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The Interannual Variability of Monthly Mean Air Temperatures over the Northern Hemisphere

by J. M. CRADDOCK, M.A.

LONDON: HER MAJESTY'S STATIONERY OFFICE

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Contents

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SUMMARY

Long-term average values of the mean temperature and rainfall experienced in each month or season form the basis for the demarcation of the main climatic regions of the world, and indicate the general suitability of each region for human habitation and the various forms of agriculture. However, the variability of individual years about the long-term average is almost equally important and far less well known. The present paper provides some information on the variability of the first element, namely, temperature.

INTRODUCTION

The statistical distribution of monthly mean air temperature varies a good deal with the time of year and the place where the measurements are made, and it is probably impossible to suggest any one measurement of variability which is adequate for all places and seasons. The measure used is the standard deviation, or more strictly, the root mean square deviation from the average, which has been calculated or estimated for a network of stations covering most of the land areas of the northern hemisphere. This is the most suitable measure of variability for any quantity which follows the Gaussian distribution: most monthly mean temperatures fall into one-humped distributions, but often there is a longer tail on the cold side in the colder months, and on the warm side in the warmer months. In a few cases the distribution is rectangular or bimodal. Nevertheless, provided these points are borne in mind, the standard deviation is a useful measure of the variability of monthly mean temperatures.

MATERIAL

While most countries include mean values of weather elements in their climatological publications they do not often provide measures of variability. The present paper is based on data from the following sources:

(i) Some charts published by Nagao[1]* based on observations published in the Smithsonian World Weather Records, mostly for the years 1921–40.

(ii) Isopleths given by Sumner[2] for the greater part of North America, stated to be based on every first class climatic record in Canada and the United States for the 50 years 1901–50.

(iii) Values given by Bagrov and Šabunina[3] for 62 stations spread over the European and Asiatic territories of the U.S.S.R.

(iv) Values computed by Craddock and Ward[4] for the eastern Atlantic area, Europe and western Siberia as a by-product of an investigation into intermonthly relationships.

*The superscript figures refer to the bibliography on page 4.

(v) Estimates made by the 'range' method to fill blanks in the chart—blanks which generally are due to the absence of the stations with the long observational records which would have made them acceptable to the preceding investigators.

The estimates by the 'range' method are the only ones available for much of the Arctic regions. While these estimates are at first sight less reliable than those based on the sums of squares, because of the smaller number of years used and the uncertainty of the conversion factor when the distributions are not strictly Gaussian, the differences do not in practice seem to amount to much. Over America, when the station values are estimated by the 'range' method, they agree with the isopleths published by Sumner which are based on the sums of squares, and the impression left, after a comparison between estimates made by both methods for the same area, is that there is little to choose between them.

From 300 to 400 observations were plotted on each of 12 charts for the months of January to December. They are enough to provide a fairly clear picture for the land areas of the northern hemisphere, apart from the central Sahara and the Tibetan plateau. Over the oceans, there are enough observations from islands and weather ships to give confidence in areas such as the north-east Atlantic and the Caribbean, but the patterns of variation over the Pacific Ocean and much of the Arctic icefield remain uncertain. Isopleths from these charts, drawn at intervals of 1°C are shown in Figures 1 to 12.

SIGNIFICANT FEATURES OF THE CHARTS

A quick examination of the 12 monthly charts (Figures 1–12) will show that the interannual variability is greater in winter than in summer, greater in the interior of the continents than it is in oceanic and maritime areas, but very low in all months in the tropics. The regions of highest variability are generally grouped round the Arctic Ocean, and southwards from these latitudes there is a general tendency for variability to decrease with latitude.

The logical starting point for examining the monthly charts is probably the end of the summer, when it seems that the atmosphere comes nearest to making a fresh start (see, e.g. Craddock and Ward[4]). Accordingly, the first chart discussed is that for October (Figure 10).

In October the standard deviation is 1°C or more in nearly all land areas outside the tropics. The only extratropical regions where it is lower are in Central America, from Sicily across the eastern Mediterranean to Iraq and a small area over Baffin Land. The highest values are between 3° and 4°C and are found in northern Siberia, northern Greenland and north-west Canada. What data there are suggest that the value over the Arctic ice is less than 3°C.

In November (Figure 11) the position of the 1°C isopleth has not altered much, but the area with standard deviation of 3°C or more has expanded and now covers most of northern Canada and Alaska, Greenland and Siberia. The values in the northern part of the Canadian archipelago are still less than 2°C, so that the highest values of 4° to 5°C lie in an oval or horseshoe around a polar region of lower variability. The Norwegian Sea and its borders show lower variability than anywhere else in the same latitudes.

In December (Figure 12) the 1°C isopleth shows little change from November, but the regions of higher variability, over 4°C, lie in two distinct areas, one covering most of Siberia and at any rate part of the Arctic Ocean, and the other covers Alaska and the northern Rocky Mountains. Between them Baffin Land and much of the Canadian archipelago have values of less than 3°C. The eastern Mediterranean area and Iraq have low values.

In January (Figure 1) the areas of greatest variability are back in the oval pattern. There seem to be four distinct areas, one over the west coast of Hudson Bay, the second extending from Greenland towards Novaja Zemlja, the third in central Siberia, and the fourth, the most intense of all, covering the northern Rocky Mountains, Alaska and the extreme north-east of Siberia. Within these areas, in which the highest values range from 5° to 7°C, the Canadian archipelago has values as low as 2°C.

