Climatic variability of the stratospheric dynamics: results of simulation and data analysis.

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Background:

•The climatic variability of the mean flow and planetary waves in the lower stratosphere has been investigated using the data of NCEP/NCAR reanalysis (*Kanukhina A. et al., 2008*).

•The results of this analysis show that during the last decades winter-time averaged geopotential height amplitude of the stationary planetary wave with zonal wave number 1 (SPW1) increases at the higher-middle latitudes of the northern hemisphere (Figure 1).

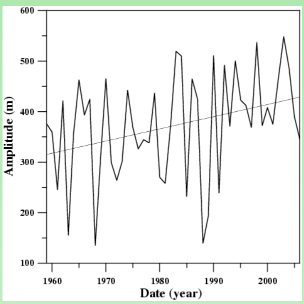

Figure 1 – The amplitude of the SPW1 in geopotential height, 30 hPa level, 62.5 N, NCEP/NCAR reanalysis.

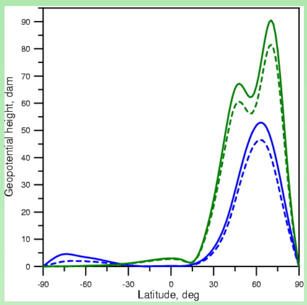

Figure 2 – The calculated with linearized model amplitude of the SPW1 in geopotential height at 25 km (blue lines) and 50 km (green lines) for 1960 and 2000 (dashed and solid lines, respectively).

• The simulation of the SPW1 propagation with account of observed changes in the zonal-mean wind in the troposphere using the linearized model of the planetary waves (*Pogoreltsev, 1999*) has been performed. Results obtained with the linearized model are in a good agreement with observations (compare Figures 1 and 2).

• It was suggested that observed increase in the SPW1 amplitude should be accompanied by the growth in the magnitude of the stratospheric vacillations.

Objectives:

• Simulation of the climatic variability of the middle atmosphere dynamics with the MUAM.

• Estimation of the contribution of an additional heating/cooling due to large-scale longitudinal ozone inhomogeneities to the SPW1 forcing in the stratosphere.

Middle and Upper Atmosphere Model (MUAM, *Pogoreltsev et al., 2007*):

• 3D nonlinear mechanistic model of the atmospheric circulation extended from the 1000 hPa surface up to the heights of the ionospheric F2-layer, based on the Cologne Model of the Middle Atmosphere-Leipzig Institute for Meteorology (COMMA-LIM, *Fröhlich et al., 2003*).

• Grid-point model with horizontal (latitude/longitude) resolution of 5°*5.625°.

• Up to 60 levels in the non-dimensional log-pressure height x = - ln(p/1000) with a step-size of about 0.4. In the present study 48 levels version of the MUAM with the upper boundary at x = 19 (geopotential height is around 150 km) is used.

• Marchuk-Strang splitting of the initial Cauchy problem according to the physical processes and Matsuno time-integration scheme with a time step-size 450s have been used.

• The prognostic equation for geopotential height at the lower boundary (1000 hPa surface) has been used to simulate the global resonant properties of the atmosphere.

• To reproduce the climatic changes of zonally averaged fields in the troposphere, the calculated zonally averaged temperature up to stratospheric levels was adjusted to the temperature obtained for January 1960 and 2000 with account of the linear trend. In result **2 sets of runs** (ensemble 1960 and ensemble 2000, respectively) with MUAM were performed to investigate a possible climatic change of the stratospheric dynamics. Each ensemble contains 10 members obtained with slightly different initial conditions.

References:

• Fröhlich K. et al., 2003. Numerical simulation of tides, Rossby and Kelvin waves with the COMMA-LIM model, Adv. Space Res., 32, 863-868.
• Kanukhina A. et al., 2008. Climatic variability of the mean flow and stationary planetary waves in the NCEP/NCAR reanalysis data, Annales Geophysicae, 26, 1233-1241.
• Peters D.H.W. et al., 2008. Longitude-dependent decadal ozone changes and ozone trends in boreal winter months during 1960-2000 , Annales Geophysicae, 26, 1275-1286.
• Pogoreltsev A.I., 1999. Simulation of the planetary waves and their influence on the zonally averaged circulation in the middle atmosphere, Earth, Planets and Space, 51, 773-784.
• Pogoreltsev A.I. et al., 2007. Planetary waves in coupling the lower and upper atmosphere, J. Atmos. Solar-Terr. Phys., doi:10.1016/j.jastp.2007.05.014.

