N85-20479

STRATWARM EFFECTS IN THE IONOSPHERIC D.REGION WIND FIELD

G. V. Vergasova

Siberian Institute of Terrestrial Magnetism
Ionosphere and Radio Wave Propagation (SibIZMIR)
Siberian Branch of the USSR Academy of Sciences
Irkutsk, USSR

ABSTRACT

An analysis is made of the wind field structure in the strato-thermosphere over Eastern Siberia during the winter stratwarms of 1975-1977. It is found that coupling between dynamical processes in the stratosphere and lower thermosphere is effected through changes of the temperature regime of the atmosphere. The circulation regime both in the stratosphere and lower thermosphere depends on location of the source of perturbations that cause stratospheric warmings. The effect of warming-induced perturbations on the dynamics of above- and underlying layers and the meridional extent of the processes are determined by the altitude and region where anti-cyclones originate. In conditions of a warmer stratosphere, there is a considerable loss of wind stability in the ionospheric D-region. A time delay of 1 to 2 days of lower-thermosphere processes is found to occur with respect to stratospheric processes of temperature variation at 30 mb level.

We have investigated the ionospheric circulation parameters and the meteorological conditions at the troposphere and stratosphere. Wind measurements in the D-region were carried on at the SibIZMIR since 1974. We believe that there is a response of D-region dynamics to the stratospheric processes, especially to the stratospheric warmings. We have found (VERGASOVA, 1978; VERGASOVA and KAZIMIROVSKY, 1979) high correlation between D-region winds and temperature variations at the 30 mb level during stratospheric warmings. As a rule we had zonal wind reversals from westerly to easterly, increasing of southward wind or even reversal of the meridional wind, and increase of semidiurnal tide amplitude. The response of the wind field is delayed by 1-3 days after the maximum of temperature at the stratosphere (T_{max}). The cross-correlation coefficients for ionospheric wind and stratospheric temperature were sometimes very high (~0.95).

The results derived by the superposed epoch method provide an average pattern of the interaction of the D-region dynamical regime with stratospheric temperature, reveal delay effects but do not give us any details about effects of each individual warming. We have been interested in examining the extension of the influence of each individual warming on the ionospheric dynamics, without limiting our attention only to temperature, but using the entire set of parameters varying during the perturbation (pressure, temperature, wind velocity, wind direction, zonal and meridional winds).

We have examined seven warmings, including also local ones, observed over Eastern Siberia since December 1975 through March 1977 (VERGASOVA, 1981). In order to evaluate the variation of the D-region wind structure as a function of the wind profile shape in the troposphere, we constructed the maps of the wind field in the tropo-, strato- and thermosphere and incomplete wind profiles (data on the height range 30 to ~85 km are missing and the linear interpolation has therefore only a conventional character).

To evaluate the effect of each individual warming a preliminary meteorological analysis was made. We considered the region giving rise to anti-cyclones, connected with the warming wave, the height of their upper boundary, further propagation of a warm region and warming-induced changes in the stratosphere at 30 mb level over Eastern Siberia. For example, during the warming of 31 December 1975 through 25 January 1976 there occurred a penetration of a warm region from the Atlantic anti-cyclone into high and temperate latitudes (CAO BULLETIN; BUGAEVA and RYAZANOVA, 1978). The Atlantic anti-cyclone was a strong one, with its upper boundary above 70 km. In the stratosphere at the end of December a kind of a three-cell baric field appeared. Over the poles there is an observable cyclone with depressions extending into the Eurasian and American continents while over the northern parts of the Pacific and Atlantic Oceans, two active anti-cyclones occurred with high upper boundary. There were no strong winter warmings in the stratosphere but there were some local warmings.