In February (Figure 2) the general pattern is very like that of January. The peak values are rather lower, but the area included in the 1°C isopleth reaches its greatest extent.

In March (Figure 3) the pattern with an oval of high values encircling the pole remains but the emphasis has changed. The standard deviations in north-east Canada, Greenland and north Siberia are still comparable with those in February, but the values over north-west Canada and Alaska have fallen from 5–6°C to 3–4°C, though they still exceed those found in the Canadian archipelago within the oval.

In April (Figure 4) standard deviations of over 3°C seem to be confined to the Arctic Ocean and its borders and to two smaller areas in Turkestan and north-west Canada. The 1°C isopleth has contracted a little, and an area from Sicily to Syria and Iraq now has values below 1°C.

In May the pattern (Figure 5) shows maxima of 2° to 3°C over European Russia, north-west and north-east Siberia, central North America and Greenland.

In June (Figure 6) the maxima exceeding 2°C are in north Russia, the Ukraine and parts of North America. The 1°C isopleth which generally follows the main coastlines has moved north over the southern United States and the Sudan.

The tendency for the variability to fall continues in July (Figure 7) and August (Figure 8), but September (Figure 9) shows the 1°C isopleth beginning to advance southwards again.

DISCUSSION

These facts are of obvious importance in studies concerned with long-range forecasting or climatic change since they determine the stability of statistics such as means and regression coefficients. They also help to determine the suitability of a region for human habitation. For agriculture, the ideal climate would have no interannual variation at all, because then crops sown at the most suitable time — as determined in ancient times by a religious festival, and in recent times by the calendar — would be always ready for harvest a certain number of days later. In such a climate, too, the improvement of breeds of plants and animals by biological or artificial selection would proceed at the greatest possible rate. While this ideal does not occur in reality, it is interesting to see how nearly it is approached in the ancient cradles of civilization, especially round the eastern Mediterranean and in the Euphrates valley.

By contrast, in an area of large interannual variability the produce of agriculture may vary greatly from one year to another, the selection of varieties able to cope with variable conditions becomes slower and more difficult, and a stable human environment cannot be maintained until means have been developed for storing the surpluses of the good years to meet the deficits of the bad.

The areas of greatest variability are not very significant agriculturally, because they are mostly too cold for serious development. Even in these regions, the effective limit of timber trees or that of human habitation may depend on the occasional winter of unendurable severity rather than on the average conditions. Large variability may also affect many crops when it occurs near the beginning or end of the growing season.

This paper deals with its subject in broad outline, and the data used are probably good enough for the purpose. If further detail is required, for particular regions, there is a good deal of extra material which could be used. However, the present account should be adequate for most purposes.

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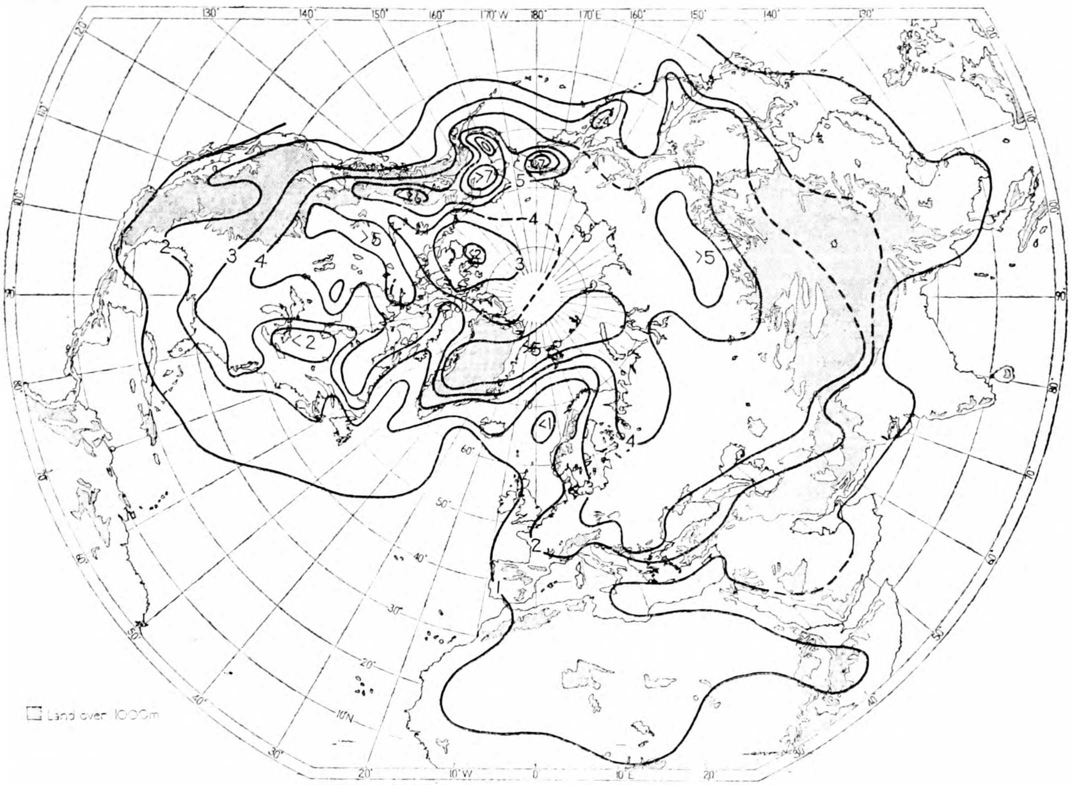

FIGURE 1. Standard deviation of monthly mean temperature in degrees Celsius—January.

