

ИССЛЕДОВАНИЕ ОТКЛИКА ТРОПОСФЕРЫ И СТРАТОСФЕРЫ НА СОБЫТИЯ ЭНЮК

STUDY OF THE RESPONSE OF THE TROPOSPHERE AND STRATOSPHERE TO ENUK EVENTS

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Data and methodology

The aim of the work is to study the climatic regime of the equatorial stratosphere (15ºS-15ºN), which was conditionally divided into 7 regions.

To study the long-term dynamics of climate variability in the equatorial stratosphere, maps of differences in meteorological quantities were constructed in the modern climatic period (1991-2020) compared to the previous climatic period (1961-1990).

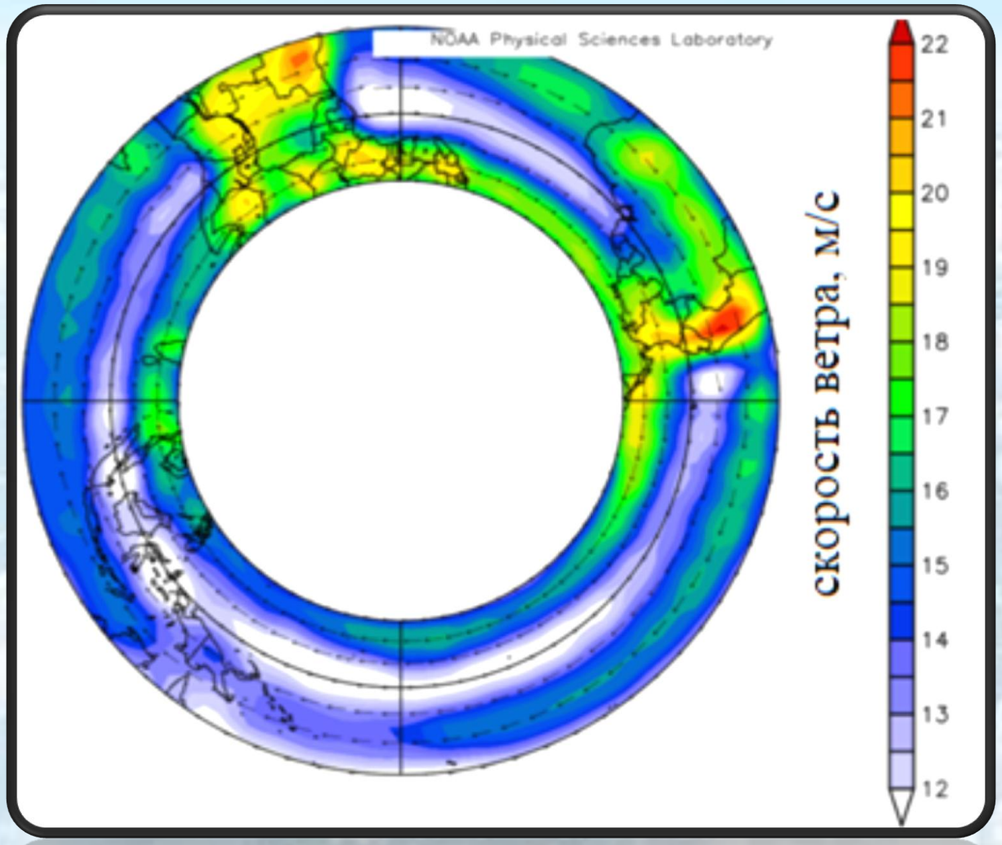
The changes in wind characteristics in the stratosphere and troposphere in relation to other meteorological parameters during the strongest **El Niño and La Niña** events are analyzed.

