Circulation features of intense rains over the Far East cost of Eurasia

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In recent years anomalous weather phenomena do occur more and more often almost everywhere in the world. In the Central and Eastern Asia this tendency is accompanied by a more frequent occurrence of southern processes. Having taken the year 2002, as an example, the synoptic conditions for intense rains in the Amur Region are studied with the special attention paid to the dynamics of high-altitude baric field. It is proposed that the meridional processes intensified due to the development of a ridge over China and Mongolia during the summer Asian monsoon could cause the enhanced amount of precipitation observed in recent years.

Forecasting atmospheric precipitations, especially the intense ones, is still one of the most important and difficult problems in meteorology.[1] The difficulties of forecasting strongly increase for the regions of intense interaction of different air masses and circulation processes. Eastern Asia is just one of such regions, where air masses of arctic and polar origin come into collision with warm and wet tropic air.

We have chosen the Amur Region as an object for our study of the features of synoptic processes associated with the intense rains. In the development period of the summer tropical monsoon, the processes of cyclone and fronts formation in this region can cause intense rains and the related floods of rivers of the Amur basin. We have studied synoptic conditions for the intense rains near Blagoveshchensk in the warm period of the year 2002.

Now it is an established fact that heavy rains in the Amur basin are caused just by the intensified cyclonic activity. This occurs, on the one hand, due to intense arctic intrusions from the Kara Sea, Taimyr Peninsula, and Laptev Sea to the Central Siberia and the Transbaikalian Region and, on the other hand, due to the invasion of warm wet air masses from southern seas (Yellow Sea, East China Sea, and the southwest sector of the Pacific Ocean) to the Amur basin.[2,3] In the majority of cases, the cyclone formation was observed over the Southern Transbaikalian region and the northeastern regions of China, and this formation was favored by activation of the upper-level frontal zone over the Transbaikalia upon the development of the upper-level trough from the northwest or northeast and the upper-level ridge from the south located to the east from the trough.[3]

According to the existing criteria, rains with the precipitation amount of 30 mm and more for 24 hours are classified as disastrous weather phenomena. Since events are relatively infrequent, we have considered the synoptic periods, in which the diurnal precipitation amount was 20 mm and more. Such rains were observed on April 6–7, May 29, June 6, July 4, 7, 12, 17, and 31, and August 1 of 2002. In these periods, local features of the surface thermobaric fields, as well as NCAP/NCER Reanalysis large-scale fields at the steering flow level (AT_{700}) and the AT_{500} altitude. The large-scale surface baric fields in combination with the isobaric surfaces at the altitude of 3–5 km give a clear idea of the spatial structure of zonal and meridional motions in the atmosphere.

Analysis of the fields of correlation with the 5–6-day lag (natural synoptic period) has revealed the main regions of formation of the baric formations and the related air masses. These correlations are seen most clearly at the AT_{500} level. The centers of positive correlation of baric field perturbations most often arise in the north and northeast, which indicates the role of advection of cold air masses in the development of air-mass and frontal processes, as well as in the west and southwest, that is, in the directions usually associated with the directions of the Rossby waves inflow.

The changes in distribution of the correlation coefficients of the surface temperature field (> 0.4) are similar. It should be noted that most often the spatial structure of synoptic processes is more complicated, especially, in the transition seasons, and can hardly be rigorously interpreted.

Analysis of regional synoptic maps in the periods of heavy rains in Blagoveshchensk has allowed us to separate out three types of the atmospheric processes.

Figure 1 shows the AT_{500} distributions characteristic of these types. The common feature of all types is the development of the upper-level trough from the northwest or north to the southeast to the Transbaikalian and Korean regions and the related ridge developing from the Tibet or Eastern China regions to the Amur Region. Such a structure of the baric field leads to either the intense advection of cold or to invasion of warm and moist air masses to the Amur Region. The inflow of cold favors the intensification of cyclone formation and the development of frontal precipitation, while the invasion of warm and moist air masses favors intensification of air-mass precipitation.

