Long-term changes of stationary waves in the atmosphere

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The goals of this work were:

1. Analysis of the spatial structure and long-term changes in stationary planetary waves in the Northern Hemisphere.

2. Calculation of the structure of stationary waves due to orographic forcing, using quasi-geostrophic barotropic model. Comparison of modeling results with observational data.

Figures show the distributions of the 500 hPa height in July, averaged over the decades 1950-1960 (Fig. 1) and 2000 - 2010 (Fig. 2).

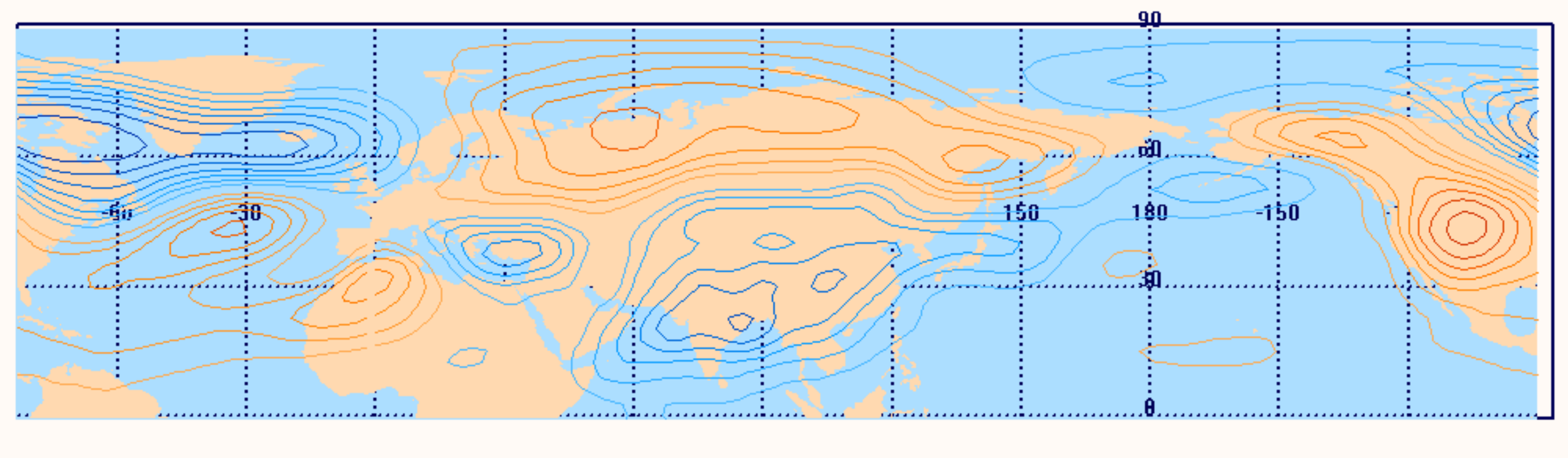

Fig. 1 – Planetary waves at 500 gPa in July 1950-1960. The distance between contours of 10 m