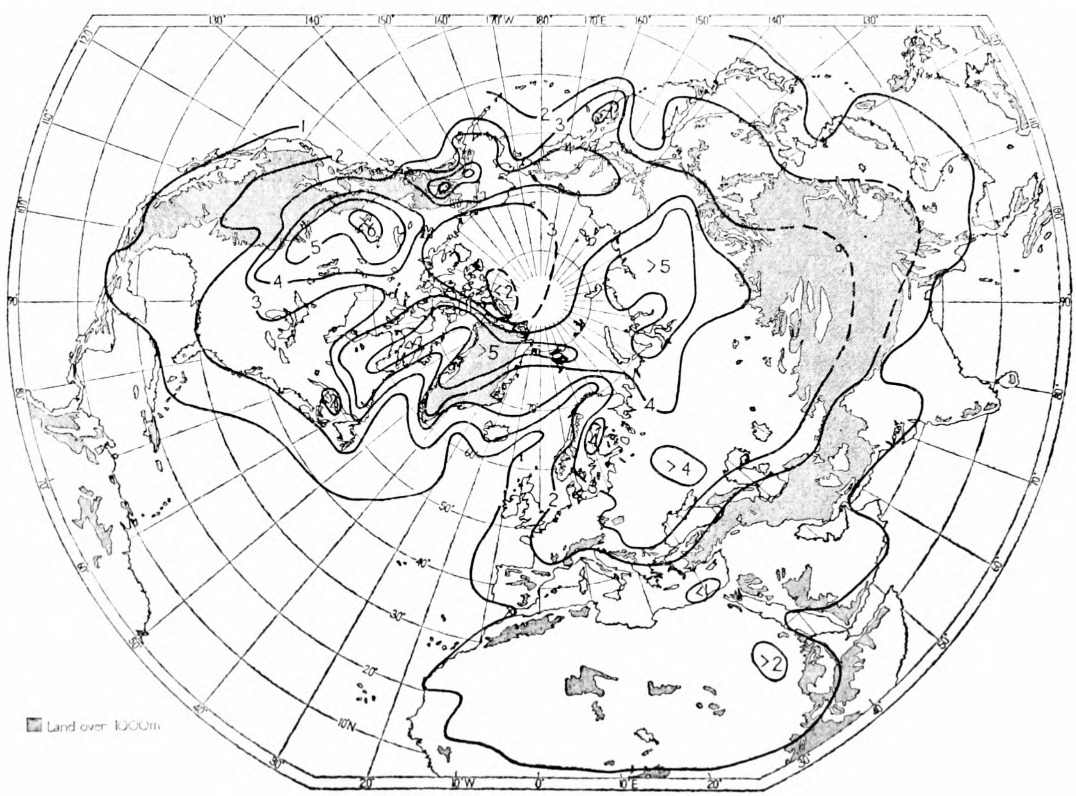

FIGURE 2. Standard deviation of monthly mean temperature in degrees Celsius—February.

