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A SIMULATION STUDY OF THE TRANSFORMATION OF CIRCUMPOLAR VORTEX FLOWS OF THE LOWER AND MIDDLE ATMOSPHERE DURING THE PERIOD FROM JANUARY TO JUNE

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Abstract. To investigate the transformation of the planetary circulation of the lower and middle atmosphere during the period from January to June, a mathematical model of the global neutral wind system of the middle atmosphere, developed earlier in the Polar Geophysical Institute, is utilized. Global distributions of the horizontal and vertical wind were calculated for conditions corresponding to six dates, which belong to six different months beginning from January. Simulations enable to investigate how the horizontal non-uniformity of the atmospheric temperature affects the formation of the middle atmosphere circulation, in particular, the large-scale circumpolar vortices.

Introduction

In the Polar Geophysical Institute, a mathematical model of the global neutral wind system in the Earth's atmosphere has been developed not long ago [*Mingalev and Mingalev*, 2005; *Mingalev et al*., 2007a]. This model enables to calculate three-dimensional global distributions of the zonal, meridional, and vertical components of the neutral wind at levels of the troposphere, stratosphere, mesosphere, and lower thermosphere, with whatever restrictions on the vertical transport of the neutral gas being absent. This model has been applied in order to study how the horizontal non-uniformity of the atmospheric temperature affects the formation of the global neutral wind system under conditions corresponding to four different seasons [*Mingalev and Mingalev*, 2005; *Mingalev et al*., 2007a; *Mingalev et al*., 2007b]. In the present study, the model is utilized to simulate the global neutral wind system in the middle atmosphere for conditions corresponding to six dates, which belong to six different months beginning from January.

Numerical model

The utilized model produces three-dimensional global distributions of the zonal, meridional, and vertical components of the neutral wind velocity and neutral gas density at the levels of the troposphere, stratosphere, mesosphere, and lower thermosphere. The characteristic feature of the model is that the vertical component of the neutral wind velocity, as well as horizontal components of the neutral wind, is obtained by means of a numerical solution of the appropriate momentum equation for a viscous gas without any simplifications of this equation, with the hydrostatic equation being not used. Moreover, the model does not include the internal energy equation for the neutral gas. Instead, the global temperature field is assumed to be a given distribution obtained from the NRLMSISE-00 empirical model [*Picone et al.*, 2002]. The model has the potential to describe the global neutral wind system under disturbed conditions when the vertical component of the neutral wind velocity at the levels of the lower thermosphere can be as large as several tens of meters per second [*Peteherych et al.*, 1985; *Widdel*, 1987; *Hoppe and Hansen*, 1988; *Price and Jacka*, 1991; *Ishii*, 2005]. The simulation domain is the layer surrounding the Earth globally and stretching from the ground up to the altitude of 126 km at the equator. The Earth's surface is supposed to coincide approximately with an oblate spheroid whose radius at the equator is more than that at the pole. The finite-difference method is applied in the numerical model. The calculated parameters are determined on a 1^{O} grid in both longitude and latitude. The height step is non-uniform and does not exceed the value of 1 km. The details of the model may be found in the studies by *Mingalev and Mingalev* [2005] and *Mingalev et al.* [2007a].

Simulation results

In the model calculations, global distributions of the atmospheric parameters were computed for conditions corresponding to six different dates, namely, 16 January, 16 February, 16 March, 16 April, 16 May, and 16 June, which belong to six different months beginning from winter in the northern hemisphere. Calculations were made for moderate solar activity ($F_{10.7}$ = 101) and low geomagnetic activity (Kp = 1). The variations of the atmospheric parameters with time were calculated until they become stationary. The steady-state distributions of the atmospheric parameters were obtained for six considered dates on condition that inputs to the model correspond to 10.30 UT for each day.

Simulation results, obtained on condition that the inputs to the model and boundary conditions are time-independent, are partly shown in Figs. 1-4. From simulation results, it is seen that the horizontal and vertical components of the wind velocity are changeable functions not only of latitude and longitude but also of altitude. Maximal absolute values of the horizontal and vertical components of the wind velocity are larger at higher altitudes. It is clear that horizontal non-uniformity of the atmospheric temperature, which is distinct in different months, influences considerably on the transformation of global circulation of the lower and middle atmosphere during the period from January to June.