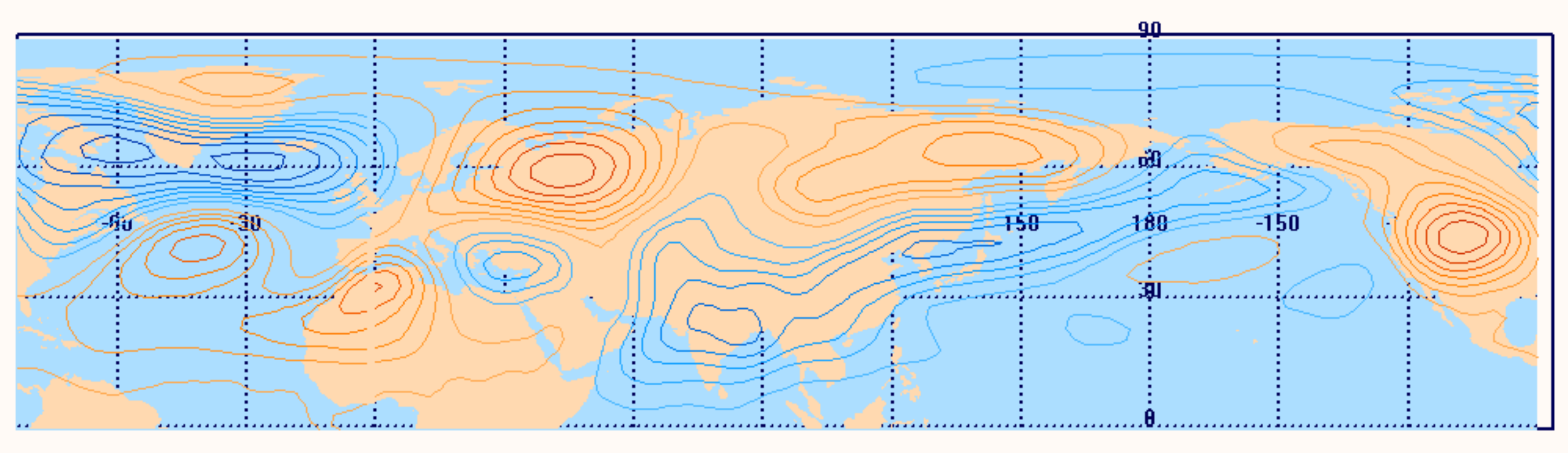

Fig. 2 – Planetary waves at 500 gPa in July 2000-2010.

Asia - Europe - Atlantic

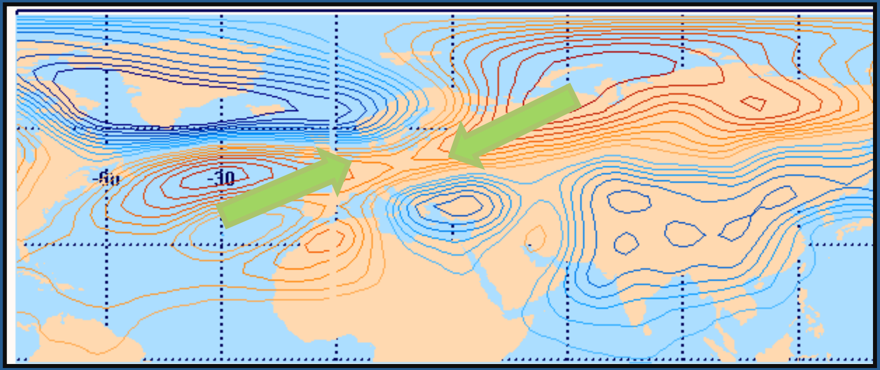

Fig. 3 – The observed structure of planetary stationary waves at 500 hPa in July 1964

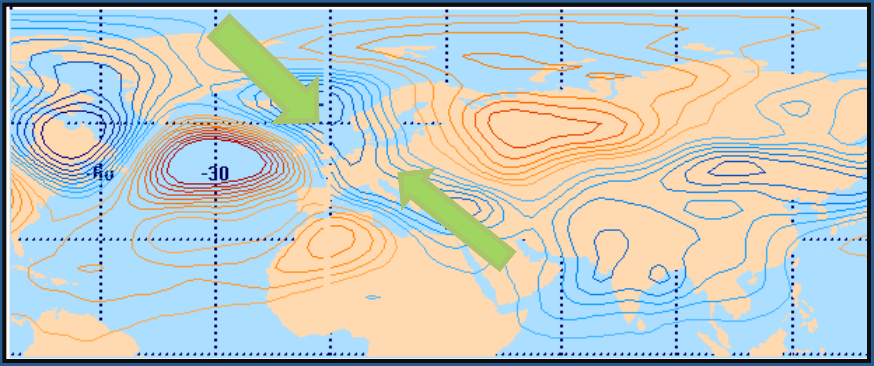

Fig. 4 – The observed structure of planetary stationary waves at 500 hPa in July 1966

Asia - Pacific - North America

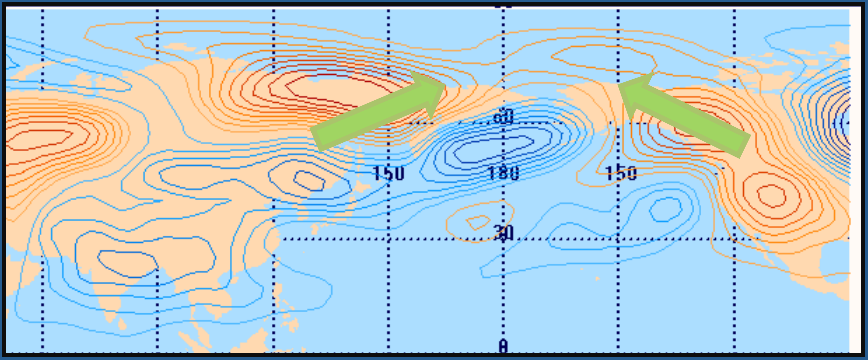

Fig.5 - The observed structure of planetary stationary waves at 500 hPa in July 1971

