Ewing, 1968) uses as a starting point an ice-free Arctic Ocean. This, it is correctly claimed, would induce evaporation, which on condensation would lead to precipitation. The precipitation, according to the authors, would be carried to the surrounding colder land and fall in the form of snow, which would gradually build up to ice, the primary condition for an Ice Age.

However, the hypothesis overlooks the fact that with an open (ice-free) Arctic Ocean, the warm ocean surface will call for a low pressure or cyclonic system with a convergent air flow, or winds blowing toward the center. The precipitation will then fall back into the ocean. Moreover, with cold air from the surrounding land being drawn in winter to the center, the ocean surface will soon freeze, preventing further evaporation.

The other hypothesis (Weyl, 1968) claims that a decrease in salinity in higher latitudes will lead to ice formation, and that the ice, in turn, will cause cooling and, in time, an Ice Age.

In support of his hypothesis Weyl cites the increase in salinity from 1902–17 to 1920–39 and the simultaneous retreat of the ice boundary in the North Atlantic Ocean, as if the increase in salinity were responsible for the retreat of the ice. However, a study of the air flow during the two periods (Figs. 1 and 2) indicated that the second period, with a higher salinity and a more northerly limit of the ice, was characterized by a stronger flow of air and water from the south over the northeastern North Atlantic than the first.

Thus, the average pressure difference between 50–70N and from 10W to 10E was 6.8 mb in the first period (1901–20), as compared with 7.6 mb in the second period (1921–39). This, as might be expected, was associated with the well-known rise in the mean annual temperature during the same period, amounting to, for example, 0.4C at Bergen, 0.4C at Thorshavn, 0.9C at Bodo, and 1.0C at Papey-Teigarhorn (Iceland). It was also associated with a rise in sea surface temperatures in the area in between Iceland and Norway and the United Kingdom (Fig. 3). In other words, the stronger southerly winds in the second period would account for both the melting and retreat of the ice and the increase in salinity due to the northward advection of warmer, more saline waters (although some of the salinity increase would also be due to increased evaporation).

In attempting to show that an increase in ice causes a lowering of temperature and eventually an Ice Age, the author cites the following sentence from the abstract of my paper (1956):

> It is shown that the mean sea ice limit in the Greenland and Barents Seas during the period April–August is a substantial measure of both the sea surface temperature near the Faroes and the east coast of Iceland and the air temperature at Iceland, during the subsequent period September–February.

From this the reader is to conclude that the sea surface temperatures at the Faroes, islands some 600 mi southeast of Iceland which may or may not be affected by the East Icelandic Polar Current, as well as the air temperatures in Iceland, were determined by the ice off Iceland. However, as I have shown in the same paper, the lowering, for example, of the sea surface temperatures several months later at the Faroes than off Iceland merely reflects the earlier appearance of the cold water (and ice) off Iceland.

As with certain other theories of climate change, there is a grain of truth in Weyl's hypothesis. A (further) lowering of temperature would indeed occur following the development of the ice sheets during an Ice Age. Also, a lowering of salinity of the surface layer at the critical temperature would facilitate the formation of ice.