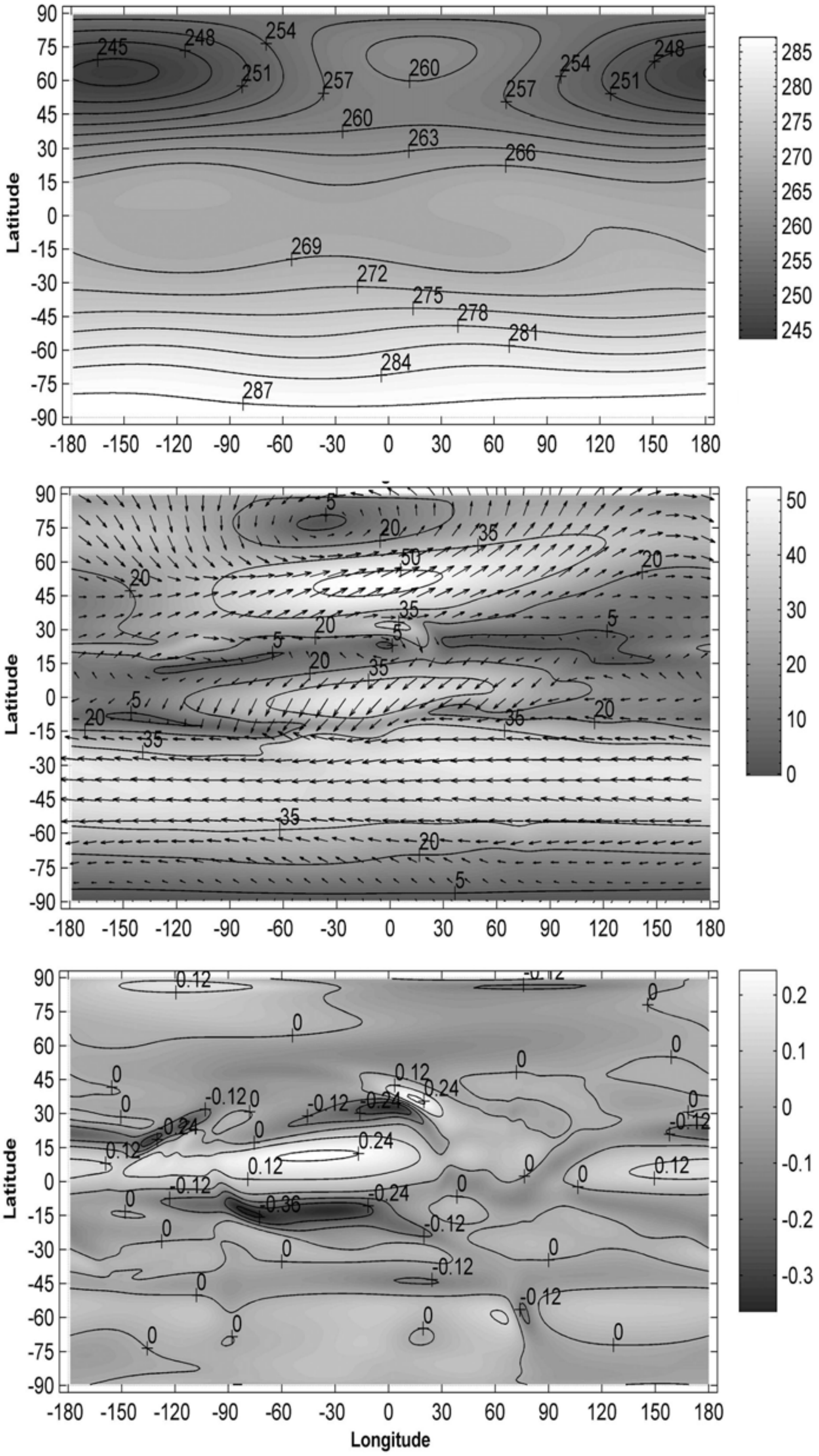

Fig.1. The distributions of the given neutral gas temperature (top panel**),** vector of the calculated horizontal component of the neutral wind velocity (middle panel), and calculated vertical component of the neutral wind velocity (bottom panel) as functions of longitude and latitude at the altitude of 50 km, obtained for 16 January. The temperature is given in K and wind velocities are given in m/s.