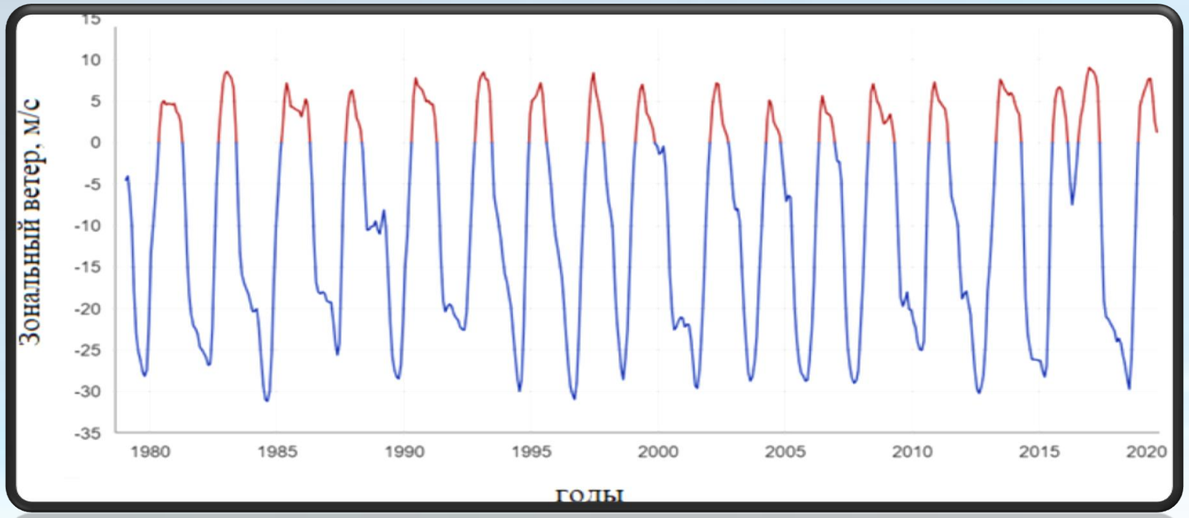


Figure 1 – Research area and regions

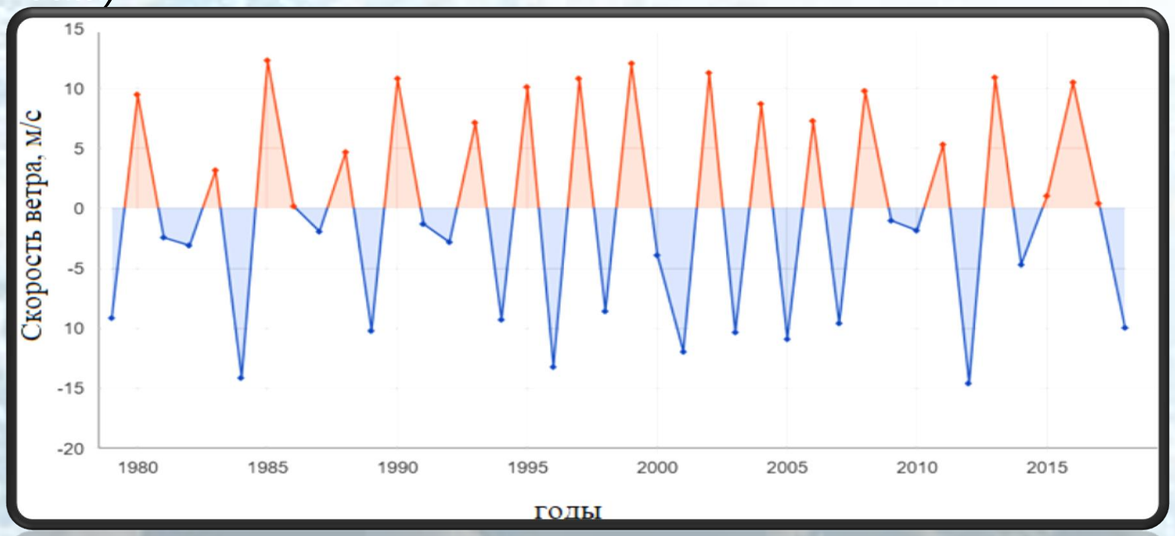
Results

In the modern climatic period (1991-2020), in the equatorial stratosphere at the isobaric surface level of 10 hPa (~30 km), average annual wind speeds vary from **10-12 m/s** over the ocean surface to **22-24 m/s** in the South American region.





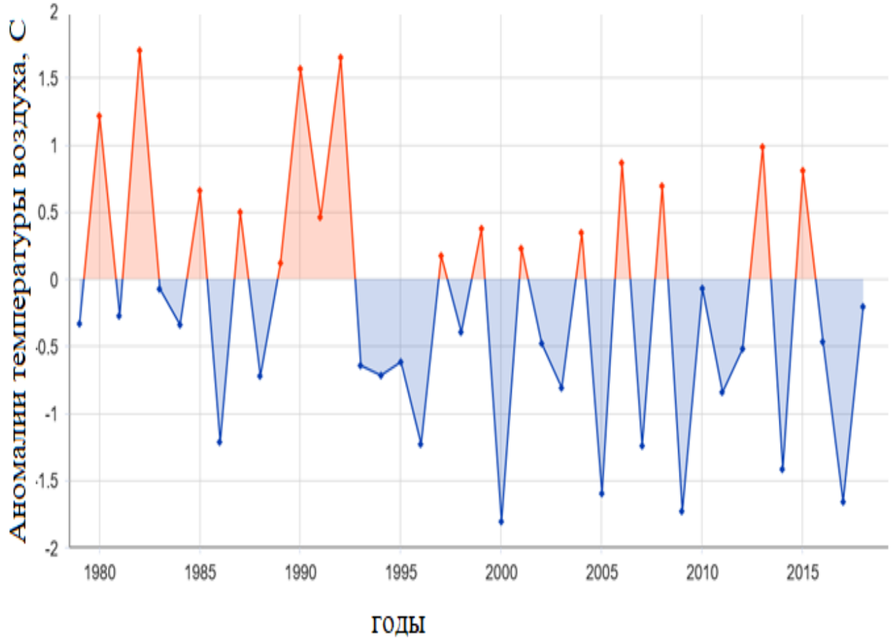
Changes in mean annual zonal wind speeds (m/s) in the equatorial stratosphere from 1979 to 2023 (ERA5 Reanalysis data)



