Specific features of wintertime circulation in the region of Asian anticyclone

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We have performed correlation analysis of variations of the pressure and temperature fields during winter in the region of Central Asia. Comparison of the correlation fields with different time lags has allowed us to estimate the spatiotemporal scale of synoptic processes in the region of the Asian anticyclone activity. It was found that, in addition to the effect of arctic intrusions or their consequences, the processes from subtropical and tropical latitudes affect the region of Central Asia. Given the observed climatic tendency of increase in the heat content of oceans, the influence of southern circulations can lead to change of intensity of wintertime processes over Asia.

In winter period, the large-scale distribution of thermal and pressure fields in the atmosphere over the Central Asia is determined by the Asian anticyclone, being the key continental center of atmospheric activity which influences the aerosynoptic and weather conditions both on the Asian continent and far away from it (Africa, Indian and Pacific oceans, etc.). Kalmykova, Laidolf, Petrosyants, Pogosyan, Khairullin, and other authors in their work studied the spatial structure of Asian High and contribution of thermodynamic and orographic factors to its formation and evolution.

The formation of Asian anticyclone is associated with the intensification of the polar frontal zone over Europe and its shift toward the cooling surface of continent.[1] The motion of anticyclones in zonal flows, with subsequent deceleration near Central Asian mountain system, is accompanied by the dynamic growth of the atmospheric pressure in the region of Asian High, whose existence is sustained by radiative cooling of the underlying surface. The anticyclone becomes most intense (at 1046 hPa) in mid-winter when the 4 to 6 closed isobars exist and large axis is oriented meridionally.[2]

The changes of intensity and structure of the Asian anticyclone observed in recent decades can be caused by both alterations of thermal and circulation regimes. The variations of thermal regime may be due to the change in the aerosol–gas composition of the atmosphere, while the dynamic variations can be caused by changes in the general atmospheric circulation. The present work has been aimed at studying the spatial structure and scales of the dynamic processes over Central Asia. For analysis we used preliminarily processed NCAP/NCER Reanalysis data for 1948–2000.[3] The preliminary processing consisted in excluding the seasonal variations from the series analyzed, for which 16-day moving mean was used. The next step was to calculate the fields of correlation coefficients of synoptic-scale variations of near-ground and high-altitude thermal-pressure fields for two winter months (60 days in January and February) at nodes of the $2.5 \times 2.5°$ spatial grid with variations at the center of Asian High. The correlation fields were calculated with time lags from –5 to +4 days, which allowed us to track most typical dynamics of pressure systems passing across the Central Asia, starting from their origin to decay. Analogous technique was used, e.g., to study the response of circulation of the Southern Hemisphere to variations of sea surface temperature in the equatorial Pacific.[4] This same paper presents estimates of the statistical significance of the correlation coefficients. Because of specific features of the correlation analysis, the perturbations were not subjected to sign separation. This limited interpretation of the correlation fields obtained because the perturbations of the cyclone and anticyclone types develop in different ways. Nevertheless, the results obtained proved to be quite interesting.

The correlation fields were calculated for all 50 years of NCAP/NCER Reanalysis archive data. The obtained correlation fields were found to be quasi-barotropic, i.e., the developing perturbations extend through almost entire troposphere and have very large spatiotemporal scale. We could track the initial and final perturbation stages over most of the Northern Hemisphere up to the equatorial latitudes. Obviously, not all perturbations are so long-lived, that explains quite natural decrease of the correlation coefficients with the increasing time lag, from about 0.7 to 0.9 for zero time lag to 0.2–0.3 for time lag of 4 to 5 days. Therefore, to increase the accuracy of estimates of correlation coefficients, we have averaged the correlation fields over 11 years, from 1990 to 2000.

The characteristics of synoptic processes, associated with the passage of pressure systems over Central Asia, were found to be quite stable, also evident from simple comparison of correlation fields for different years; as a result, the correlation coefficients after averaging over the region, where these processes operate, have changed a little, while the level of random fluctuations significantly decreased. The decrease of the level of random fluctuations was most

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easily observed from values of the correlation coefficients in the Southern Hemisphere, not exceeding 0.1 after averaging. This level was taken as the reliability limit of the estimates of the correlation coefficients. An additional evidence of the realism of estimates was the regularity of time variations of the structure characteristics of the correlation fields for the Northern Hemisphere.

Figure 1 presents distributions of the correlation coefficients between variations of the height H_{500} at the nodes of 2.5×2.5° grid and those of near-ground pressure at the center of Asian anticyclone, averaged over 11 years, from 1990 to 2000. These data allow us to track complete cycle of the development of most long-lived pressure systems and associated processes at the center of Asian anticyclone.