Classical meteorology can also serve well for testing

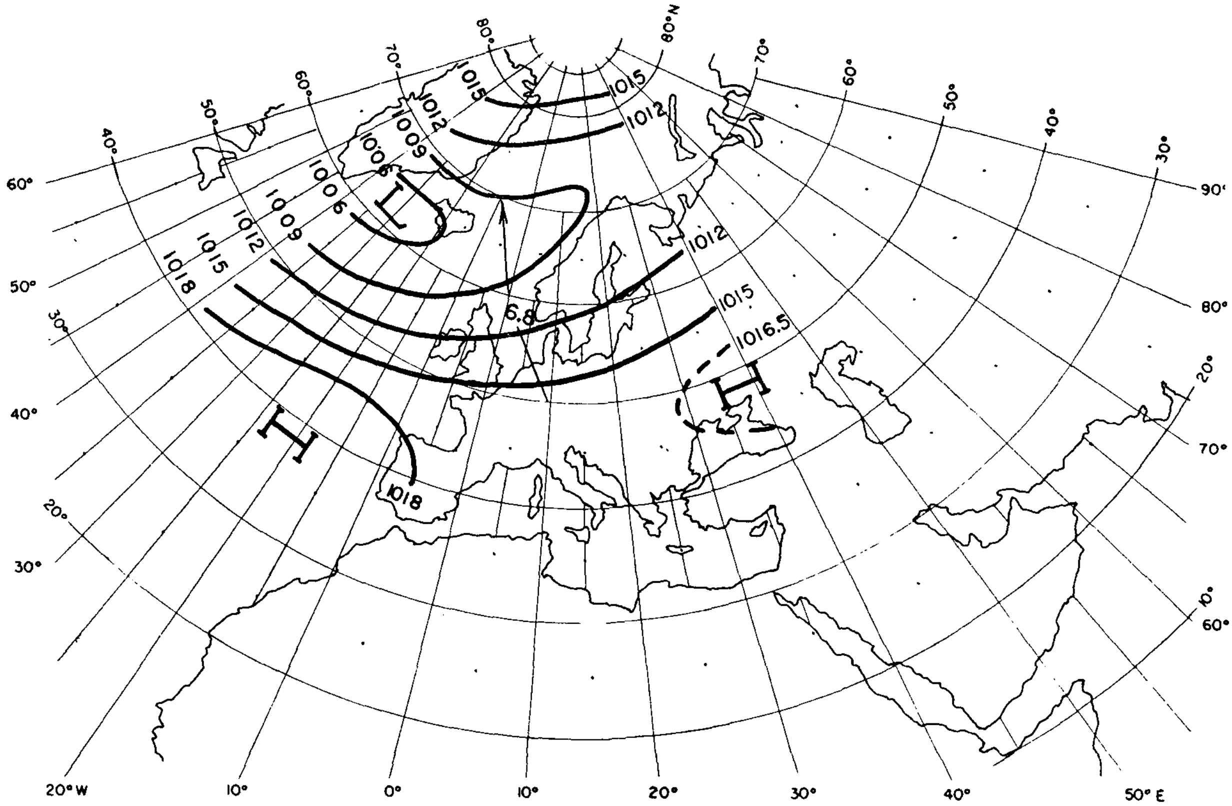

FIG. 1. Mean annual sea level pressure and pressure difference from 10E to 10W and 50–70N during the period 1901–20.