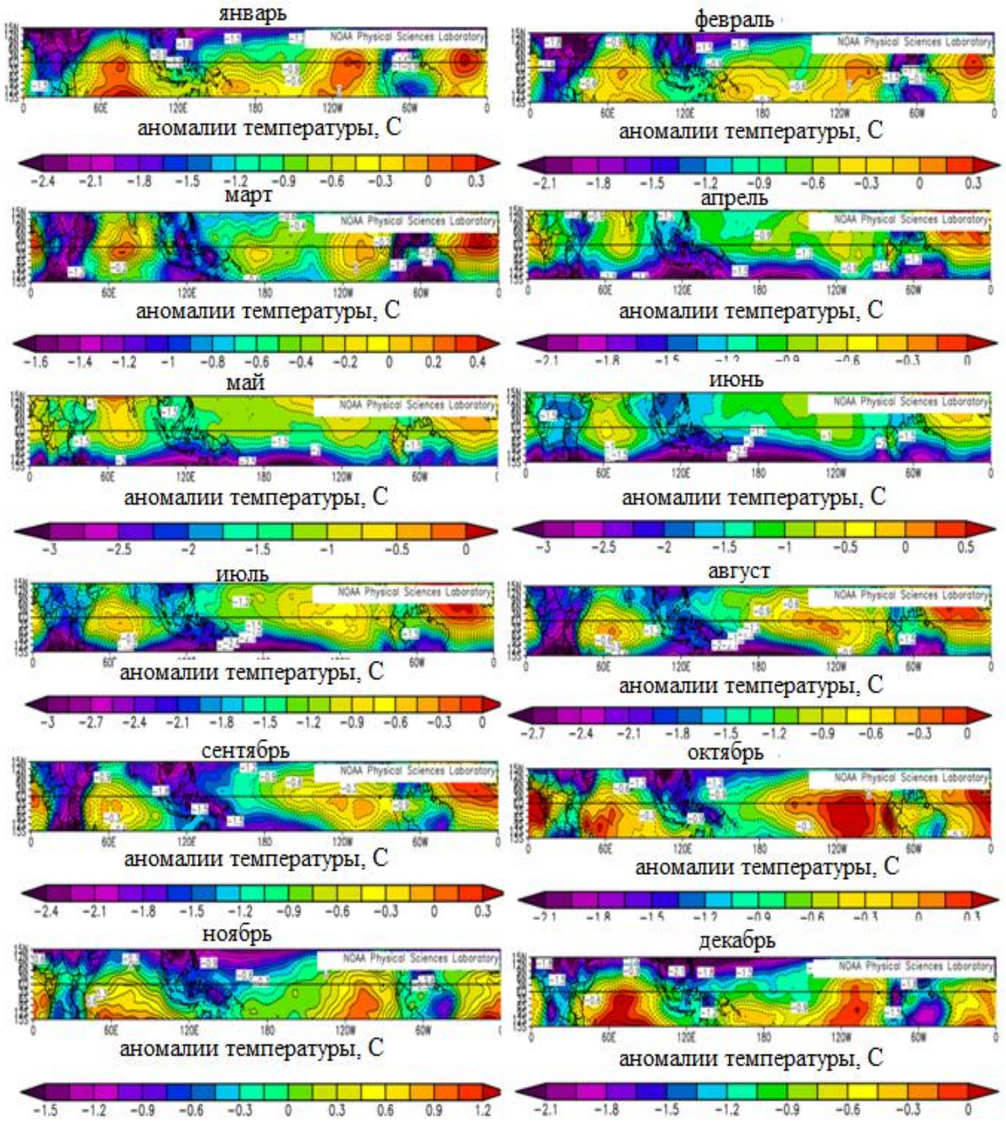
Changes in average annual values of the zonal wind speed (m/s) in the equatorial stratosphere from 1979 to 2023 (ERA5 Reanalysis)

Results

Compared to the troposphere, where **climate warming** is occurring, in the stratosphere throughout the equatorial zone in the modern climatic period, compared to the previous climatic period, a **cooling of up to minus 2 ºC** is observed in the African and South American regions.

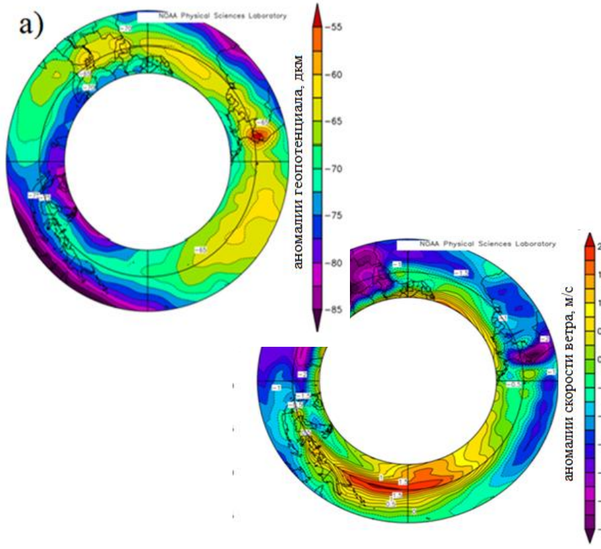


Change in mean annual air temperature (°C) in the equatorial stratosphere from 1979 to 2023 (ERA5 Reanalysis data)



Anomalies in mean monthly air temperatures (°C) at the 10-hPa level in the modern climate period (1991–2020) relative to the previous climate period (1961–1990) (Reanalysis data NCEP/NCAR)

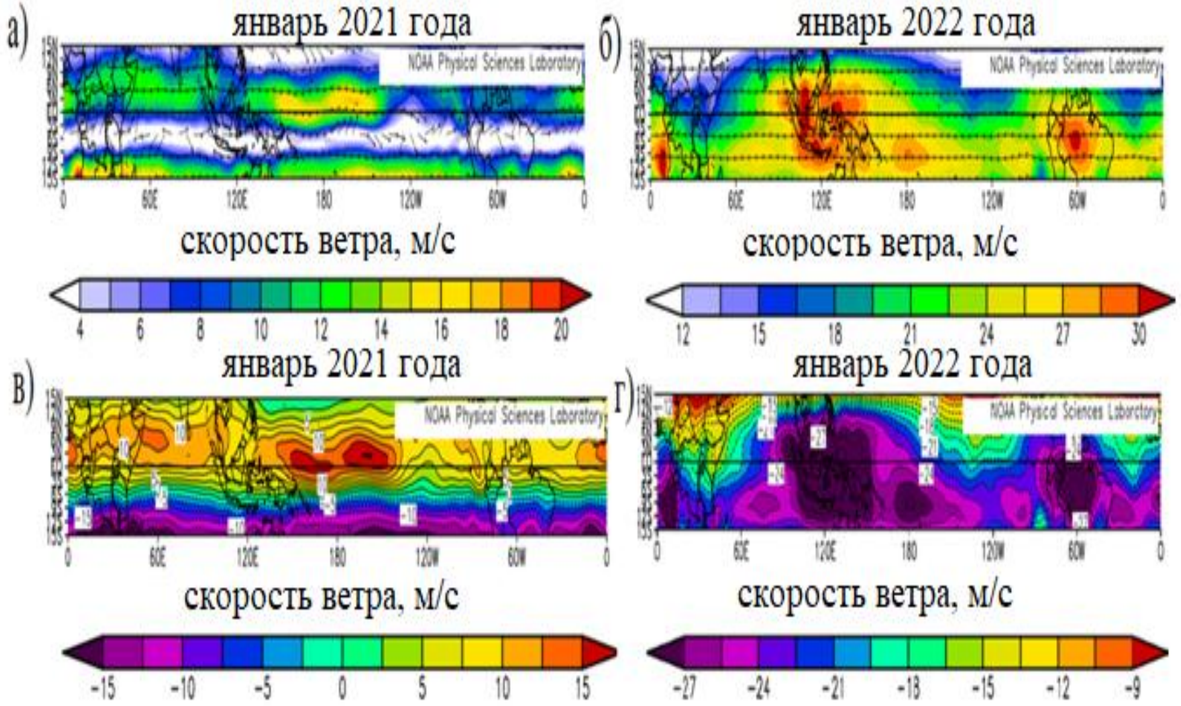
The cold spell is accompanied by a decrease in geopotential heights, strengthening of winds over the Pacific Ocean and weakening in the African region and over the Indian Ocean.



