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MERIDIONAL HEAT TRANSPORT AT THE ONSET OF WINTER STRATOSPHERIC WARMING

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16. Abstract

There exists a series of synoptic indices which appear to validate the following hypothesis. In the second half of January 1978 a continuous vertical flow of energy toward high altitude was verified. This process produced a dynamic instability of the stratospheric polor vortex. During this phase a meridional heat transport was primed toward the north, which generated the warming trend in question.

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1. Introduction

Previous works [2, 3, 4] examined, above all from a synoptic point of view, many general and unique characteristics of the winter stratospheric warming phenomenon which appears, sometimes spectacularly, especially at high latitudes with a dynamic instability of the stratospheric polar vortex, accompanied by disturbances in circulation and intense and rapid rises in temperature. In these circumstances we paused also to analyze what could be the causes of this event, causes which have not yet been understood or explained clearly by any author but which can be summarized in three hypotheses: /303*

a) the origin of winter stratospheric warming is to be found in the upper atmosphere or directly in solar activity;

b) a turbulent vertical transport of energy from the troposphere to the stratosphere simultaneously generates dynamic instability in the stratospheric polar vortex and the warming itself;

c) the vertical transport of the preceding point generates only dynamic instability of the stratospheric polar vortex, while the concomitant warming of the high latitudes of the winter stratosphere is carried out by a meridional heat transport which occurs in the stratosphere itself from low latitudes toward polar ones.

While the first hypothesis has been almost completely discarded, there is general agreement on the second.

However, the analysis (usually synoptic) of particular cases

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*Numbers in the margin indicate pagination in the foreign text.

[3, 4, 5, 6], the most general examination of many situations [1], not to mention the results of Nimbus series satellite observations made available by several foreign studies (for example [7]) have pointed the way for this writer toward the third hypothesis. The stratospheric warming of January-February 1978 appears to supply optimum support in this matter.

2. Some Characteristics of Stratospheric Warming in January-February 1978

During the winter of 1977-1978 there was seen no stratospheric warming with characteristics that would define it as "major";[1] instead, an event occurred which must be defined as "minor" but which intensely /304 involved the Euro-asiatic part of our hemisphere.

It is synthetically represented in Fig. 1, where an appreciable rise in stratospheric temperature at the end of January/beginning of February is noted, accompanied by two events typical of the phenomenon: lowering of the stratopause and simultaneous strong cooling of the mesopause [4, 5]. The split was obtained with data from the Soviet rocket probe station on Heiss Island in the subpolar archipelago /305 of Franz Josef Land.

To illustrate the subject of interest we examined the sequence of the three 10-mbar maps recorded in Figs. 2, 3, and 4 prepared with radiosonde data.

In the first, on 24 January, the warm nucleus is found over northern Africa and the Mediterranean (in truth, the idea for writing this brief report was born because of the unusually high stratospheric

[1] Note that, according to the WMO definition, stratospheric warming can be considered "major" if the following two events are produced in the stratosphere simultaneously: a) inversion of heat gradient between the polar latitudes and the median latitudes (in practice temperature of the polar latitudes higher than that of the median latitudes); b) inversion of circulation at 60°N (in practice passage from western to eastern circulation).