At Irkutsk the warming attained its maximum stage on 6 January, the temperature at 30 mb level increasing by about 20°C. The formation of anti-cyclones had significantly increased the dynamical instability in 20-60 km layers, which is apparent from Figure 1, showing wind field maps for the tropo-, strato- and thermosphere. In the stratosphere this dynamical instability occurs as a decrease of the modulus $|V_x/V_y|$ (ratio of the zonal to meridional components), i.e., as an increase of meridionality with increasing temperature and pressure in the stratosphere. In the period of interest the disturbed region ($h \sim 70$ km) was rather close to the lower thermosphere and may influence the ionospheric D region dynamics (Figure 1). We have seen the significant decrease and reversal of the zonal flow and a significant increase and reversal of the meridional component of the wind. Figure 2 shows the influence of temperature and pressure fluctuations at a height $h \sim 25$ km upon the wind profile structure in the tropo-strato-thermosphere. For the higher values of temperature and pressure the profile seems to be narrower, approaching the vertical axis. These changes are connected with a decrease of the "velocity gradient" ($\text{grad}_h V$) of zonal and meridional flows when temperature increases. The "velocity gradient" for the incomplete wind profiles may roughly be estimated as a velocity difference at the ionospheric D-region and at 30 mb level, attributable to a relevant height difference of ~60 km. This is particularly typical of the zonal flow.

A change of the modulus of the ratio of the zonal to meridional wind component $|V_x/V_y|$ for 30 mb level and in the ionospheric D-region, as the warming evolves, is illustrated in Figure 3. For comparison this figure also shows the state of the thermobaric field at $h \sim 25$ km for each of the two measurement times. For the maximum warming phase this ratio is minimal. Thus, at the highest values of pressure and temperature in the stratosphere in winter, meridional flows predominate both below (at $h \sim 25$ km) and above (in the ionospheric D region). For this warming the action of perturbation maybe penetrates even above the ionospheric D region.

The analysis of the seven warmings permits the following conclusions:

(1) Evidently winter tropo-, strato- and thermosphere circulation systems are affected by a common source of perturbations that generate stratospheric warmings.

(2) The character of meteorological impact varies not only from year to year but also from warming to warming.

(3) The circulation regime both in the stratosphere and in the lower thermosphere depends on localization of the source of perturbations that cause stratospheric warmings. The force of action of the warming-induced perturbations on the dynamics of above- and underlying layers and the meridional extension of processes depend on the altitude and localization of anticyclones. Similar inferences have been reached by BUTKO et al. (1978).

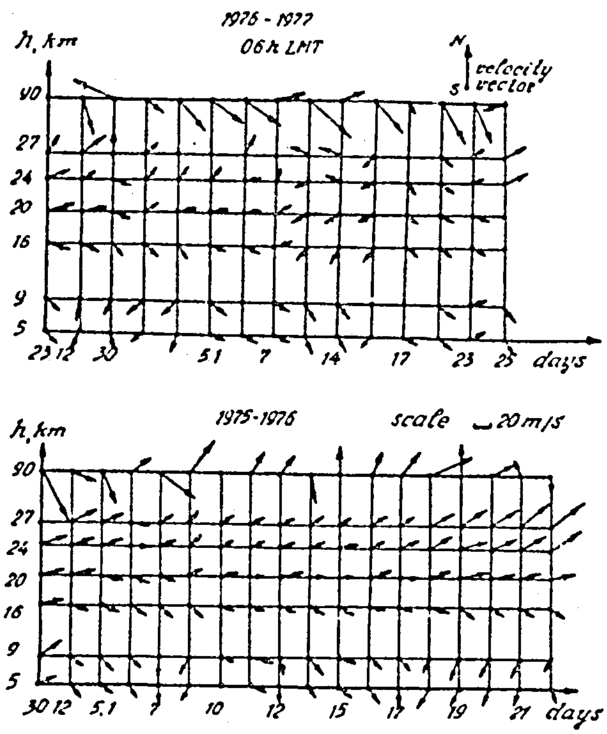

Figure 1. Maps of tropo-strato-thermospheric wind field during the warmings: 31 December 1975 through 25 January 1976 (bottom) and 17 December 1976 through 20 January 1977 (top) at 0600 LMT.

(4) The experimental data obtained over Eastern Siberia confirm the theoretical prediction of CHARNEY and DRAZIN (1961), that the winter provides most favorable conditions for perturbations to propagate upwards from below because at that time in the stratosphere strong zonal flows are weakened and the meridional extension of processes grows. The decrease of the modulus of the ratio of the zonal to meridional wind components (Figure 3) is illustrative in this regard.

We may assume that the energy of perturbations through planetary waves, can be relayed also into higher ionospheric heights, thus causing relevant changes in its dynamical regime.