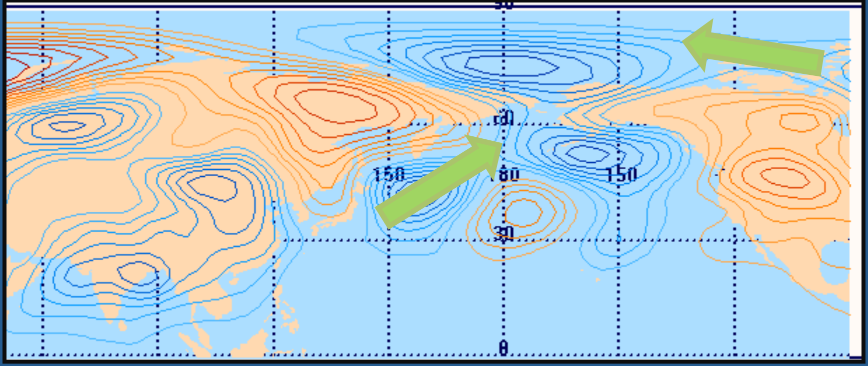

Fig.6 - The observed structure of planetary stationary waves at 500 hPa in July 1973

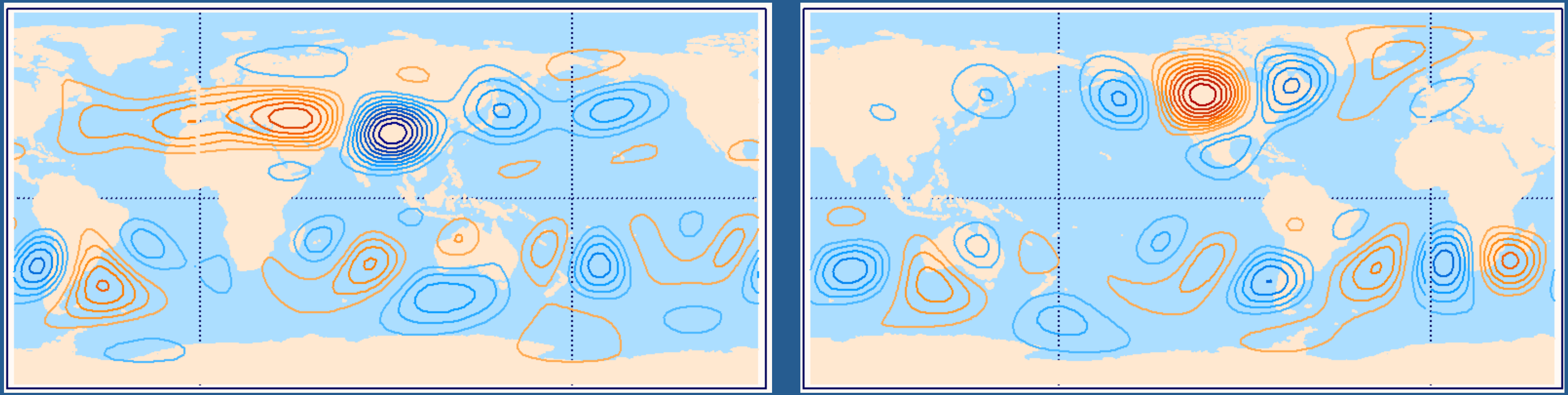

Fig.7 - Simulation of orographic forcing of stationary waves in stream function by Himalayas - Tibet (left figure) and the Cordillera - Rocky Mountains (right figure) in July 1950-1960 for the velocity at 500 hPa