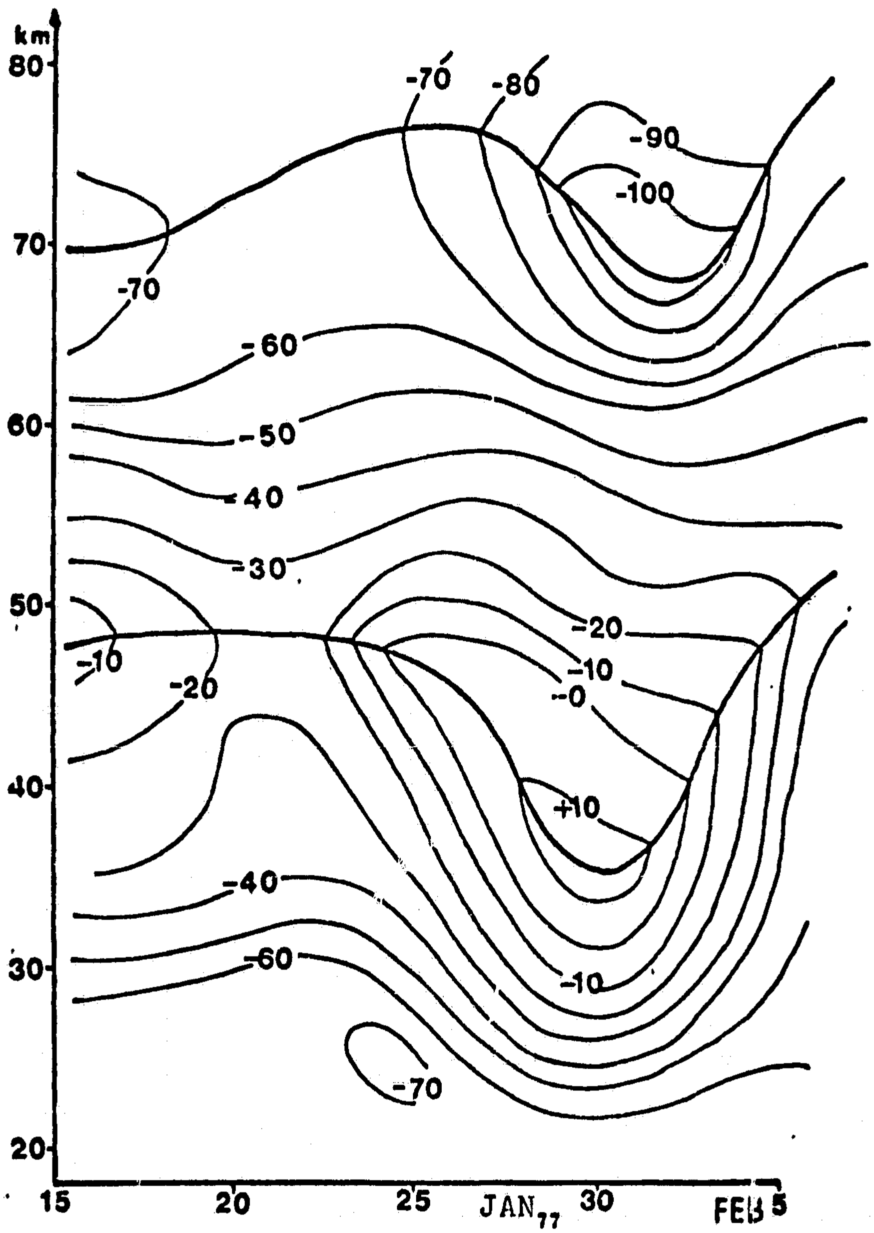

Figure 1. Vertical section of temperature at Heiss Island (80 37° N-58 03° E). Thick line, lower: stratopause; upper: mesopause.

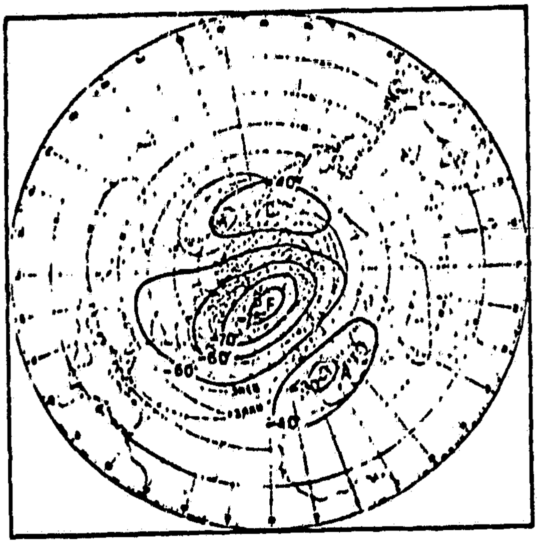

Figure 2. 10 mbar, situation on 24 January 1978; altitude in dam (thin line), temperatures in °C (thick line).

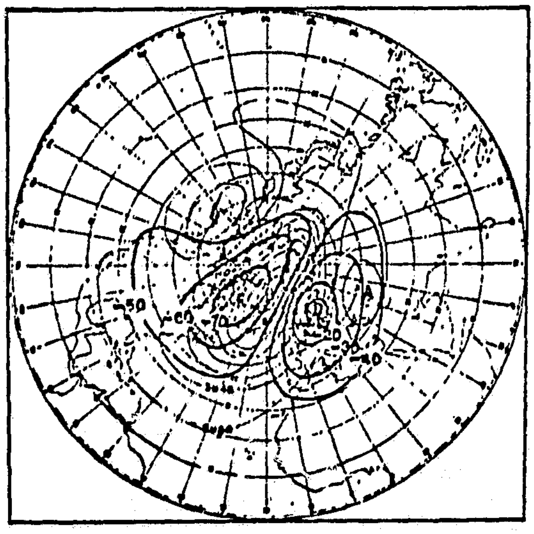

Figure 3. 10 mbar, situation on 28 January 1978; altitude in dam (thin line), temperatures in °C (thick line).