From Fig. 1*a* it is seen that the appearance of perturbations at the center of Asia is preceded by the development of negative correlation at heights of the regions over Scandinavia and south of the Western Siberia, whose evolution and southeastward propagation was accompanied by the development of conjugate region of positive correlation over the north of Western Siberia. Intensification of the activity in this region and its eastward motion favored the development of perturbations in the pressure field over Mongolia. The anomalies of correlation fields of near-ground pressure were found to be analogous to those of high-altitude pressure, preceding the former in time and slightly shifted to the east.

The analysis of correlation fields of the near-ground pressure and temperature with time lag from −5 to 0 days has shown that the development of synoptic-scale perturbations in the region of Asian High was preceded by the appearance of the region of negative correlation in the temperature field in the north-west Eurasia, shifting toward Western Siberia, where in the pressure/geopotential correlation field a saddle of positive correlations was observed. Over the elevated regions of Tibetan plateau and Middle Asia, North of Africa, and Mediterranean and Caspian Seas, there was an intensification in the region of positive correlations in the temperature field. In "zero" day over Mongolia, a stable region of negative correlations in temperature field remained, consistent with the fact that the intensification of anticyclogenesis most frequently occurs over cooled surface.[1]

It is also interesting to consider the subsequent pattern of the development of pressure perturbations passing across the Central Asia (Fig. 1*b*). Part of the perturbations, propagating along the southeastern direction generates pressure systems of the opposite sign on the coast of the Pacific, then migrating to the northeast. Perturbations with the trajectories oriented more north to south reach India. Possibly, the situation is even more complicated because, in some years, one can confidentially discern the region of negative correlations in the tropics of the Pacific, migrating westward well before "zero" day. Then, this region joins the perturbation having reached the coast of the Indian Ocean. Its occurrence may point out to two possible mechanisms of the formation of perturbations over Asia, namely due to propagation of thermal-pressure perturbations from north and propagation of perturbations from south and southeast, such as of the type of tropical depressions generated by the regions of active convection in the tropics or baroclinic regions in the south of Asia. However, it should be noted that, after averaging over 11-year period, the correlation coefficients in the tropical Pacific were found to be approximately at the background level; therefore, in accordance with the above accepted criterion of the estimate reliability, this speculation cannot be accepted with a confidence.

The analysis performed leaves us with the following circulation mechanism of the development of pressure perturbations over Central and Eastern Asia. In our opinion, a significant influence on variations of the thermal-pressure fields on the studied territory is exerted by synoptic perturbations at both high and low latitudes. In northern regions, they come as intense outbreaks of cold to the low latitudes during the formation and development of the secondary waves in the rear region of main altitudinal troughs migrating eastward. The meandering motion of long waves is frequently favored by blockage of processes in Europe, as well as by the orographic influence of mountain ranges in Middle Asia and Tibetan plateau. If during wave formation, the horizontal axis of the altitudinal trough is tilted from northeast to southwest, then, as numerous studies suggest,[5] there is an intense transport of perturbations from tropical to midlatitudes. In the correlation fields H_{500} plotted (see Fig. 1*a*), the most stable region is the one with negative correlation, oriented along this direction, indicating toward strong influence of the south latitudes. A source of perturbations in the tropical latitudes may be the baroclinic zone between the radiatively cooled troposphere over Asia and troposphere over the Indian Ocean. The baroclinic instability in this zone can increase due to the release of the latent heat during the development of cumulus clouds in tropical perturbations or to advection of cold from midlatitudes, because the subtropical and polar jet streams become closer. The wavelike perturbations, arising in the baroclinic region, transport the heat to the north and favor establishing of the hydrodynamic instability at the polar front, leading to deformation of long waves in the troposphere and outbreak of cold air from polar region to the south.

Unfortunately, the correlation analysis of synoptic perturbations does not provide a more convincing evidence of the influence of the southern processes on Central Asia. An indirect confirmation of this hypothesis comes from the maps of correlation coefficients of monthly mean pressure fields on interannual timescales. In Fig. 2*a*, such maps are plotted for January. Grid point values represent correlation coefficients of the interannual variations of January-mean near-ground pressure with the variations of pressure at the center of Iceland depression.