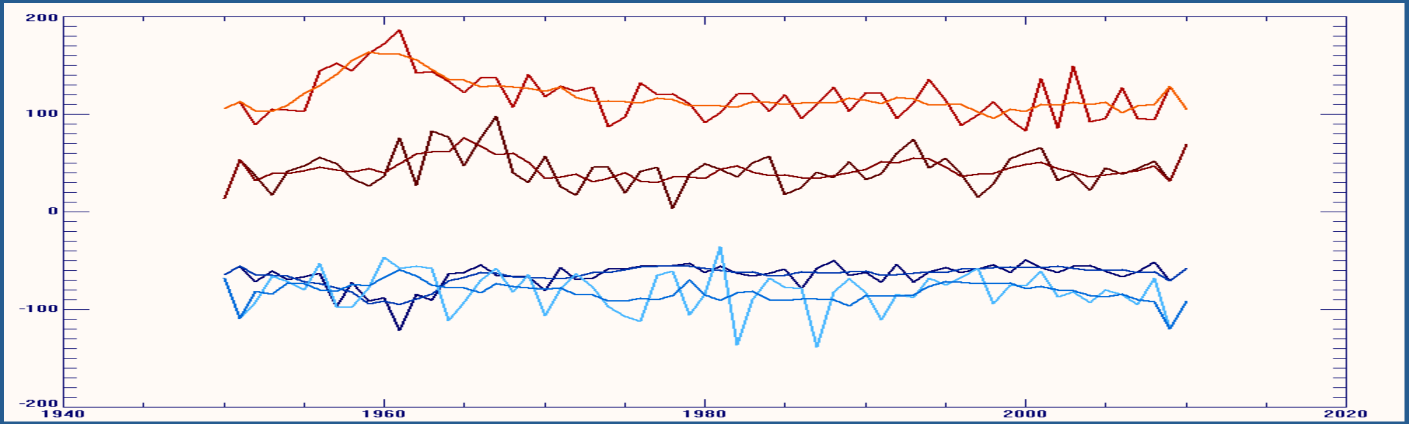

Fig. 8 - Variations of the intensities of the positive geopotential height 500 hPa anomalies over the Hawaiian Islands (red), two negative anomalies over the Asian part of Eurasia (blue) and propagating away trough over the Pacific Ocean (blue) and orographic vorticity source Himalaya - Tibet (pink) in July, 1950-2010.

For more information about this study please go to the poster

Long-term changes of stationary waves in the atmosphere

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The paper presents the results of a study of long-term changes in stationary summer planetary waves at 500 hPa in the northern hemisphere according to the NCEP / NCAR Reanalysis from 1950 to 2010 [1]. The observed structure of planetary waves changes over the northern part of Eurasia, East Asia and the Pacific Ocean. Variations of geopotential height anomalies in these regions resembled quasi-decadal damped oscillations after a strong local perturbation in the late 50s - early 60s. These fluctuations can be related to the weakening in recent decades the East Pacific monsoon. In some intervals, the structure of stationary waves changed markedly in the middle latitudes, with a characteristic period of 2-4 years. As shown by model calculations in the barotropic quasi-geostrophic approximation, only the part of the waves variations can be explained by changes in orographic forcing.

The goals of this work were:
1. Analysis of the spatial structure and long-term changes in stationary planetary waves in the Northern Hemisphere.
2. Calculation of the structure of stationary waves due to orographic forcing, using quasi-geostrophic barotropic model. Comparison of modeling results with observational data.

1) Asia - Europe - Atlantic

Figures show the distributions of the 500 hPa height in July, averaged over the decades 1950-1960 (Fig. 1) and 2000 - 2010 (Fig. 2). Fig. 3 illustrates changes over time the intensity of the positive anomalies over the northern part of the Eurasian continent. Analysis of variance allowed the following conclusions:

1. There are not significant trend in the intensity of positive geopotential height anomalies over the northern part of Eurasia. In the last decade, the anomaly over Europe has been better expressed than over Asia.
2. Changed the configuration of the anomalies. One possible reason for this could be spread trough from the Asian part of the European continent to Western Siberia, which divided a large positive anomaly over the northern part of Eurasia into two separate anomalies.
3. Fluctuations in the smoothed curves have quasi decadal component, but the reliability of this component is low, since the amplitude of component is comparable to the standard deviation of interannual fluctuations.
4. From 1950 to 1985 stationary waves in the middle latitudes had specific variations in the range of 2-4 years, with the character sequence fusion anomalies of different signs. If in any of the summer season the negative geopotential height anomalies over the Black Sea and north-eastern regions of North America and Greenland were connected, in the following summer anomalies over northern Eurasia and central regions of the Atlantic Ocean were combined. An example of such a sequence of mergers of anomalies of different signs in 1984 (Figure 4) and 1986 (Figure 5) shown. After 1985, this alternation was dominated by the merger of positive anomalies.