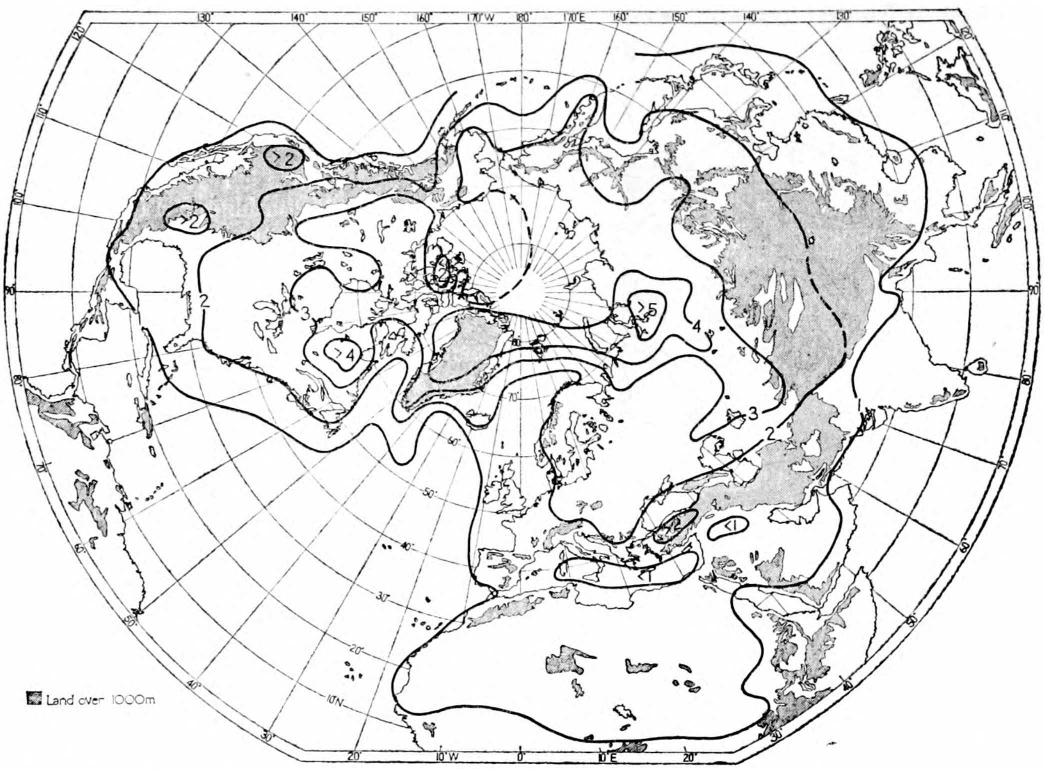

FIGURE 3. Standard deviation of monthly mean temperature in degrees Celsius—March.

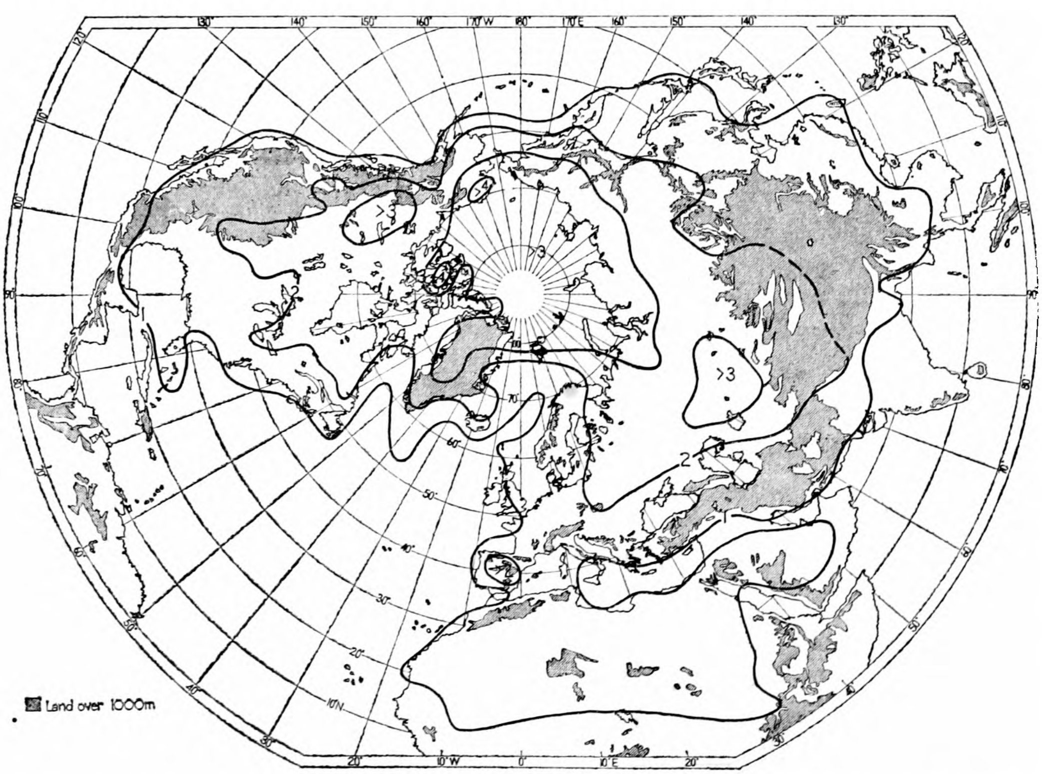

FIGURE 4. Standard deviation of monthly mean temperature in degrees Celsius—April.