temperatures found on that date by the Italian radiosonde stations). Four days later, the warm nucleus moved and intensified over the zone Poland-Russia (Fig. 3), and, finally, on January 30, the final date of warming, it appears centered over the Barents sea with maxima of /306
-5°C, an exceptionally high temperature at that baric level (Fig. 4). Figure 5 shows the course followed by the heat center at 10 mbar from January 24 to 30, 1978.

At the meridional edge of the heat nucleus an anticyclone formation is noted, as usual, which also moved toward the northeast.

The comparison between the situation at 10 mbar (Figs. 2, 3 and 4) and the simultaneous situations at 1 mbar (Figs. 6, 7 and 8) is interesting. The latter were prepared with rocket probe data from Northern hemisphere stations [3, 4].

Note that on 24 January /307
(Fig. 5) the circulation in the high stratosphere is already slightly disturbed, but later an anticyclone rapidly formed which is always found situated to the west of the homologous configuration at 10 mbar. This fact is very important, because such a situation, i.e. inclination to

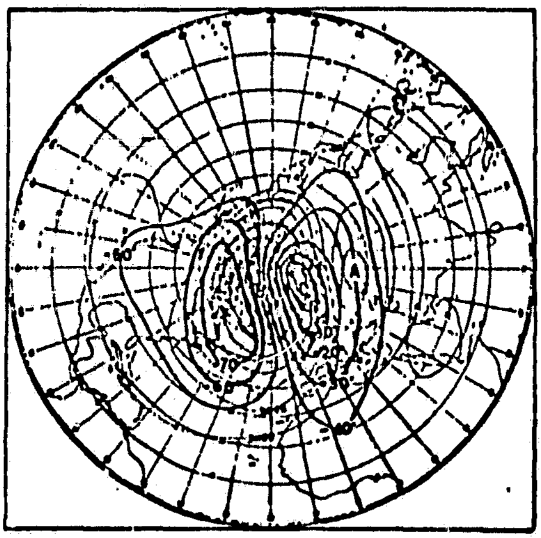

Figure 4. 10 mbar, situation on 30 January 1978; altitude in dam (thin line), temperatures in °C (thick line).

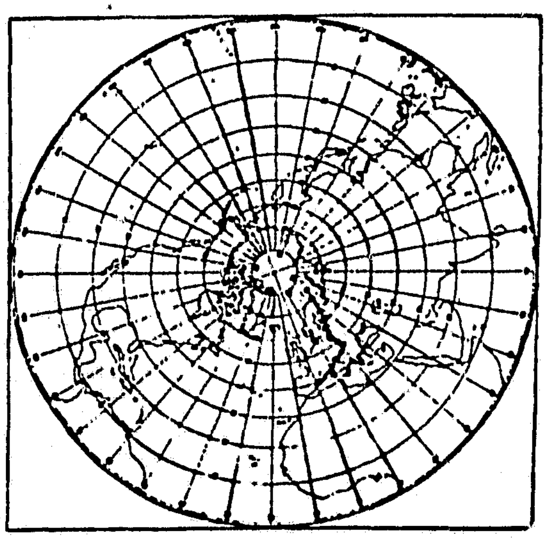

Figure 5. Course of heat nucleus at 10 mbar from January 24 to 30, 1978.

increase altitude toward the west, is one of the most important conditions which indicates a vertical energy propagation toward high altitude [2].

That this propagation occurs also at lower levels has been demonstrated by Figure 9, which reports the geopotential flow (in mW/m^2s) through the surfaces of 50 mbar at 60° N, as was deduced from STRATALERT messages [3, 4]. Note that when this flow operates from vertical baric velocities ω it should be considered toward high altitude when negative; note also that this parameter is an index of turbulent vertical propagation of energy [3, 4].

Figure 9 illustrates that in the second half of January there was a continuous transport from the troposphere toward the stratosphere with the maxima of the entire winter period which were verified on the 18th and 22nd of that month.