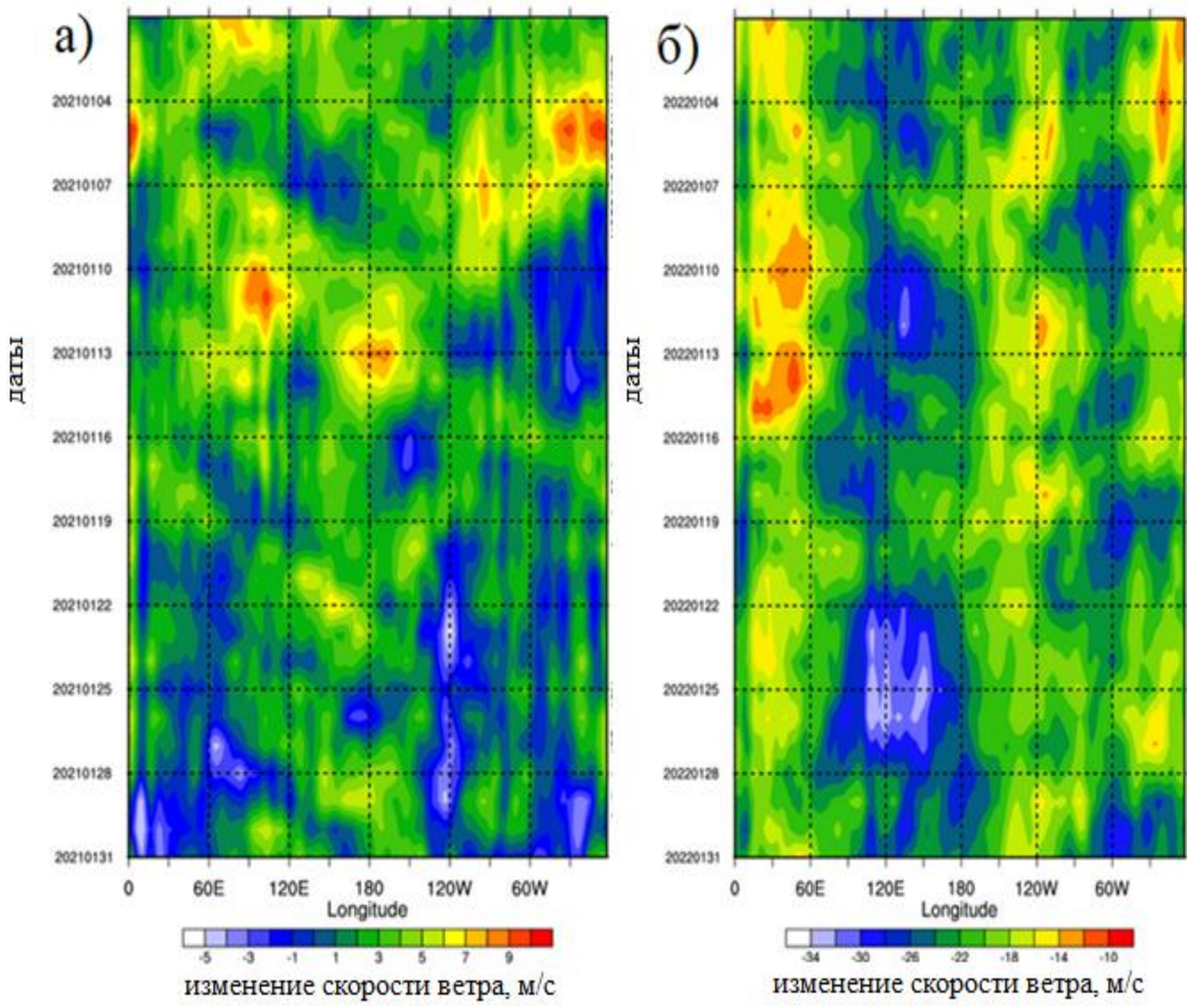
Anomalies of geopotential (dkm) (a) and wind speed (m/s) (b) in the equatorial stratosphere at 10 hPa during the current climate period (1991–2020) relative to the previous climate period (1961–1990)

Results

This paper presents a comparative analysis of meteorological fields during different phases of the quasi-biennial wind cycle in the equatorial stratosphere. Two periods were chosen for this purpose: January 2021, when **westerly winds** were observed in the equatorial stratosphere, primarily in the Northern Hemisphere, and January 2022, when **easterly winds** were dominant in the equatorial stratosphere.



