Relation of interannual variations of surface pressure in Asia with El Niño and variations of circulation in the Southern Hemisphere

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According to the NCEP / NCAR Reanalysis data, synchronous long-term changes in the surface thermobaric field occur over the vast territory of Asia, including Southern Siberia, in the equatorial and tropical Indian and Pacific, in Africa, and in the circumantarctic depression. The relation between these changes can be caused by changes in the El Niño occurrence or by transequatorial mass transfer. The correlation coefficients of surface pressure variations with variations of the ocean surface temperature in the El Niño zone and pressure variations in the circumantarctic depression are estimated. The results indicate that the most probable relating processes are the processes on inter-hemispheric interaction.

Introduction

A peculiarity of climatic variations in Southern Asia is the stable rise of pressure starting from the late 1960s, which is especially true for the summer period. In winter, the zone of pronounced long-term variations, assessed by the coefficients of correlation between interannual variations of the surface pressure and the linear function, includes not only Southern Asia, but also the equatorial and tropical latitudes, Africa, Indian Ocean, and the circumantarctic depression. In summer, it expands further to the north and reaches Southern Siberia.[1] The configuration of this zone in the tropics resembles the zone of influence of El Niño–Southern Oscillation (ENSO) processes.[2] Variations of El Niño occurrence and power could likely explain the observed trends everywhere except for the middle and high latitudes, in which the response to interannual variations of the ocean surface temperature (OST) in the Pacific is relatively weak.

The large extent of the zone of synchronous interannual variations may be caused by the transequatorial air mass transport, initiated by some perturbations of the circulation immediately in the mid-latitudes. Then the variations in the tropics may be a result, rather than a cause of these processes. It can be supposed that the initial impulse arises in the Southern Hemisphere, for example, in Antarctica or the circumantarctic depression, where the trend of pressure decline is especially pronounced. We compare the degree of correlation of the interannual variations of the surface pressure with respect to the El Niño zone and relative to the zone of circumantarctic depression. These estimates can be indicative, to some extent, of the source of variations.

El Niño effect on the circumantarctic depression

The ENSO is studied in numerous publications. The El Niño manifestation in the middle and high latitudes of the Southern Hemisphere has been studied most poorly. The circumantarctic depression is a zone of intense cyclonic activity, and therefore the investigations of long-range relations usually are focused on the position and intensity of stormtracks, relating the depression with the middle and low latitudes.[3] The main belt of stormtracks begins near Australia and encircles, along a spiral, the Southern Pacific and the Southern Atlantic. During the ENSO warm phase, the stormtrack axis intensifies and shifts over the Pacific Ocean to the equator and over the Southern Atlantic to the pole. The transition to La Niña over the South America manifests itself in the baroclinity of the 35°S region. El Niño also features the positive geopotential anomalies in the Bellingshausen Sea, which correspond to blocking episodes to the south-west from the southern end of the South America. Cyclonic stormtracks and related Rossby waves in the upper troposphere, or blocking in the Bellingshausen Sea, likely interact with Rossby wave packets of the circumantarctic depression and thus affect its characteristics.

The lower bound of the degree of El Niño influence can be found by the correlation method. For this purpose, we used the SST Reynolds archive of the ocean surface temperature data with the $1 \times 1°$ spatial resolution for the period since 1981 through 2002 and the NCEP / NCAR Reanalysis archive of meteorological data at the nodes of the $2.5 \times 2.5°$ grid.[4] Figure 1 shows the isocorrelate fields of the

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interannual variations of the monthly mean surface pressure in the Southern Hemisphere and the interannual variations of the annual average OST at an equator point with a coordinate of 100°W.

OST variations are quite chaotic in time; to be noted is the increase in the intensity of anomalies in the past decades.

