winter, in the year 2000

Long-range weather forecasting is
becoming commonplace,
but until comparatively recently
it has not been possible
to make predictions with any confidence
about the likely course of the
weather over a period as long as
the next thirty years.
Research workers who studied samples
taken from a North Greenland
ice core 1400 metres long
believe they may have a clue to what
is going to happen.

The work was described by Professor W. Dansgaard, of the H.C. Ørsted Institute, University of Copenhagen, who gave a scientific lecture at the headquarters of the IAEA a few weeks ago. He and fellow workers, S. J. Johnsen and H. B. Clausen, from the Institute, and C. C. Langway, from the Cold Region Research and Engineering Laboratory of the United States Army, New Hampshire, have also described their results briefly in the British scientific journal "Nature."

Professor Dansgaard has co-operated with the International Atomic Energy Agency in work undertaken during the past ten years on measurement of the stable isotopic composition of precipitation, using samples obtained as part of a joint IAEA — World Meteorological Organization precipitation survey; and in March he was a participant in a symposium at Agency headquarters on the use of isotopes in hydrology. He proposed in a paper published in 1954 that the isotopic composition of ice contained in glaciers could be used as an indicator of the climatic

conditions at the time it was formed. It is possible to form such conclusions because the concentration of both deuterium and oxygen-18 in snow in high polar regions increases with the temperature of formation of the snow. In areas such as Greenland, or in the Antarctic, successive falls of snow accumulate as ice and build to great thicknesses. Within practical limits, not only seasonal temperature variations but long-term climatic patterns can thus be deduced.

"This," said Prof. Dansgaard, "is one of the most intriguing aspects of deep ice cores. They contain formation about past climatic conditions, and in regions where there is considerable snow each year and little or no surface melting, a deep ice core represents a continuous sequence of sedimentation spanning tens of thousands of years. To me it is fascinating to think that over the entire ice sheet of Greenland — for example — there has not been one single widespread snowstorm in the last hundred thousand years which is not represented in a deep ice core. If you measure an increasing oxygen-18 content upwards in part of a core, that corresponds with a warming climate at the time of deposition of the ice; if you find a decrease, that corresponds to a cooling climate."

It is one thing to know this, it is another to be able to carry out an actual study of deep ice. Samples are difficult to obtain. But Prof. Dansgaard and his fellow workers were able to take advantage of an opportunity offered by the work of the American team, who succeeded in recovering a core 1400 metres long from a site known as Camp Century, on the North Greenland ice sheet. The core could not be dated using "conventional" techniques, because they could take too little ice from each layer, but it was found possible to work out the time of deposition by calculating the flow of ice through the sheet, checking the ages obtained for various depths against the known dates of major climatic events calculated by other methods. Once the correlation had been established it was possible to extrapolate data obtained from the core along the whole of its length — which, it was found, gave an unbroken and detailed climatic record spanning probably 100 000 years. Near the surface, each sample analysed for its isotopic composition represented about 10 to 15 years' deposition of snow; toward the bottom, each sample represented about 100 years. The research team measured thousands of samples.

Climatic history in a core

There was the record. The last ice age could be distinguished: its onset 70 000 years ago, its termination 10 000 years ago, and many details, only a few of which had been known before.

The scientific reward for detailed study of past millenia could be great. But the study of the record for the last thousand years, and what may be deduced from it in conjunction with data for earlier times, could have greater relevance to the present day — and, in particular, to an attempt to forecast the likely pattern of climatic change for the rest of this century and beyond.