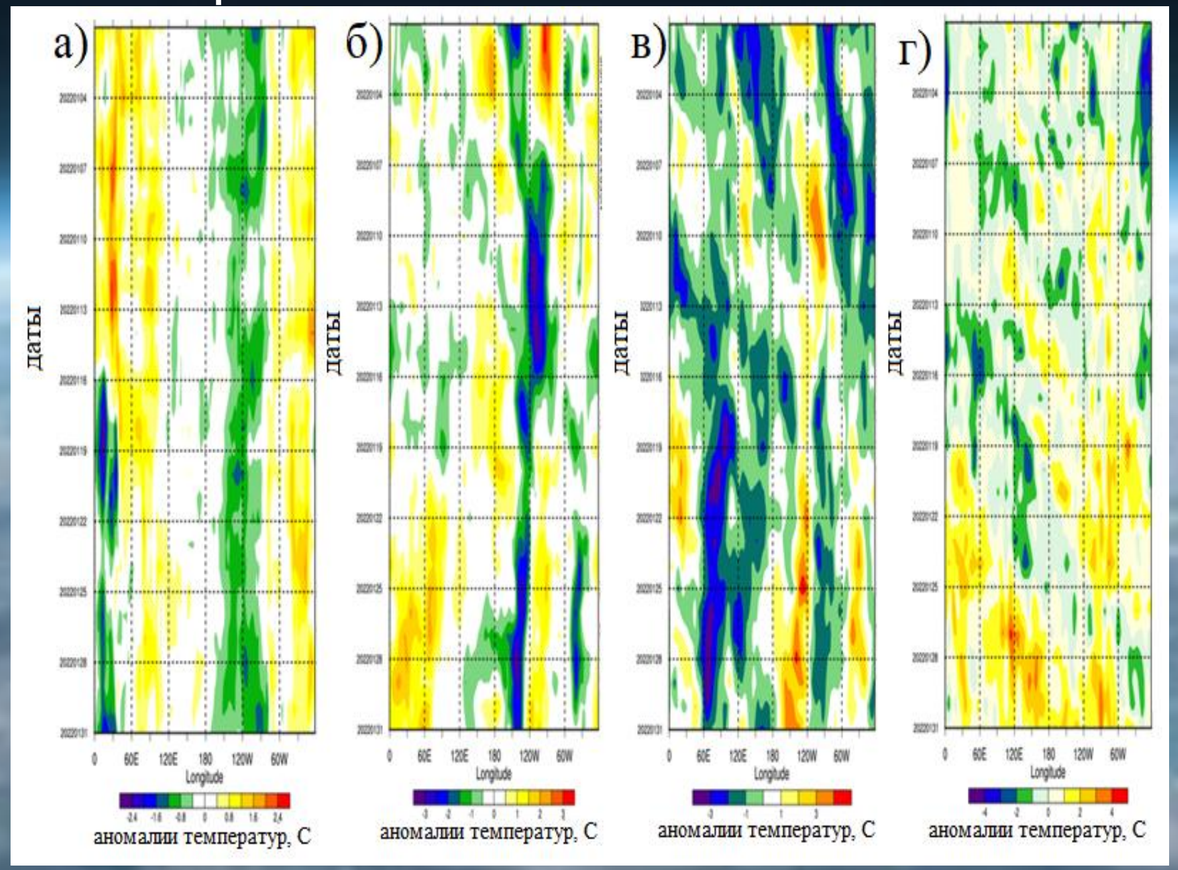
Wind vector (a, b) and zonal component of wind speed (c, d) at the 10 hPa level in the equatorial zone in January 2021 and 2022 (Reanalysis data NCEP/NCAR)



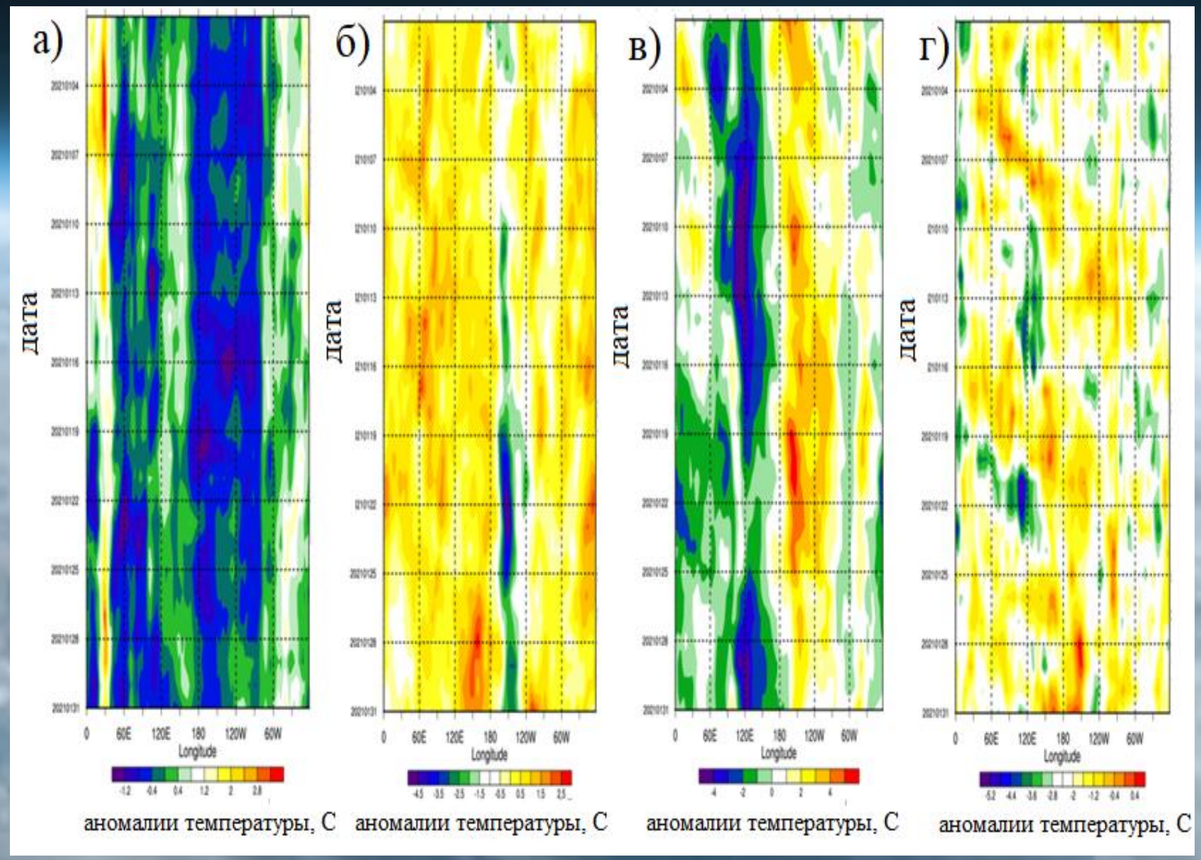
Change in the zonal component of wind in the equatorial stratosphere between 15ºN and 15ºS for each day in January 2021 (a) and January 2022 (b) (Reanalysis data NCEP/NCAR)