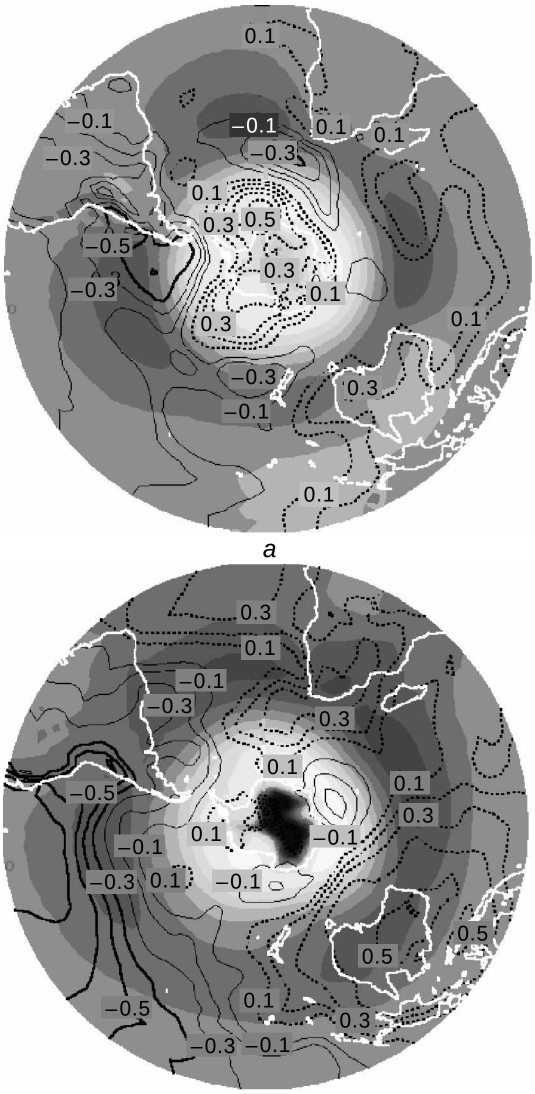

Fig. 1. Distribution of correlation coefficients of interannual variations of monthly mean surface pressure and interannual variations of the annual average OST in the El Niño zone for July (*a*) and January (*b*). Different color indicates isobars of the mean surface pressure, the light color corresponds to the low pressure (circumantarctic depression), the dark color indicates the high pressure (subtropical anticyclones).

The isocorrelate fields are drawn for July and January. For a comparison of the El Niño response with the features of distribution of the surface pressure, the isocorrelates are drawn on the maps of the monthly mean baric field, averaged by the NCEP/NCAR Reanalysis data over 19 years. Isobars are drawn with the interval of 5 hPa. The plot of OST variations at the El Niño point is shown in Fig. 2.

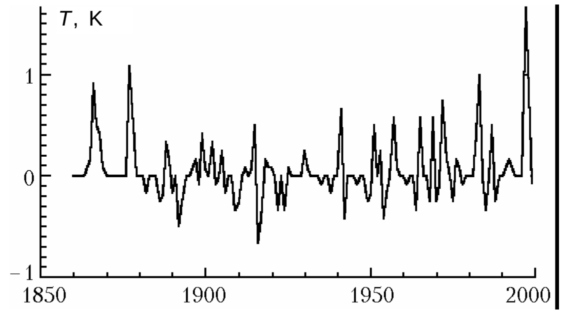

Fig. 2. Time variations of annual average OST anomalies in the El Niño zone.

The analysis of Fig. 1 shows that in the tropics and subtropics the correlation is relatively high and stable both in winter and summer. In the high and middle latitudes, the correlation fields are weak and irregular. The mid-latitudes of the Pacific are likely in the closer correlation with El Niño. To estimate the integral effect of El Niño on the entire zone of the circumantarctic depression, the correlation coefficients were averaged for all the node points of the grid along the 60°S parallel, roughly coinciding with the depression axis. The calculated results are shown in the diagram (Fig. 3) by light columns. The correlation coefficients were higher in the summer months, though their absolute values in these months did not exceed 0.2. It turned out that longer OST and pressure variations in circumantarctic depression correlate better. The dark color on the diagram shows the correlation coefficients of 5-year smoothed variations. The maximum absolute value of the correlation coefficient in July exceeded 0.3, and the seasonal behavior of the correlation has changed, in particular, the correlation coefficients became negative not only in summer, but also in winter. It was, probably, a manifestation of the long-term tendencies: increase in the El Niño occurrence and power and fall off of the mean pressure in the circumantarctic depression.

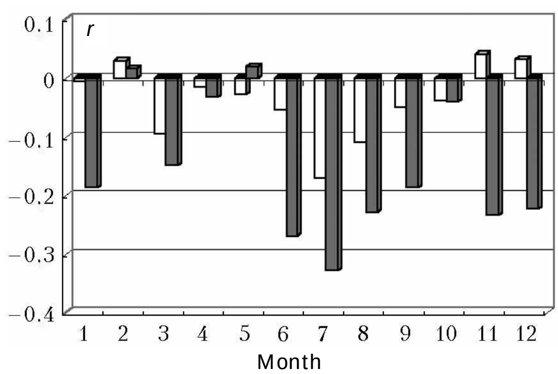

Fig. 3. Seasonal behavior of the correlation coefficients of OST in the El Niño zone and interannual variations of pressure in the circumantarctic depression, averaged at the grid nodes along the 60°S parallel. Dark color is used for the correlation coefficients of 5-year smoothed variations.