Prof. Dansgaard illustrated his talk with reference to the chart reproduced here (Fig. 1). The deviation in oxygen-18 content in a sample from that of standard mean ocean water, in parts per thousand, is plotted

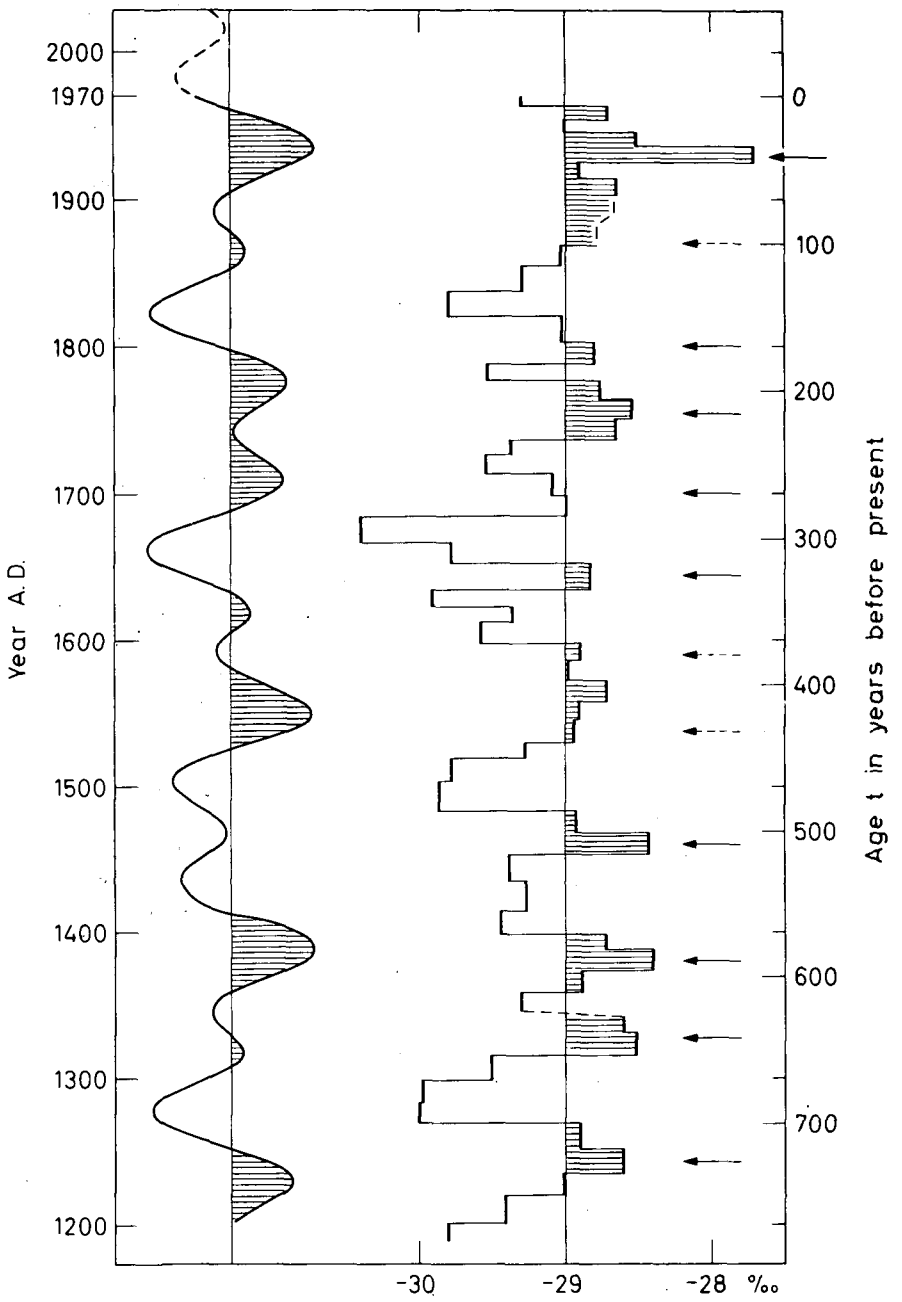

Fig. 1. (Reproduced by permission of *Nature*)

here against time. On the left hand side is plotted a synthesis of two harmonics which dominate the Fourier transform of the raw data on oxygen-18 deviations — termed, for ease of reference, delta-^{18}O. The hatched areas reflect relatively warm periods.