Results

In January 2021, with a **westerly wind** component, **negative temperature anomalies** prevailed in the equatorial stratosphere and **positive temperature anomalies** at the Earth's surface, compared to January 2022, when an **easterly wind** component was observed in the stratosphere.

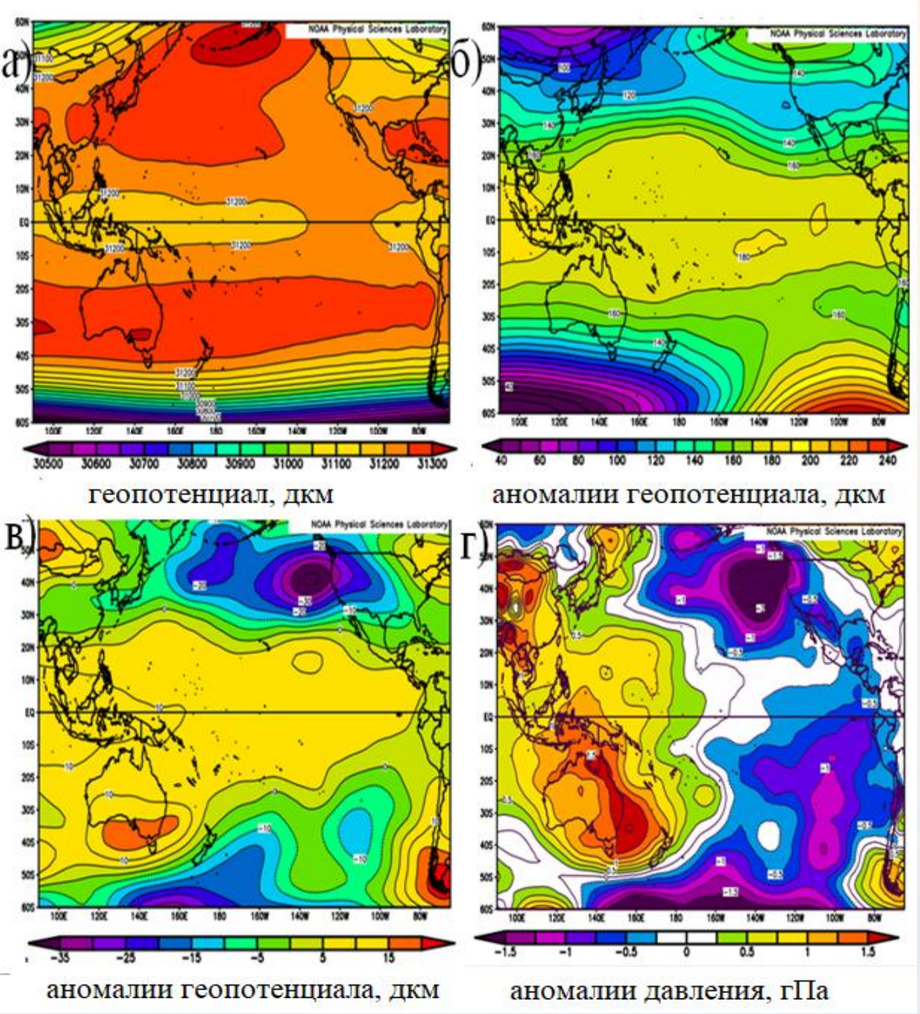


Monthly mean air temperature anomalies in the equatorial zone from 15ºN to 15ºS at the Earth's surface (a), at 500 hPa (b), 100 hPa (c), and 30 hPa (d) in January 2021 (Reanalysis data NCEP/NCAR)