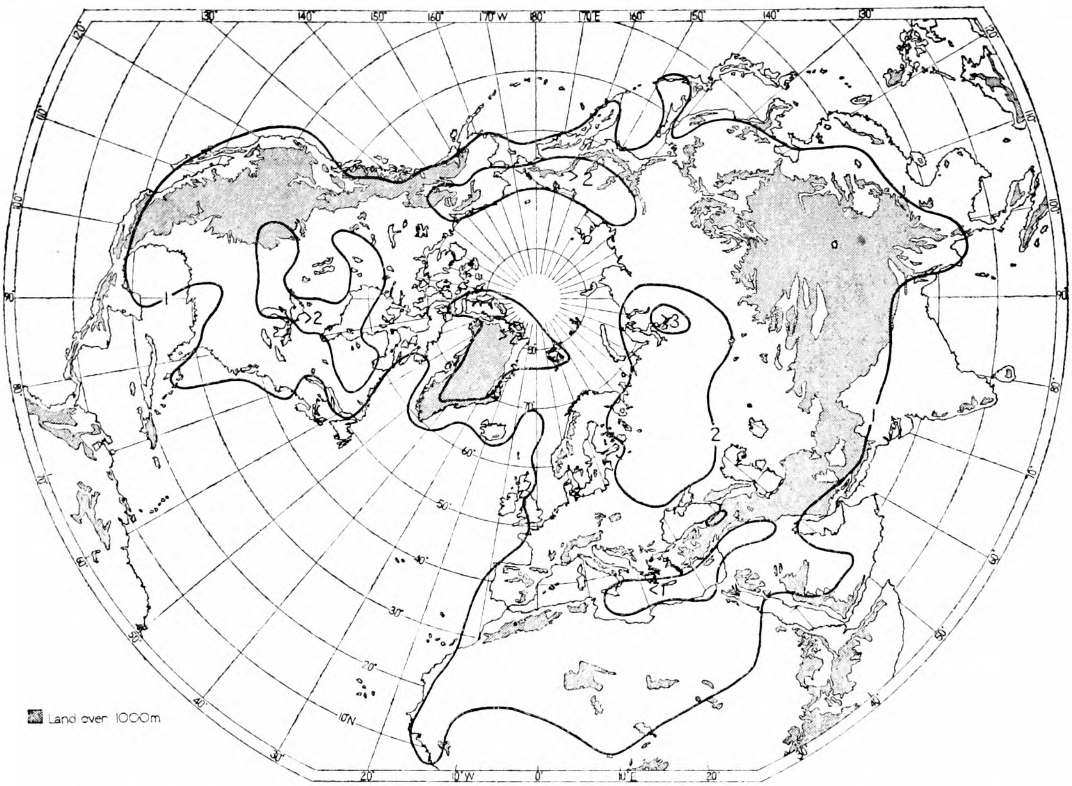

FIGURE 5. Standard deviation of monthly mean temperature in degrees Celsius—May.

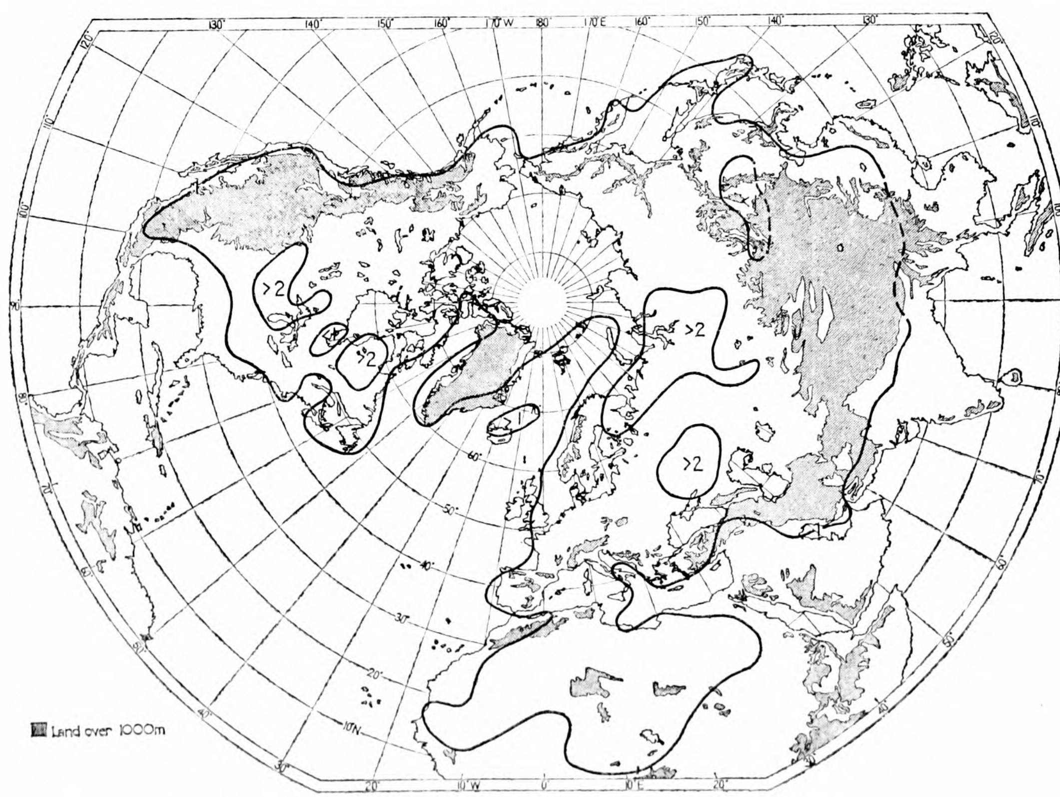

FIGURE 6. Standard deviation of monthly mean temperature in degrees Celsius—June.