It is know that the global atmospheric circulation can contain sometimes so called circumpolar vortices that are the largest scale inhomogeneities in the global neutral wind system. Their extent can be very large, sometimes reaching the latitudes close to the equator. It is well known from numerous observations that circumpolar vortices are formed at heights of the stratosphere and mesosphere in the periods close to summer and winter solstices, when there is no rebuilding of the atmosphere. The circumpolar anticyclone arises in the northern hemisphere under summer conditions, while the circumpolar cyclone arises in the southern hemisphere under winter conditions. On the contrary, the circumpolar cyclone arises in the northern hemisphere under winter conditions, while the circumpolar anticyclone arises in the southern hemisphere under summer conditions. Let us compare these experimental data with the simulation results obtained.

We can see from simulation results that, for winter period in the northern hemisphere, at levels of the middle atmosphere, the motion of the neutral gas in the northern hemisphere is primarily eastward, so a circumpolar cyclone is formed. It can be noticed that the center of the northern cyclone is displaced from the pole for a distance corresponding to approximately 10^{O} of latitude. Simultaneously, the motion of the neutral gas is primarily westward

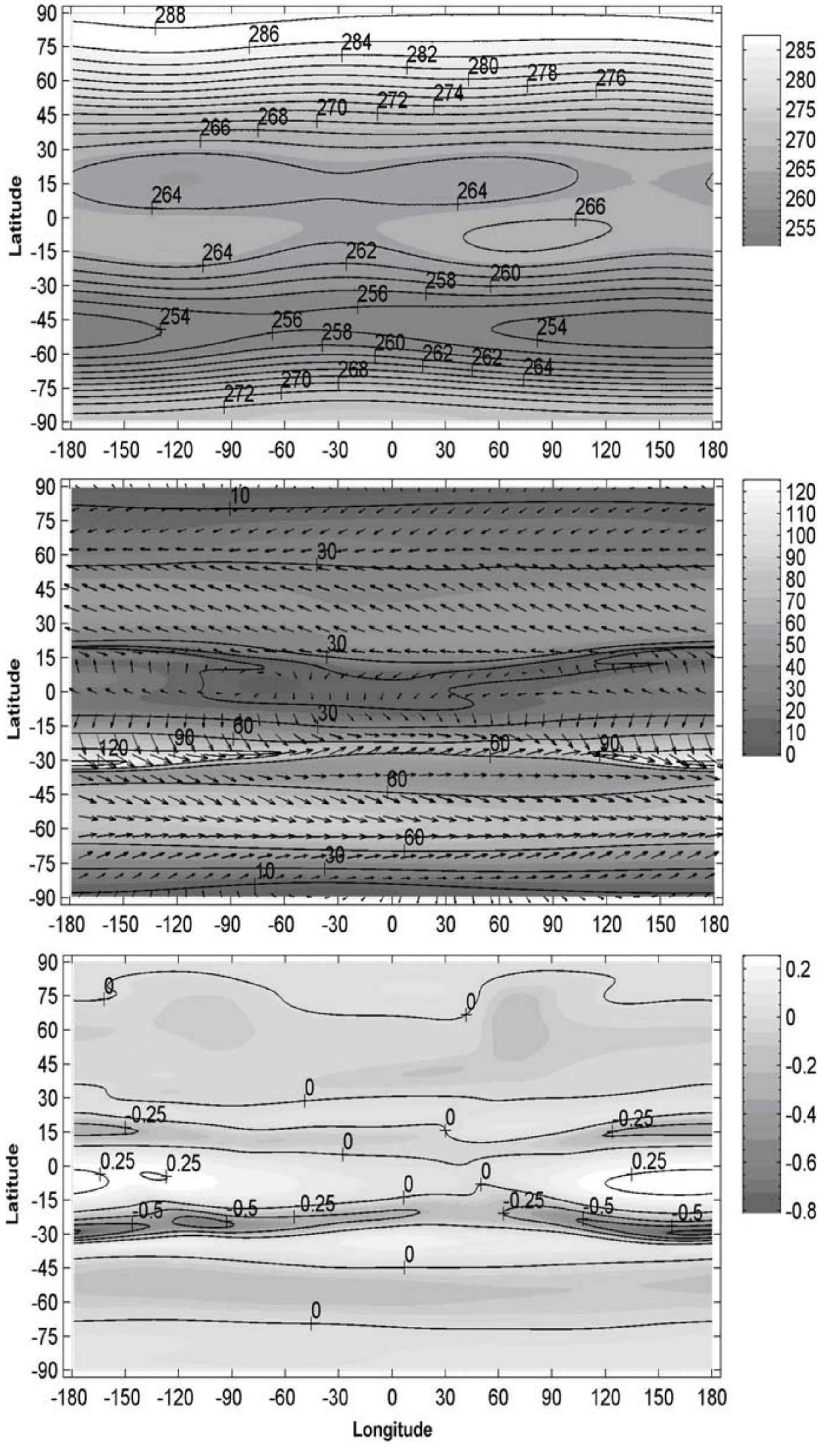

Fig.2. The distributions of the given neutral gas temperature (top panel), vector of the calculated horizontal component of the neutral wind velocity (middle panel), and calculated vertical component of the neutral wind velocity (bottom panel) as functions of longitude and latitude at the altitude of 50 km, obtained for 16 June. The temperature is given in K and wind velocities are given in m/s.

in the southern hemisphere at levels of the middle atmosphere, so a circumpolar anticyclone is formed for summer period in the southern hemisphere. From simulation results, we can see that the global distributions of the neutral wind, calculated for summer period in the northern hemisphere, in particular, the large-scale circumpolar vortices, are consistent with the planetary circulation of the atmosphere, obtained from observations.