The situation in the Northern Hemisphere is similar. Figure 4 depicts the isocorrelate fields analogous to those in Fig. 1.

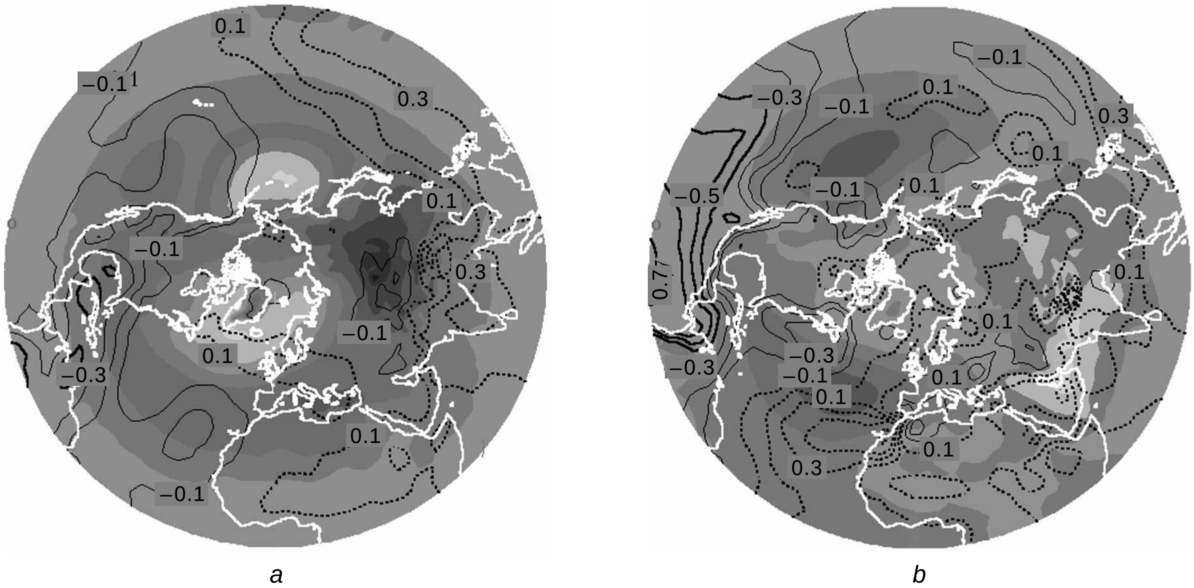

Fig. 4. Distribution of correlation coefficients of interannual variations of the monthly mean surface pressure and interannual variations of the annual average OST in the El Niño zone for July (*a*) and January (*b*). Designations are the same as in Fig. 1.