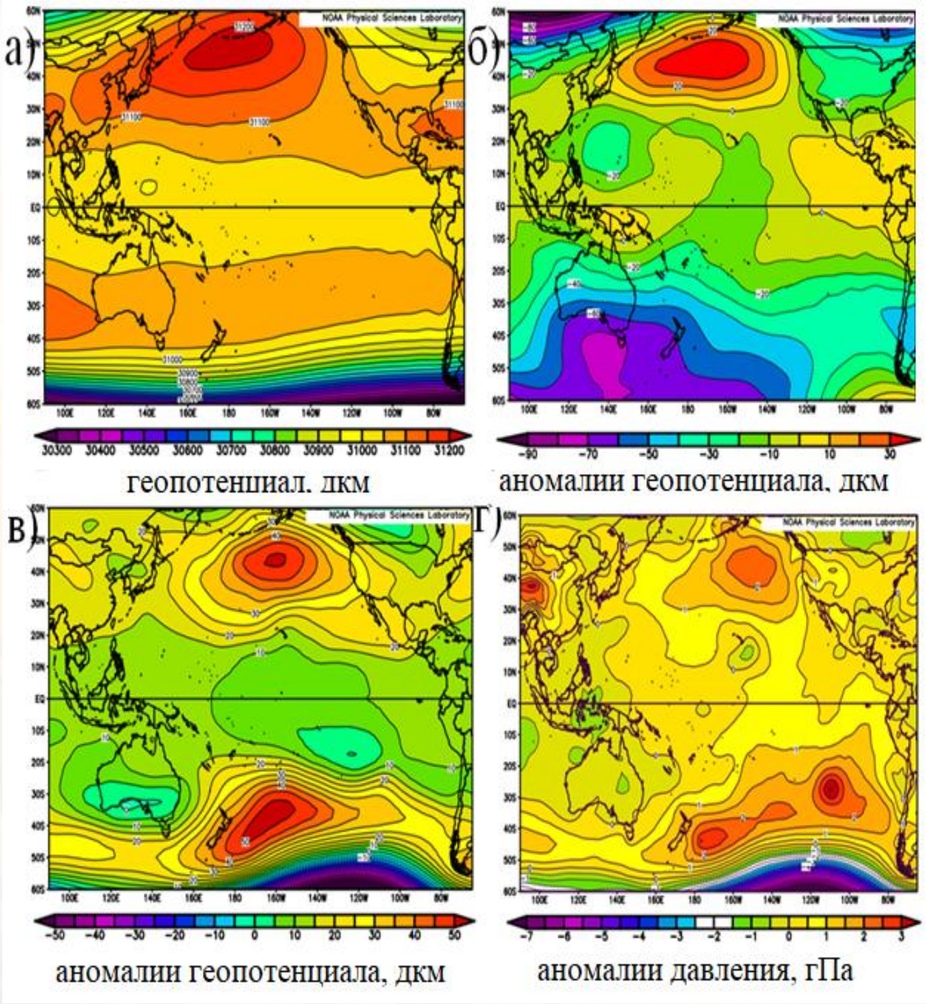
Monthly mean air temperature anomalies in the equatorial zone from 15ºN to 15ºS at the Earth's surface (a), at 500 hPa (b), 100 hPa (c), and 30 hPa (d) in January 2022 (Reanalysis data NCEP/NCAR)

Results



Average values of geopotential heights at the stratosphere level (10 hPa) (a), geopotential anomalies at the level of isobaric surfaces AT-10 hPa (b) and AT-500 hPa (c), surface pressure anomalies (d) during the years of strong El Niño 1982-1983.

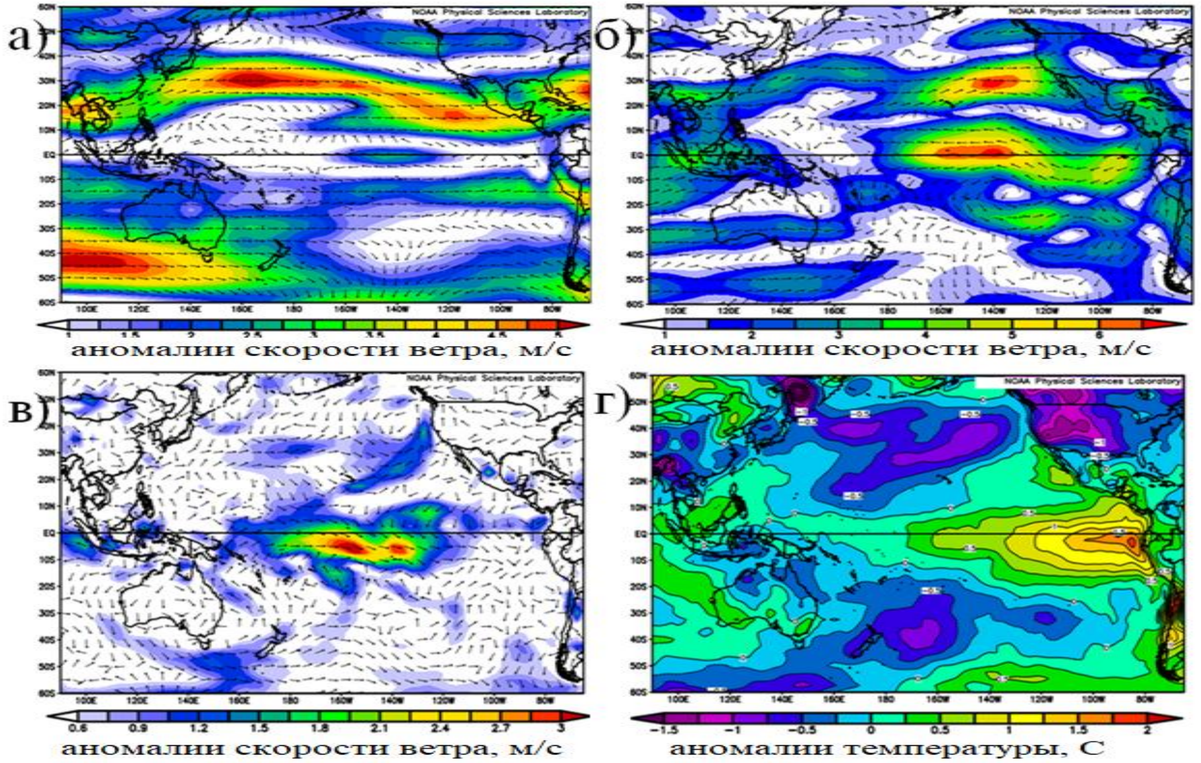
To determine the possible influence of El Niño and La Niña on equatorial stratospheric winds or the converse influence of wind shifts in the equatorial stratosphere on the temperature regime of the equatorial and tropical Pacific Ocean, maps of wind anomalies, geopotential heights, surface pressure, and surface air temperature were constructed for the stratosphere, tropopause, middle troposphere, and Earth's surface. The strongest El Niño (1982-1983, 1997-1998, and 2015-2016) and La Niña (1999-2000, 2010-2012, and 2020-2022) events were selected.



Average values of geopotential heights at the stratosphere level (10 hPa) (a), geopotential anomalies at the level of the AT-10 hPa (b) and AT-500 hPa (c) isobaric surfaces, surface pressure anomalies (d) during the strong La Niña years 2020-2022.