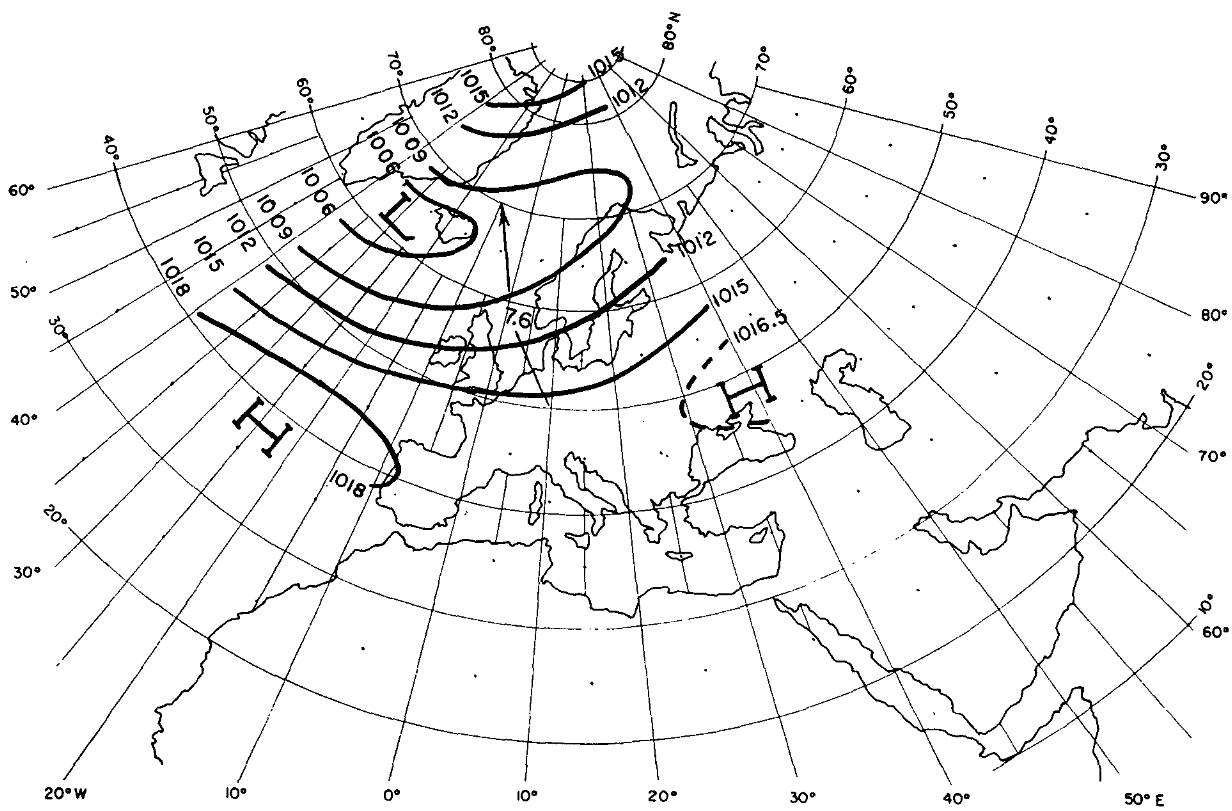

FIG. 2. Same as Fig. 1 except for the period 1921–39.

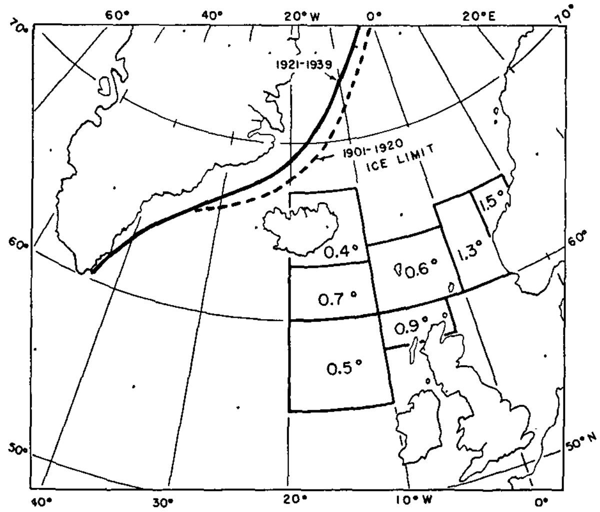

FIG. 3. Increase in the sea surface temperature (°C) in the northeastern North Atlantic from 1901–20 to 1921–39 (after Brown, 1953, and Schell, 1956).

other theories of climate change, such as that involving CO_2, which calls for an essentially equal rise or fall in temperature everywhere, as opposed to the actual small rise or fall observed in low latitudes, and the much larger rise or fall at higher latitudes.

We may also call attention to the limitations imposed by mathematical models as expressed by Lorenz: "Such a solution may give us little insight as to why the changes took place"; and: "As to what features *did* produce climate changes, we still have this privilege of arguing." Such insights are needed; the basic, though not detailed solution of this problem, is slowly being realized through a study of past climates, nature's own models, by fitting together the evidence from ice and ocean bottom cores, land and sea features, and a more complete historic record; analyses of such data as these will make it possible to eliminate the majority of the current theories, hypotheses and explanations.

It further needs to be pointed out that the majority of the explanations have had their origin in the long-held misconception that evaporation can only increase with an increase in temperature, and therefore, that an Ice Age, characterized by a huge transfer of moisture from the ocean onto land, could not have developed. The fact is that evaporation can also increase with a decrease in temperature *if the winds are strong* (Jacobs, 1949; Tabata, 1961; Shellard, 1962; Yamamoto and Kondo, 1964; Bøyum, 1966; Kraus and Morrison, 1966); such would indeed be the case during an Ice Age as a result of the extremely rapid exchange of air which would occur between low and high latitudes, as a result of the steepness of the latitudinal temperature gradient (Schell, 1970).

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Detection of Chloride Ions in a Klucel Medium

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1. Introduction

Sampling by impaction has been a widely used technique for obtaining information on particulates. Seely (1952) extended the usefulness with a gelatin medium containing a reagent specific for selected given compounds. Vittori (1956) extended the technique to more substances and in addition used a $AgNO_3$ reaction as