"Consider the record of the last 800 years," Prof. Dansgaard invited his audience at the IAEA. "The fifteenth century was dominated by a long-lasting cool period. This might be the reason why the Norsemen settlements in south Greenland disappeared about this time. They could not graze cattle any more, grass did not grow.

"The sixteenth century was somewhat warmer. But the next 130 years were very cold. This period corresponds with the so-called 'little Ice Age', which might be one of the coldest periods since the end of the last real ice age. Icelandic historical sources talk about enormous amounts of ice in 1690 — pack ice surrounded Iceland and reached as far as the Faroes. There are many other indications that this cold period was dominating the climate of Europe.

"But in 1730 or so, conditions improved a little, then again in 1810—1820 it was cold, but from that time onward the climate generally improved. A very high peak occurred in the 1930s, corresponding to the climatic optimum 40 years ago.

"Now, the delta curve has dropped considerably since the 1930s," said Prof. Dansgaard. "We are now dropping below the average. This cooling, particularly during the last decade, has been recognised in other work, too. Temperature records shop a drop in temperature, within the last 30 years, of a considerable fraction of a degree Centigrade on a global basis, and a drop of one or two degrees in latitudes higher than about 70°, indicating that the climatic change is more pronounced in high latitudes. Greenland fishery, in consequence of this climatic set-back, is declining noticeably. Within the last five years the number of fishing boats and trawlers has doubled, and at the same time the total catch of hish has been reduced by a factor of two or three. It is not very optimistic, but it is a fact that the east Greenland pack ice in the last few years has reached around Cape Farewell and far up along the west coast of Greenland. All this pack ice melts there, cools off the water — and the fishing industry declines because the water simply gets too cold for the fish.

"This is a serious situation. Also, farms in north Iceland are being abandoned because grass cannot grow there any more. The English climatologist, H. H. Lamb, has described the recent climatic setback in England; he points out that the growing period for plants, grass, has diminished by three weeks, which is certainly a noticeable effect. Furthermore, the number of days with snow cover on the ground has doubled, and the frequency of strong westerly winds has increased by some 20 per cent in the last 20 years, which suggests that this climatic change is associated with a movement in the mean position of the polar front towards the south..."

Looking to the future

"Now, what is the prognosis? We have put all the delta oxygen-18 data into a computer and asked whether there is any regular, persistent oscillation in it. And the answer came out."

Fourier spectral analysis showed, said Prof. Dansgaard, that there was one regular oscillation in the delta oxygen-18 data with a period of about 180 years, and a second with a period of about 78 years. Other, minor peaks which were found could be due either to "noise," so-called, or to less dominant oscillations. The two dominant periods are probably caused by similar oscillations in solar activity, because the period (about 11 years) of the sunspot cycle varies also with periods of some 80 years and of some 180 years, in anti-phase with the delta oxygen-18 data. This was one reason why Prof. Dansgaard and his fellow workers felt entitled to make an extension of the regular oscillations in the smooth curve on the left of the chart into the future: it is the synthesis of the two dominant harmonics in the "delta data." Something like a weather forecast could be obtained.

"The dashed curve" (beginning in 1970 and extending into the 21st century) "suggests that within the next 10 or 15 years the cooling trend will continue," he said. "Then this will be taken over by a warming trend, going to a little maximum in the first or second decade of the next century.

"But, of course, in this prognosis we have neglected possible climatic influences of human activity, such as the pollution of the atmosphere by dust and CO_2.

"Presumably, increasing dust content in the atmosphere would further amplify the cooling trend, whereas increasing CO_2 concentration would have the opposite effect. Nobody can tell even the direction of the combined effects. Other human interferences in nature might be climatically significant — just think of the increasing generation of heat, or the plan to divert Siberian rivers to use their water for irrigation in central Asia. I do not know about this, but it could have a considerable effect.

"We can only say that if we neglect these poorly known effects, we believe we can see the most probable trend in climatic development."

The outlook for tomorrow: cooler.