In April 1976 when a local-scale warming was observed only over Eastern Siberia, D-region winds and E and F2 region drifts were simultaneously measured by the D1 method. The experimental data thus obtained proved the possibility of meteorological control of the dynamical regime of the ionospheric D and E regions. (The correlation coefficient of the zonal component of the wind velocity in the D region with stratospheric temperature is 0.77 and that for the E region is 0.95, see Figure 4. We had, however, no effects in the ionospheric F region dynamics (VERGASOVA and KAZIMIROVSKY, 1980).

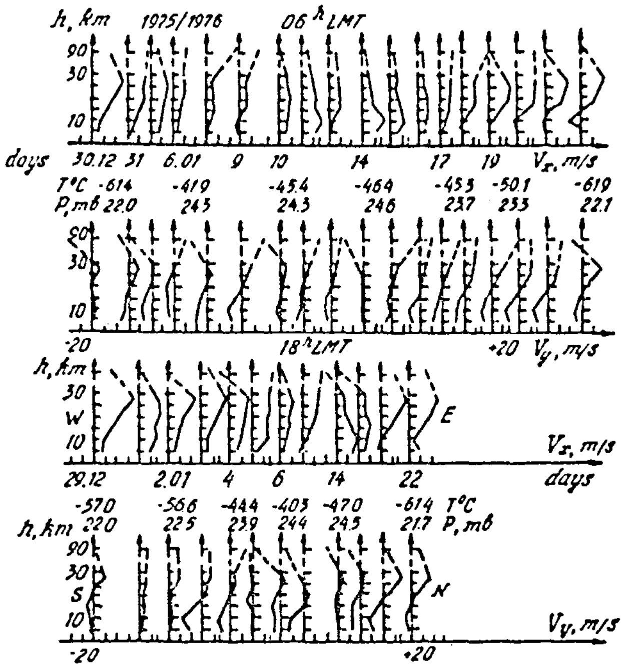

Figure 2. Zonal and meridional wind profiles for the warming 31 December 1975 through 25 January 1975.

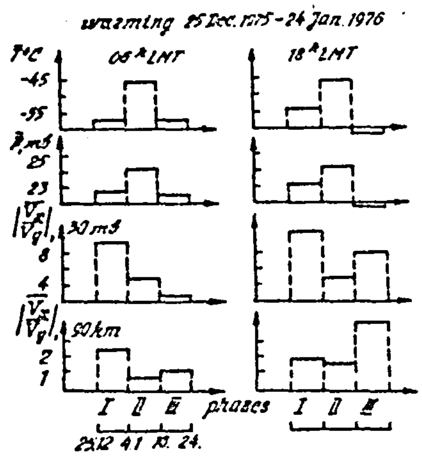

Figure 3. T, P, $|\overline{V_x/V_y}|_{30mb}$ and $|\overline{V_x/V_y}|_{90km}$ for different phases of the warming 25 December 1975 through 24 January 1976: I - initial phase, II - main phase, III - recovery phase.

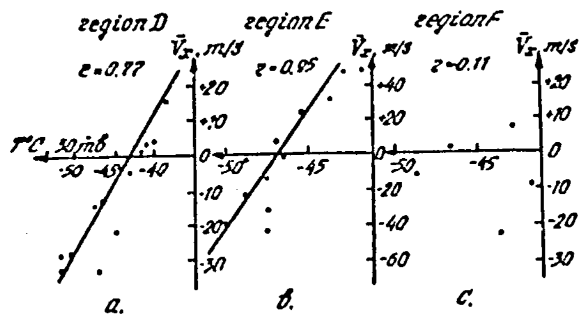

Figure 4. Correlograms for zonal and 30-mb level temperature.

On the basis of the experimental results obtained we can draw a general conclusion that during periods of very strong perturbations of the thermal field of the type of sudden winter stratospheric warmings the structure of the dynamical regime in the D and E regions of the ionosphere over Eastern Siberia is largely influenced by the meteorological situation from below.

ACKNOWLEDGEMENT

I would like to thank my colleagues from Ionospheric Dynamics Laboratory (SibIZMIR). Special thanks are due to Prof. E. S. Kazimirovsky for many pieces of valuable advice and comments.

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