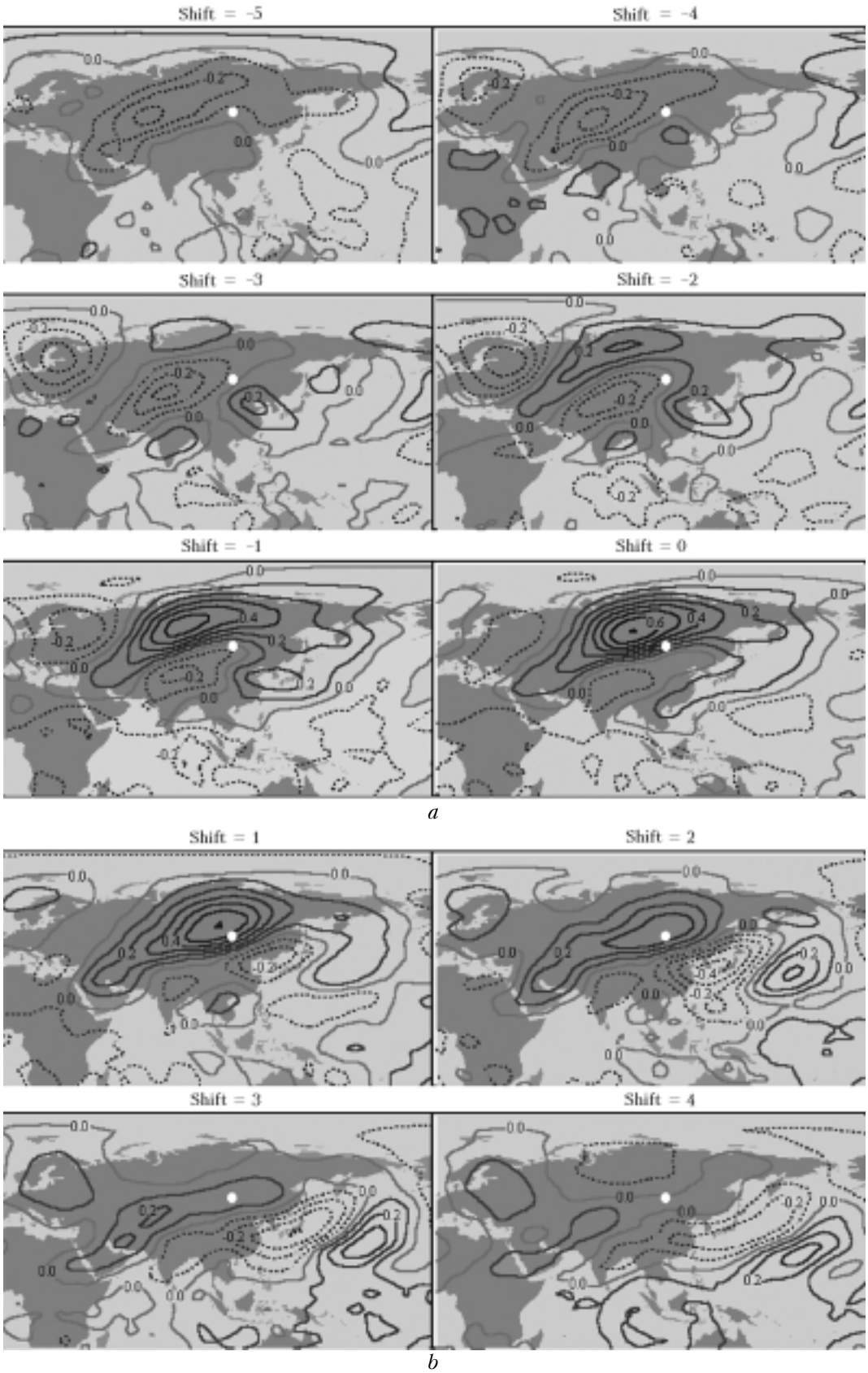
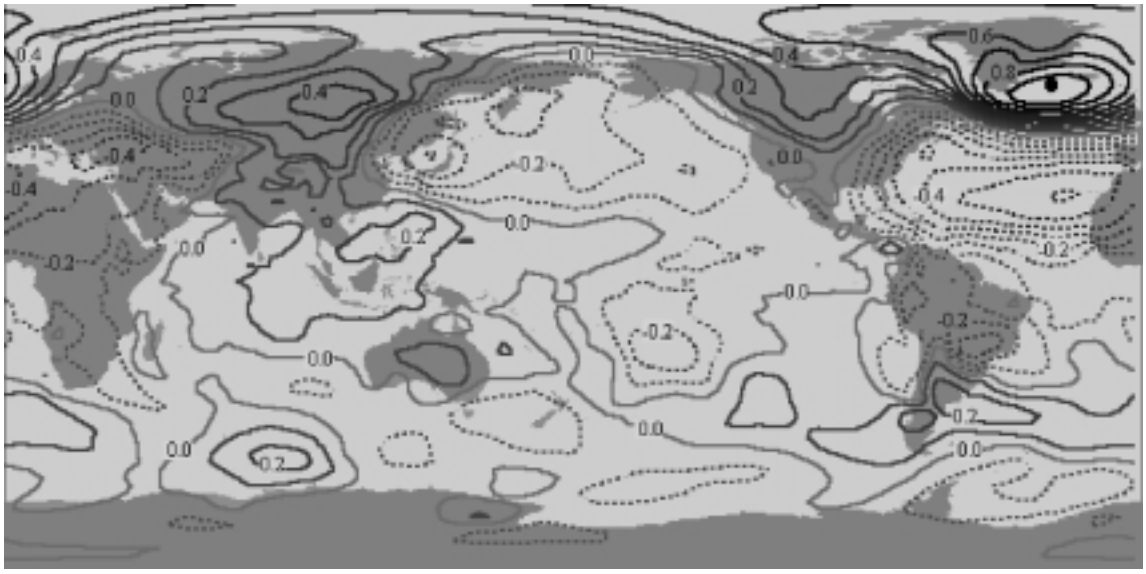
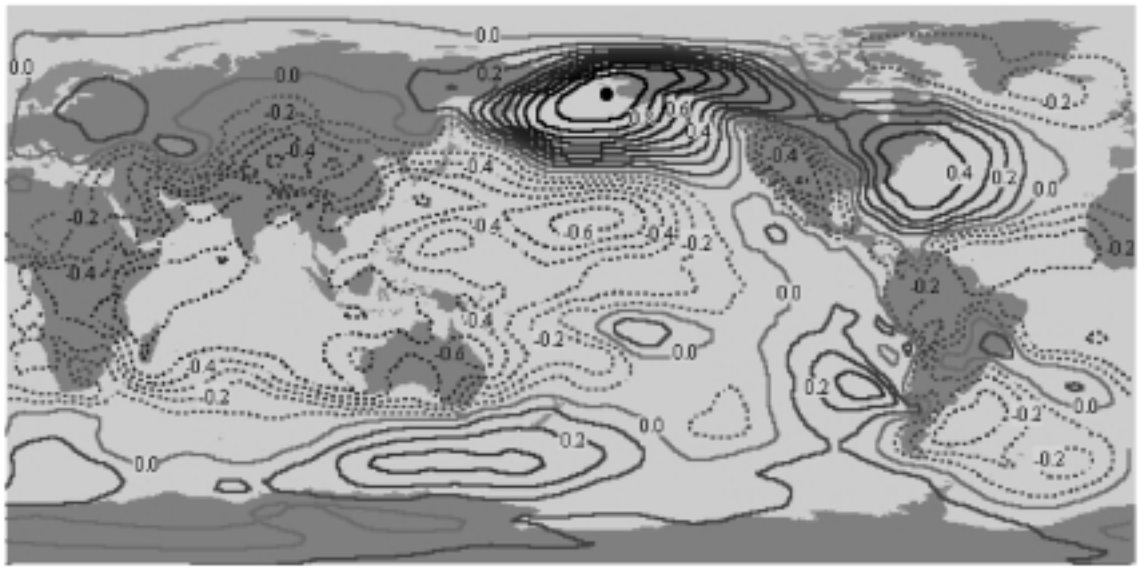