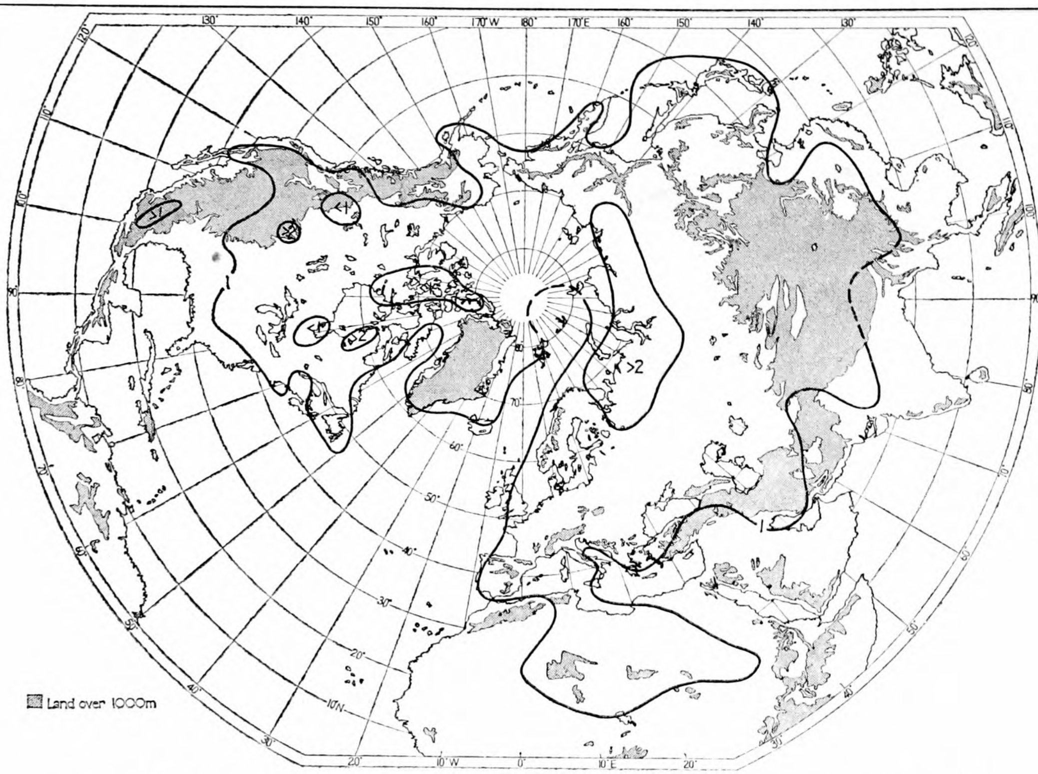

FIGURE 7. Standard deviation of monthly mean temperature in degrees Celsius—July.

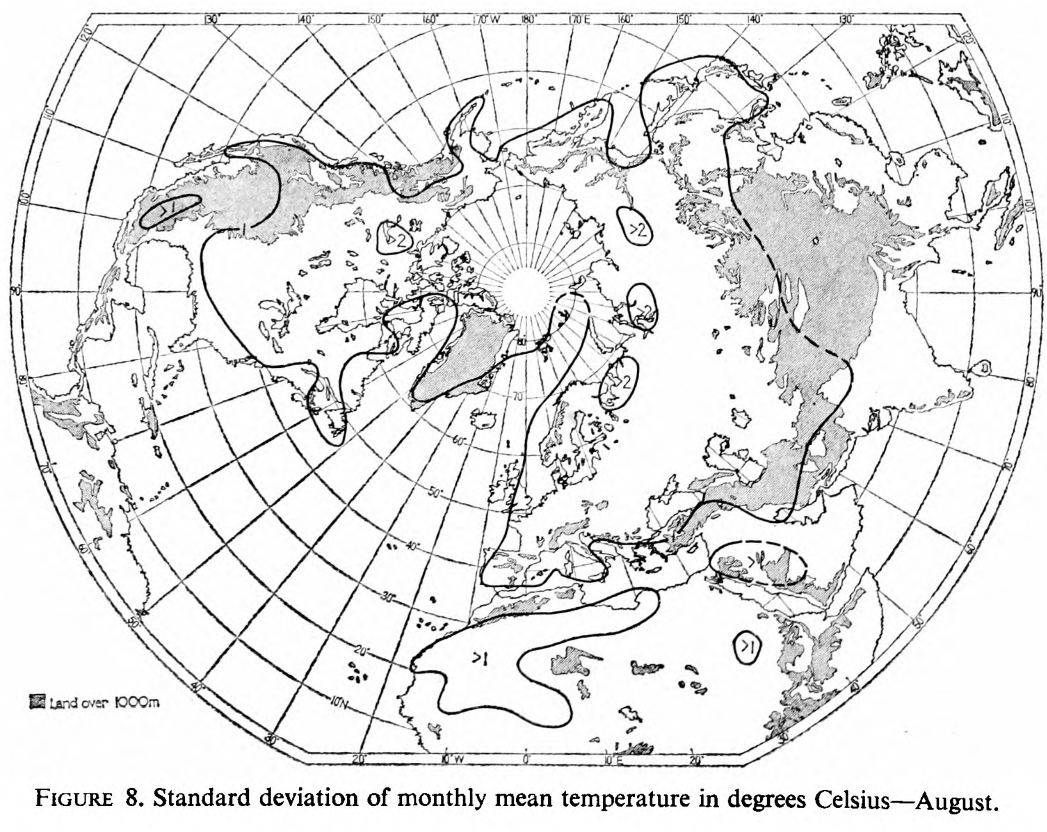

FIGURE 8. Standard deviation of monthly mean temperature in degrees Celsius—August.

