THE ROSSBY WAVE 2000–2021
CLIMATOLOGY IN THE ARCTIC
SUDDEN STRatosphere WARMINGS

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Summary. The temporal-spatial-altitude evolution of the main components of planetary waves with wavenumbers 1 and 2 at the middle and polar latitudes are considered. The planetary wave parameters were retrieved to identify long-term changes and evaluate possible trends in Rossby wave characteristics. The planetary wave parameters are examined by considering variations in the geopotential height Z field in the stratosphere and mesosphere in the 2000–2021 period at altitudes ~15, 30, and 45 km and latitudes of 0-90°N. We used the MERRA-2 reanalysis data. The most significant wave-1 amplitude is observed in the latitude range 50–80°N and at a pressure level of 10 hPa.

Keywords. Polar stratosphere, planetary wave, geopotential height, reanalysis, warming

The large-scale disturbances of the dynamic structure of the atmosphere, which spread in the horizontal direction, in the physics of the atmosphere are called the Rossby waves or planetary waves. They are associated with a polar-front jet stream [1]. They are generated by the interaction of the air flow of atmosphere with orography heterography and temperature contrasts between land and the ocean and are a consequence of the preservation of potential vorticity in the atmosphere.

Rossby atmospheric waves usually spread from west to east. Being a dominant part of spatial and temporal variability in the troposphere, penetrate into the stratosphere and can also cause perturbation of the parameters of the mesosphere. They have a significant impact on wind speed, temperature, ozone distribution and other characteristics of the structure of the middle atmosphere [2]. The increase in the activity of planetary waves can lead to the polar vortex is weakening, the temperature in the stratosphere increases sharply, zonal circulation changes from
the westerlies to the easterlies in an event called as sudden stratosphere warming [3]. Therefore, the parameters of the Rossby waves and their changes over two decades are important characteristics in view of the impact of the SSW event on atmospheric circulation and even on weather conditions in midlatitudes [4].

The important characteristics of the Rossby waves are the period and zonal wave number. The zonal wave number (m) is determined by the number of full waves along the parallel. The largest role is played by the most powerful planetary waves with m = 1 and planetary waves with m = 2 [5]. Therefore, the study of the features of wave-1 and -2 development in these layers of the atmosphere is important for the establishment of new data on the general dynamics of the atmosphere.

So far, the altitude evolution of the wave-1 and wave-2 in the middle latitudes remains poorly studied. It is also important to identify long term changes in planetary wave parameters for many years to evaluate possible trends of their characteristics. Rossby wave parameters are convenient to study, considering the amplitudes and anomalies of geopotential height Z at the heights of the stratosphere and mesosphere using MERRA-2 Reanalysis data (https://gmao.gsfc.nasa.gov/reanalysis/merra-2/).

In Figure 1 Rossby waves amplitudes are shown according to climatology 2000-2021 by averaged geopotential height values for that period according to the MERRA-2 reanalysis data at altitudes 100, 10 and 1 hPa in the latitudinal range 0-90°N from December to April.

The latitudinal position of the maximum wave-1 amplitude is located at the pressure level of 10 hPa in 50-80°N (Figure 1). Over time, with reducing the size of the stratosphere polar vortex, it shifts to the pole. The area of maximum wave-2 amplitudes is located in the latitudinal band 50-75°N. The most prominent trend towards the pole is seen for wave-1 (see lines drawn through the peaks of amplitude in Figure 1), while this displacement is much smaller for wave-2 at 10 hPa. When comparing the time rows of amplitudes for wave-1, the maximum is at 65°N, for the wave-2 is at 60°N.

**Fig. 1.** Rossby wave amplitudes climatology 2000–2021 by averaged data of geopotential height anomalies according to the MERRA-2 reanalysis data at altitudes 100, 10 and 1 hPa (~ 15, 30 and 45 km) in altitudes latitudes 0–90°N from December to April (upper row is wave-1, lower row is wave 2)

In Figure 2 the dependence on height of temporal changes in wave-1 and
-2 amplitudes is shown. When comparing the time rows of amplitudes of waves with height it can be determined that for wave-1 the average height of the maximum is located at 1 hPa, for wave-2 - at 10 hPa. According to climatology 2000-2021, two peaks of planetary wave-1 activity in the winter and spring are observed: the first seen at the end of December-the beginning of January, and the second at the end of January-mid-February. It is important to note that the maximum wave-2 activity is recorded in the interval between the two peaks of wave-1 activity and occurs in mid-January. These two periods of Rossby wave-1 activity and the period of increase in wave 2 activity are also visible in Figure 1.

Figure 2 also shows how the decrease in wave-1 amplitude is accompanied by increased wave-2, and perturbations move from top to bottom. The range of maximum wave-2 amplitude (~ 27 km) is lower than the wave-1, which increases significantly with height, with a maximum near the stratopause.

![Climatological seasonal changes (from December to March) daily amplitudes of Rossby waves with m = 1-2 According to anomalies of geopotential height, averaged from 2000 to 2021. 2–64 km) on latitude 60°N according to reanalysis MERRA-2](image)

At a height of 100 hPa (16 km), it is the same as the amplitude of the wave-2, and at a height of 1 hPa (48 km) it is already much higher. The data from climatology 2000-2021 shows that the periods of variability of wave-1 and -2 amplitudes are reduced with height (compare the frequencies of the occurrence of peak waves in Figure 1).

Waves 1 and 2 are anticorrelated with during their evolution, which can be seen from the location of maxima and minima at pressure levels of 1 hPa in the latitude band 50°–70°N during November to May, as shown in Figure3. The decrease in amplitude wave 1 accompanied by increased wave 2 amplitude.

![The amplitude of wave 1 (black) and wave 2 (red) averaged in the 50°N–70°N latitude zone at heights of 1 hPa according to averages for 2000–2020 geopotential heights from the MERRA-2 reanalysis](image)
We study planetary wave parameters to identify long-term changes. The largest wave-1 amplitude was revealed in the latitude range 50-80°N and at a pressure level of 10 hPa. Long-term wave amplitude changes can influence the polar vortex, as well as the frequency SSW occurrence and dynamic characteristics of the SSW events. In the future work, the possible trends in PW characteristics will be evaluated.

Acknowledgements. This work was partly supported by the College of Physics, International Center of Future Science, Jilin University, China, and by the Ministry of Education and Science of Ukraine in the framework of the project BF30-2021 at the Taras Shevchenko National University of Kyiv and the National Antarctic Scientific Center (project reg. No. 0123U103587).

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