Fig. 1 – Planetary waves at 500 gPa in July 1950-1960. The distance between contours of 10 m

Fig. 2 – Planetary waves at 500 gPa in July 2000-2010

Fig. 3 - Variations of the intensities of geopotential height anomalies in July 1950-2010 over the European (red) and Asian (blue) parts of the continent

Fig. 4 – The observed structure of planetary stationary waves at 500 hPa in July 1984.

Fig. 5 – The observed structure of planetary stationary waves at 500 hPa in July 1986.

Asia - Pacific - North America

1. In the region of Asia and the Pacific, there were large-scale fluctuations in the circulation, which began with the strong perturbations in the late 50s - early 60s. Later, geopotential height variations at the different regions were less agreed and resembled the relaxation process after a strong disturbance. One consequence of this process was to change the configuration of stationary waves over East Asia. Figure 8 shows graphs of changes in the intensity of positive geopotential height anomalies over the Hawaiian Islands and two negative anomalies over East Asia and the Pacific Ocean. Significant variations of the anomalies mostly completed by the 70 th year. Reduce pressure over the East Asia was accompanied by mass transfer, first in the western Pacific, and then, with some delay - in the region of Hawaii maximum. Correlation coefficients (Table 1) between the negative anomalies over the Pacific Ocean and Asia and between the negative anomaly over the Pacific Ocean and positive anomalies over Hawaii confirmed this conclusion.

2 - 4-year fluctuations of the same type as those of Europe - the North Atlantic, notes, and over the Pacific Ocean and the Bering Sea and the central regions of North America. On the right are examples of this variation in 1971 (Fig. 6) and 1973 (Fig. 7), respectively.

Fig 6 The observed structure of planetary stationary waves at 500 hPa in July 1971

Fig 7 The observed structure of planetary stationary waves at 500 hPa in July 1973

anomalies	Years	Unfiltered data	Smoothed data for 5 years
The negative anomaly in the Pacific the negative anomaly, Asia	1950 – 1985 1985 – 2010	-0,39 0,14	-0,72 0,35
The negative anomaly in the Pacific The positive anomaly over Hawaii	1950 – 1985 1985 – 2010	-0,11 0,11	-0,42 0,32

2) **The basis of the model is the equation of quasigeostrophic potential vorticity in the barotropic (divergence) approximation [2].**

R is an orographic source of vorticity, which has been selected in the mountain system of the Eurasian continent - the Himalayas and Tibet, and in North America - Andes - the Rocky Mountains.

Fig 9 Simulation of orographic forcing of stationary waves in stream function by Himalayas - Tibet (left figure) and the Cordillera - Rocky Mountains (right figure) in July 1950-1960 for the velocity at 500 hPa

Orographic source of vorticity determines the spatial structure of the geopotential height anomalies near the mountains, the intensity of which have consistently change when the flow incident on the mountain. Fig. 9 shows examples of calculation of orographic stationary waves from different sources, 1950-2010.

Fig. 10 shows the variations of the vorticity source Tibet - Himalayas and the intensity of the negative geopotential height anomalies over the Asian part of Eurasia and the Pacific Ocean and positive anomalies over the Hawaiian Islands. It is seen that the variation of the vorticity source and negative anomaly are closely related (correlation coefficients for unfiltered data -0.59 and for smoothed data -0.91). The consequence of orographic forcing had to be coherent oscillation of other geopotential height anomalies over northern Eurasia. However, comparison of changes in the intensity of these anomalies did not confirm this assumption. To a lesser extent on the variation of static nary waves affect the Cordillera mountain range - the Rocky Mountains.

Fig. 10 - Variations of the intensities of the positive geopotential height 500 hPa anomalies over the Hawaiian Islands (red), two negative anomalies over the Asian part of Eurasia (blue) and propagating away trough over the Pacific Ocean (blue) and orographic vorticity source Himalayas - Tibet (pink) in July 1950-2010.

Список литературы:
1. Kalnay E., Kanamitsu M., Kistler R. et al. The NCEP/NCAR 40-year reanalysis project. – Bull. Amer. Meteor. Soc., 1996, V. 77, pp.437-471.
2. Branstator G.W. Horizontal Energy Propagation in a Barotropic Atmosphere with Meridional and Zonal Structure // J. Atmos. Sci. 1983. V.40. № 7. pp. 1689-1708.

Thank you for your attention.