Fig. 1. Distributions of the correlation coefficients of diurnally mean H_{500} at the nodes of 2.5×2.5° grid and pressure at the center of the Asian anticyclone (105°E, 48°N, open circles). Solid (dashed) contour lines show positive (negative) correlations: the time lag is from –5 to 0 days (*a*) and from 1 to 4 days (*b*).



a



b

Fig. 2. Distribution of the correlation coefficients of interannual variations of the monthly mean pressure at the nodes of 2.5×2.5° spatial grid and at the center of the Iceland depression (*a*), and at grid points and at the center of the Aleutian depression (*b*). Solid (dashed) contour lines show positive (negative) correlations.

Plotted in Fig. 2*b* is the distribution of the correlation coefficients with respect to the center of Aleutian depression. Figure 2*a* indicates quite convincingly that one of the main sources of interannual variations in Central Asia is North Atlantic Oscillation (NAO); whereas Fig. 2*b* not only illustrates the influence of the southern processes on Central Asia, but also suggests that a relation may exist between these processes and the dynamics of the Aleutian depression.

Analysis of correlation fields of pressure and temperature in the region of Central Asia has made it possible to estimate the spatial and temporal scales of synoptic processes in the region of the Asian anticyclone activity. It was found that together, or in association, with the Arctic intrusions, the Central Asian region is influenced by the processes developing in subtropical and tropical latitudes. Given the observed tendency of increasing heat content of the oceans, the influence of southern processes may lead to change of the intensity of wintertime processes over Asia. The final phase of the dynamics of perturbations, passing across the Central Asia, is the generation of pressure systems of the opposite sign over south and southeast of Asia, then propagating, respectively, along the western and northeastern directions.

Acknowledgments

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