Results & Discussion:

•The results of simulation show that in average the calculated amplitude of the SPW1 increases during the last decades (Figure 3) and there is also an increase in its intraseasonal variability (right panels in Figure 4) conditioned by nonlinear interaction with the mean flow. These results of SPW1 simulation with the MUAM are in a good agreement with the behavior of SPW1 observed in the NCEP/NCAR data.

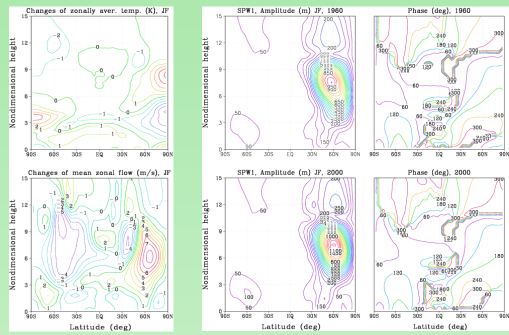

Figure 3 - Differences in the zonally averaged temperature and zonal mean flow calculated as averaged over 10 ensemble members and January-February for 2000 and 1960 (left panel). The same, but for the amplitude and phase of the SPW1 in the geopotential height calculated for 1960 and 2000 conditions (right panels).

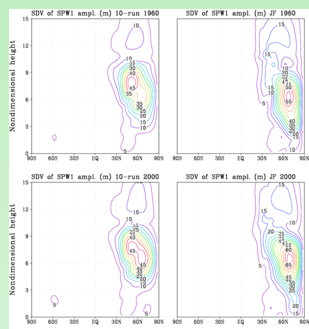

Figure 4 - Interannual (between the ensemble members, left panels) and intraseasonal (January - February, right panels) variability (standard deviations) of the SPW1 amplitude in the geopotential height for 1960 and 2000, respectively.

•The increase in the intraseasonal variability of the SPW1 amplitude can be interpreted as a growth of the stratospheric vacillations magnitude during the last decades. This result is supported by the analysis of the NCEP/NCAR data (not shown here) and indicates that stratospheric dynamics becomes more stochastic.

•These irregular oscillations of the SPW1 and mean flow in the stratosphere can be extended into the troposphere as it was demonstrated in the recent papers on the stratosphere-troposphere coupling.

•The accounting of the large-scale longitudinal ozone inhomogeneities into the radiative scheme of the MUAM leads to changes in zonally averaged temperature and zonal mean flow (Figure 5) and to increase in the amplitude of the SPW1 (of about 200 m, Figure 6). These longitudinal inhomogeneities in ozone mixing ratio at the upper troposphere and lower stratosphere heights are caused primarily by planetary waves and can influence on dynamical processes via radiative feedback mechanisms (*Peters D. et al., 2008*). Thus we can suggest that an accounting of the longitudinal variation of ozone heating/cooling in the MUAM (positive feedback) will amplify the obtained climatic variability.

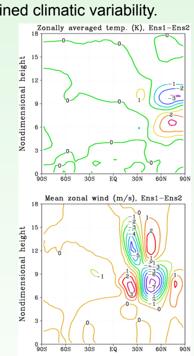

Figure 5 – Differences between zonally averaged temperature (upper panel) and zonal mean wind (lower panel) obtained in the ensembles *with (Ens1) and without (Ens2) account of longitudinal ozone inhomogeneities,* January 2000.

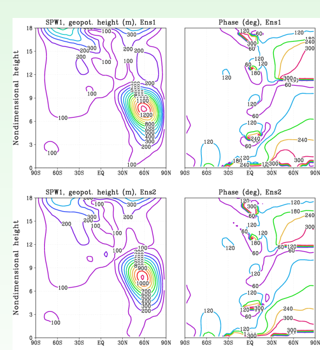

Figure 6 - Latitude-height sections of the SPW1 amplitude and phase in geopotential height (left and right panels, respectively) for *Ens1* and *Ens2,* January 2000.