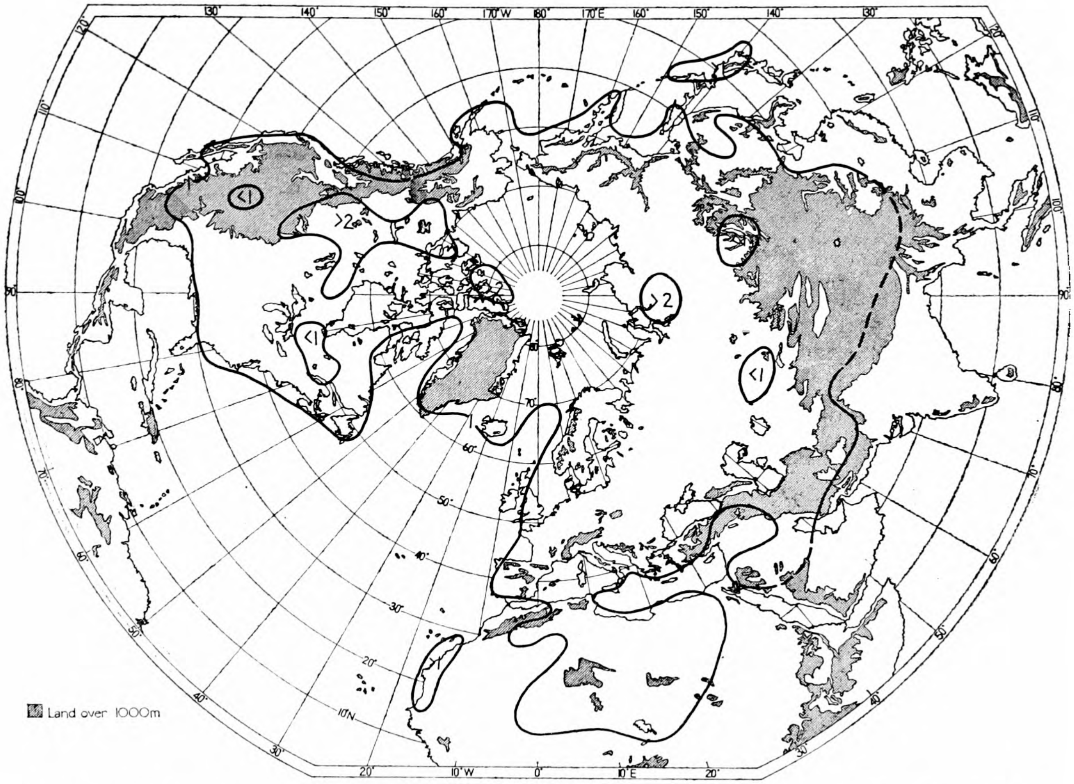

FIGURE 9. Standard deviation of monthly mean temperature in degrees Celsius—September.

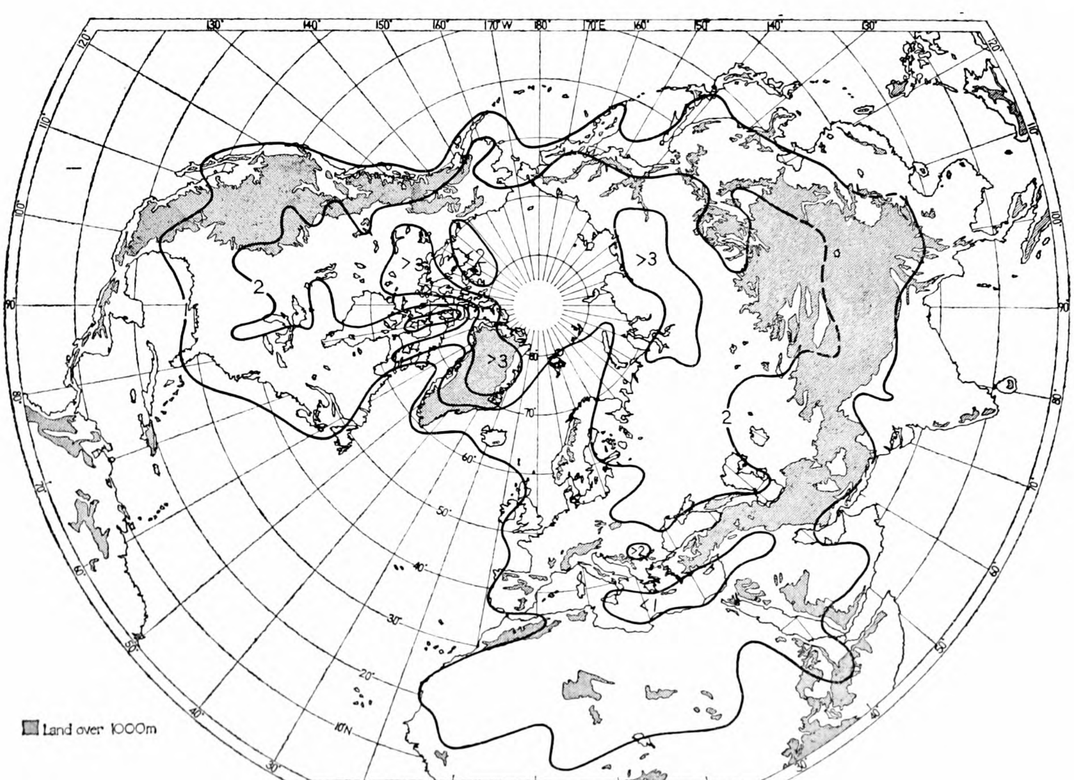

FIGURE 10. Standard deviation of monthly mean temperature in degrees Celsius—October.