It can be seen that the circumpolar vortices of the northern and southern hemispheres, simulated in the present study at levels of the middle atmosphere for winter and summer periods in the northern hemisphere, correspond qualitatively to the global circulation, obtained from observations. It can be seen that, during the spring period in the northern hemisphere, the global neutral wind system of the atmosphere is transformed considerably.

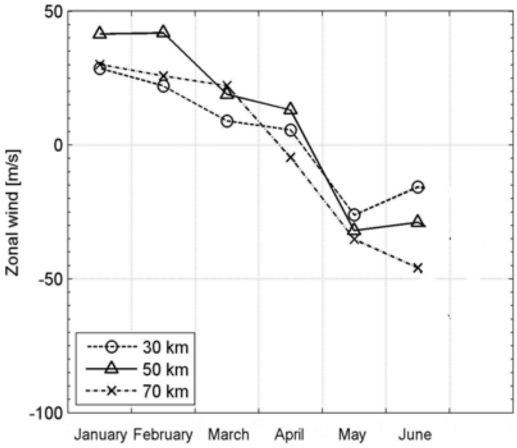

Fig.3. The temporal evolution of the zonal component of the neutral wind derived from simulation results for the point of the glob having the geographical coordinates of 45^{O}N and 22,5^{O}E (northern hemisphere, noon meridian) at three altitudes: 30, 50, and 70 km.

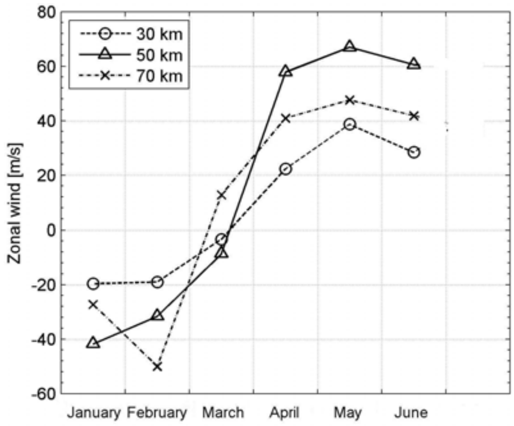

Fig.4. The same as in Fig.3 but obtained for the point of the glob having the geographical coordinates of 45^{O}S and 22,5^{O}E (southern hemisphere, noon meridian).

Conclusion

The mathematical model of the global neutral wind system of the lower and middle atmosphere was utilized to simulate global distributions of the horizontal and vertical wind for conditions corresponding to six dates, which belong to six different months beginning from January. Simulation results indicate that the horizontal non-uniformity of the neutral gas temperature, which is distinct in different months, influences considerably on the transformation of global circulation of the lower and middle atmosphere during the period from January to June. It can be noticed that the circumpolar vortices of the northern and southern hemispheres, obtained using the applied mathematical model at levels of middle atmosphere, are consistent with existing observational data, in particular, for winter and summer periods.

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