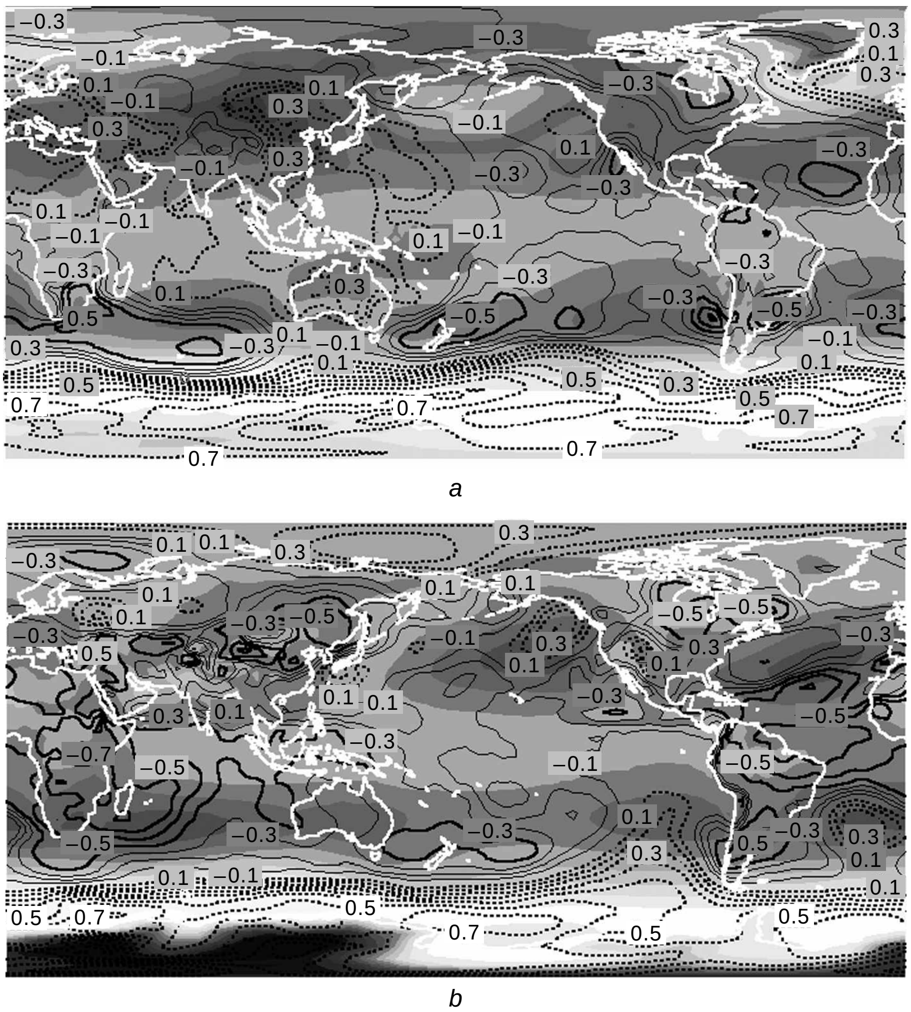

Fig. 5. Distribution of correlation coefficients of interannual variations of the monthly mean pressure at the nodes of the regular grid and the mean pressure along the 60°S parallel for July (*a*) and January (*b*).

The correlation of El Niño and pressure in Central Asia is low, but can be easily separated out. After smoothing, the correlation increases. In general, in both the Northern and Southern Hemispheres the interannual pressure variations in the mid-latitudes, caused by El Niño, correlate with the sign of the trends, if we assume that the occurrence of this phenomenon increases with time. However, this correlation is very low and can hardly cause the pressure fall off in the circumantarctic depression. More interesting results can be obtained from analysis of correlation between variations arising in the depression.

Variations of the surface pressure in the circumantarctic depression

Figure 5 shows the distributions of isocorrelates of the monthly mean pressure at the nodes of a regular grid and the mean pressure along the 60°S parallel for July and January. Oscillations with the characteristic time longer than 5 years are rejected from the data series, that is, trend variations are excluded. To increase the homogeneity of the data series, the period from 1948 to 1963, during which the surface pressure varied with large amplitude, was excluded.

The reduction of the time series had almost no effect on the spatial configuration of the isocorrelate field. The very high correlation with pressure fluctuations in the circumantarctic depression was characteristic of South America, Africa, Southern and Eastern Eurasia, and the tropics of the Western Pacific in summer.

It is interesting that the zone of high negative correlation coincides with those regions of the Southern and Eastern Asia, where the trends of pressure increase in the summer period are especially pronounced. This is likely not occasional, and the increase of pressure over Asia is the result of the inter-hemispheric air mass exchange. Air transport from the south to the north in summer likely takes place in the Indo-African and Western-Pacific sectors of the Southern Hemisphere, connected by current lines with the Central-Asian depression.

In winter the correlation fields change significantly (Fig. 4*b*). The processes in the Eastern Hemisphere are still in closer correlation, but over Eurasia the correlation sites have already the opposite sign, that is, the pressure fall off in the circumantarctic depression is accompanied by weakening of the Asian anticyclone. The mechanism of this correlation is still unclear. An interesting feature of the correlation fields in both winter and summer is relatively weak correlation of variations of the circumantarctic depression with variations of subtropical anticyclones. To a higher extent, these centers of action take part only in the formation of the current fields, providing for the mass flow.

Conclusions

In our opinion, the estimates of the magnitude and character of the correlation between interannual variations of the surface pressure in different regions on the globe and OST variations in the El Niño zone, as well as pressure variations in the circumantarctic depression, are indicative of the direct relation between pressure variations in different hemispheres, which is likely caused by the transequatorial mass transport. The indirect effect of El Niño on the circulation in both hemispheres is less probable, though long-term tendencies of El Niño occurrence and pressure changes in the high latitudes of the Southern Hemisphere coincide with the character of correlations in the interannual variations.

Acknowledgments

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