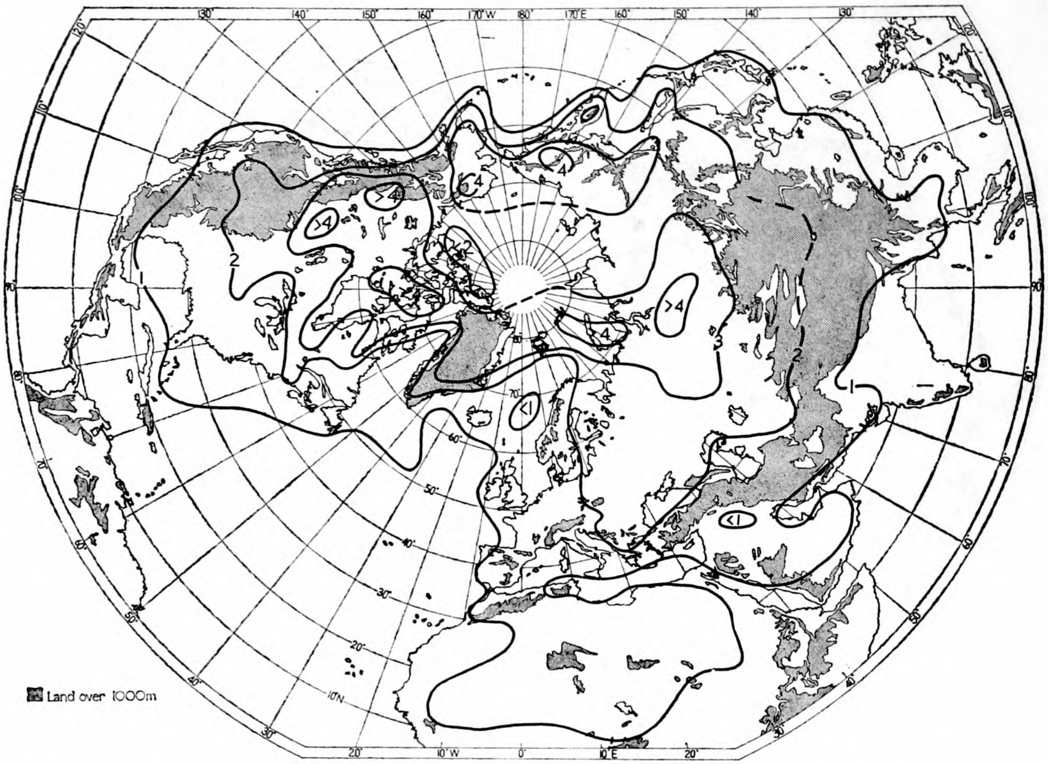

FIGURE 11. Standard deviation of monthly mean temperature in degrees Celsius—November.

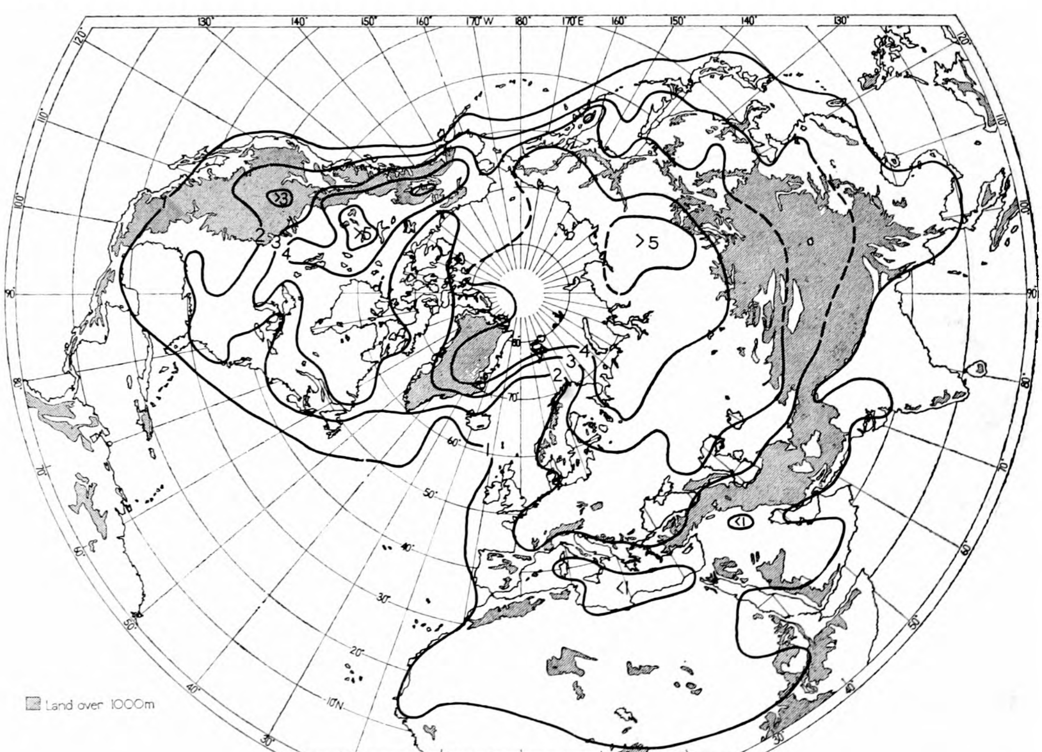

FIGURE 12. Standard deviation of monthly mean temperature in degrees Celsius—December.

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