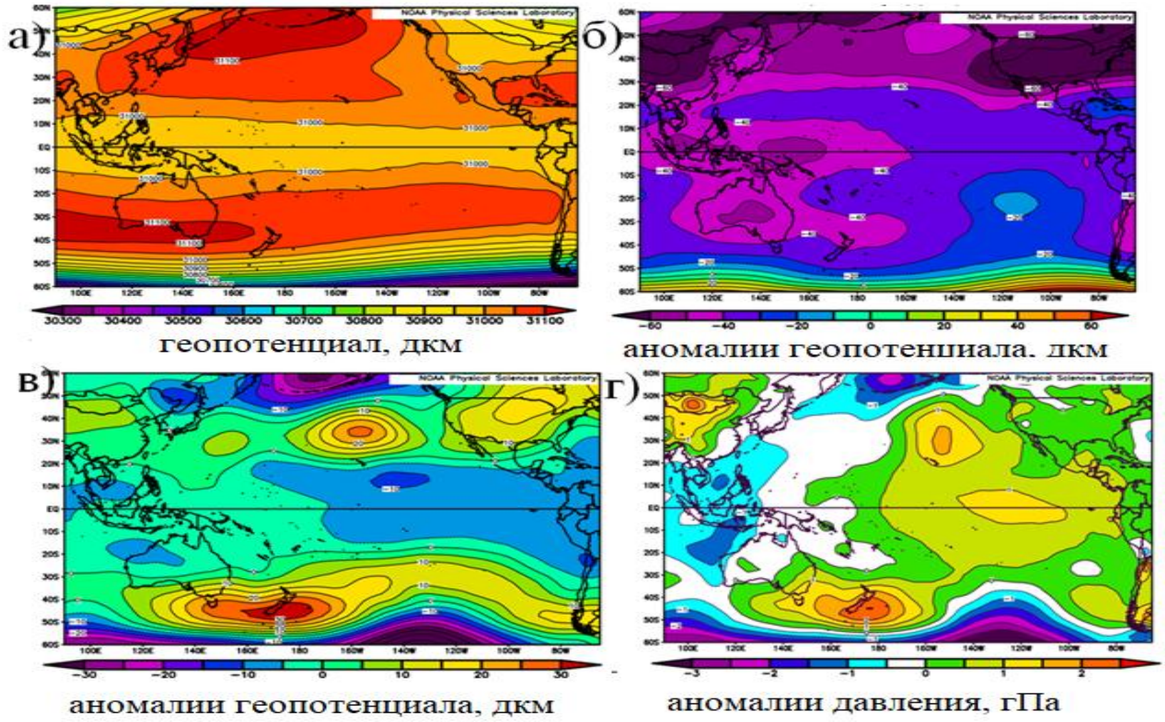
Results

In the stratosphere, strong El Niño events weaken easterly winds, which is accompanied by a deepening of the stratospheric vortex and the circumpolar tropospheric vortex.



Wind anomalies in the stratosphere (10 hPa) (a), at the tropopause (b)and at the Earth's surface (c), surface air temperature anomalies (d)during the strong El Niño years of 1982-1983.

During La Niña events, either easterly winds are observed or weaken in the equatorial stratosphere, which is accompanied by a decrease in geopotential heights in the stratosphere over almost the entire Pacific Ocean.



Average values of geopotential heights at the stratosphere level (10 hPa) (a), geopotential anomalies at the level of isobaric surfaces AT-10 hPa (b) and AT-500 hPa (c), surface pressure anomalies (d) during the years of strong La Niña 1999-2000.

Conclusion

В работе выполнено исследование возможного отклика квазидвухлетних колебаний зональной составляющей ветра в приэкваториальной стратосфере на события ЭНЮК. События сильного Эль-Ниньо и сильного Ла-Нинья отличаются противоположным характером ветра в стратосфере и вблизи тропопаузы: восточный ветер в стратосфере и западный ветер вблизи тропопаузы в экваториальной стратосфере - при сильных событиях Эль-Ниньо и западный ветер в стратосфере и восточный ветер вблизи тропопаузы - при сильных событиях Ла-Нинья.

При событиях Эль-Ниньо хорошо прослеживается влияние экваториальной области в развитии антициклональной завихренности над Северной частью Тихого океана, более выраженное углубление циркумполярного вихря, что может способствовать более активному переносу тепла и влаги, а при холодных эпизодах Ла-Нинья более выраженное влияние антициклогенеза у поверхности Земли.

По ранее проведенным исследованиям другими авторами при западной составляющей стратосферного ветра усиливался циркумполярный вихрь, что согласуется с полученными нами данными.

Если в экваториальной стратосфере господствующими являются ветры восточной четверти, то, по ранее проведенным исследованиям усиливаются меридиональные атмосферные процессы, в нашем исследовании при восточных ветрах усиливается высотный и приземный антициклогенез в средней тропосфере и у поверхности Земли.

This paper examines the possible response of quasi-biennial oscillations of the zonal wind component in the equatorial stratosphere to ENSO events. Strong El Niño and strong La Niña events are characterized by opposing wind patterns in the stratosphere and near the tropopause: easterly winds in the stratosphere and westerly winds near the tropopause in the equatorial stratosphere during strong El Niño events, and westerly winds in the stratosphere and easterly winds near the tropopause during strong La Niña events.

During El Niño events, the equatorial region clearly influences the development of anticyclonic vorticity over the North Pacific, leading to a more pronounced deepening of the circumpolar vortex, which can facilitate more active heat and moisture transport. During cold La Niña episodes, the influence of anticyclogenesis at the Earth's surface is more pronounced.

Previous studies by other authors have shown that the circumpolar vortex intensifies with a westerly component of the stratospheric wind, which is consistent with our findings.

While eastern winds are dominant in the equatorial stratosphere, previous studies suggest that meridional atmospheric processes are enhanced. In our study, easterly winds intensify high-altitude and surface anticyclogenesis in the middle troposphere and at the Earth's surface.