In conclusion, there exists a series of synoptic indices which appear to validate the following hypothesis. In the second half of January 1978 a continuous vertical

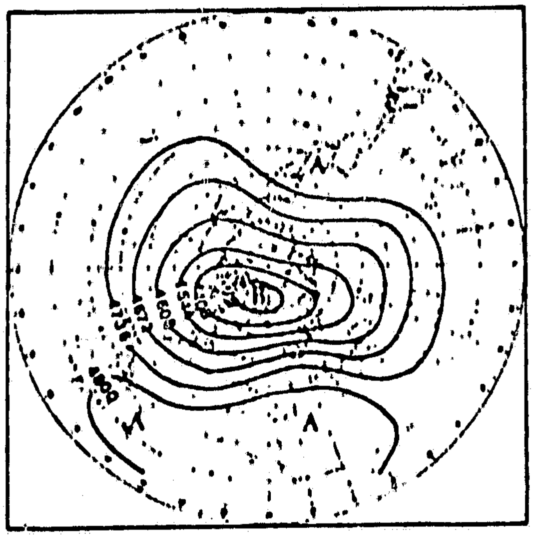

Figure 6. 1 mbar, situation on 24 January 1978; altitude in dam.

flow of energy toward high altitude was verified. This process produced a dynamic instability of the stratospheric polar vortex. During this phase a meridional heat transport was primed toward the north, which generated the warming trend in question.

(Work presented on 10 October 1978)

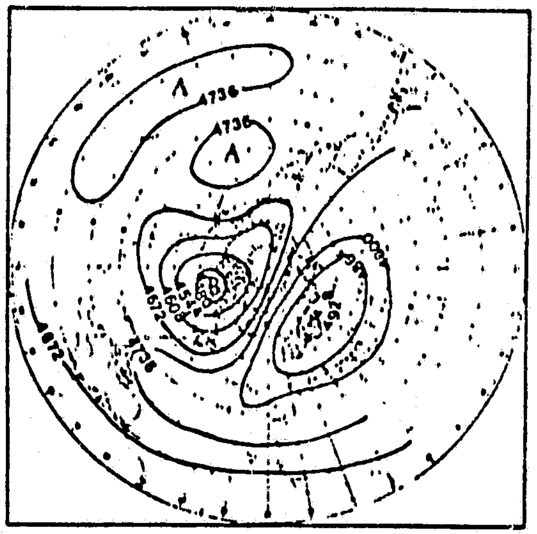

Figure 7. 1 mbar, situation on 28 January 1978; altitude in dam.

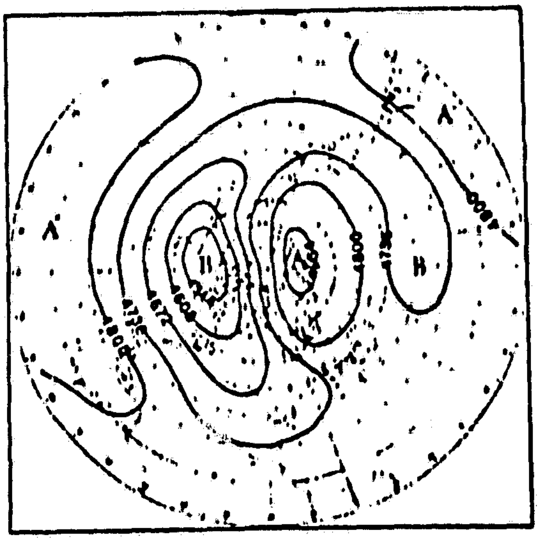

Figure 8. 1 mbar, situation on 30 January 1978; altitude in dam.

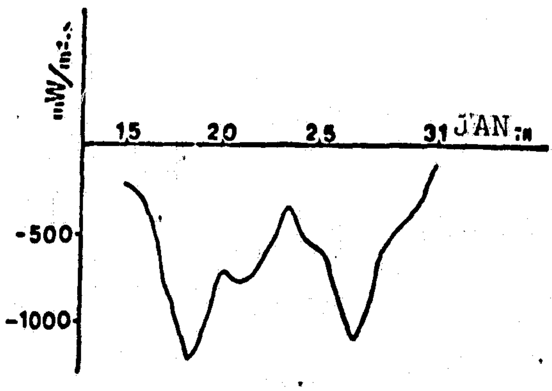

Figure 9. Geopotential flow through surfaces of 50 mbar at 60°N; the negative values indicate flow toward high altitude.

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