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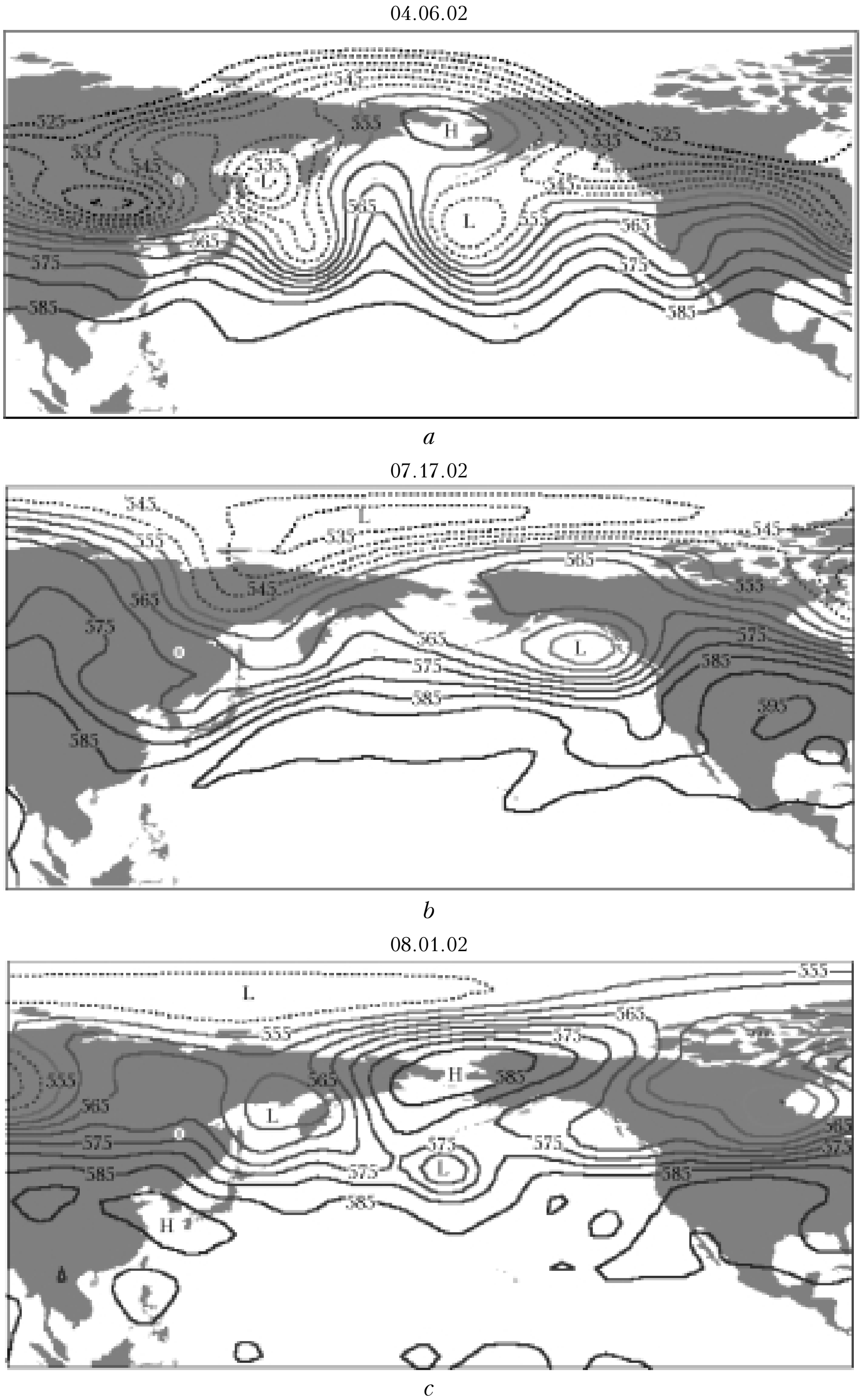

Fig. 1. Altitude distributions AT_{500} (dkm) characteristic of the three types of synoptic processes. Solid lines show isohypses above the level of 555 dkm.

Frontal precipitations occurring most often in the warm period (April 6–7, May 29, and July 12) form the *first group* of the processes. On these days, in the region of Taimyr Peninsula, a deep upper-level trough oriented from the northwest to the southeast toward the Transbaikalian and Korean regions was observed at the altitude of 3–5 km. In its rear part, northwestern flows caused intrusion of cold arctic air masses favoring the development of cyclone formation over the southern Transbaikalian region, eastern Mongolia, or

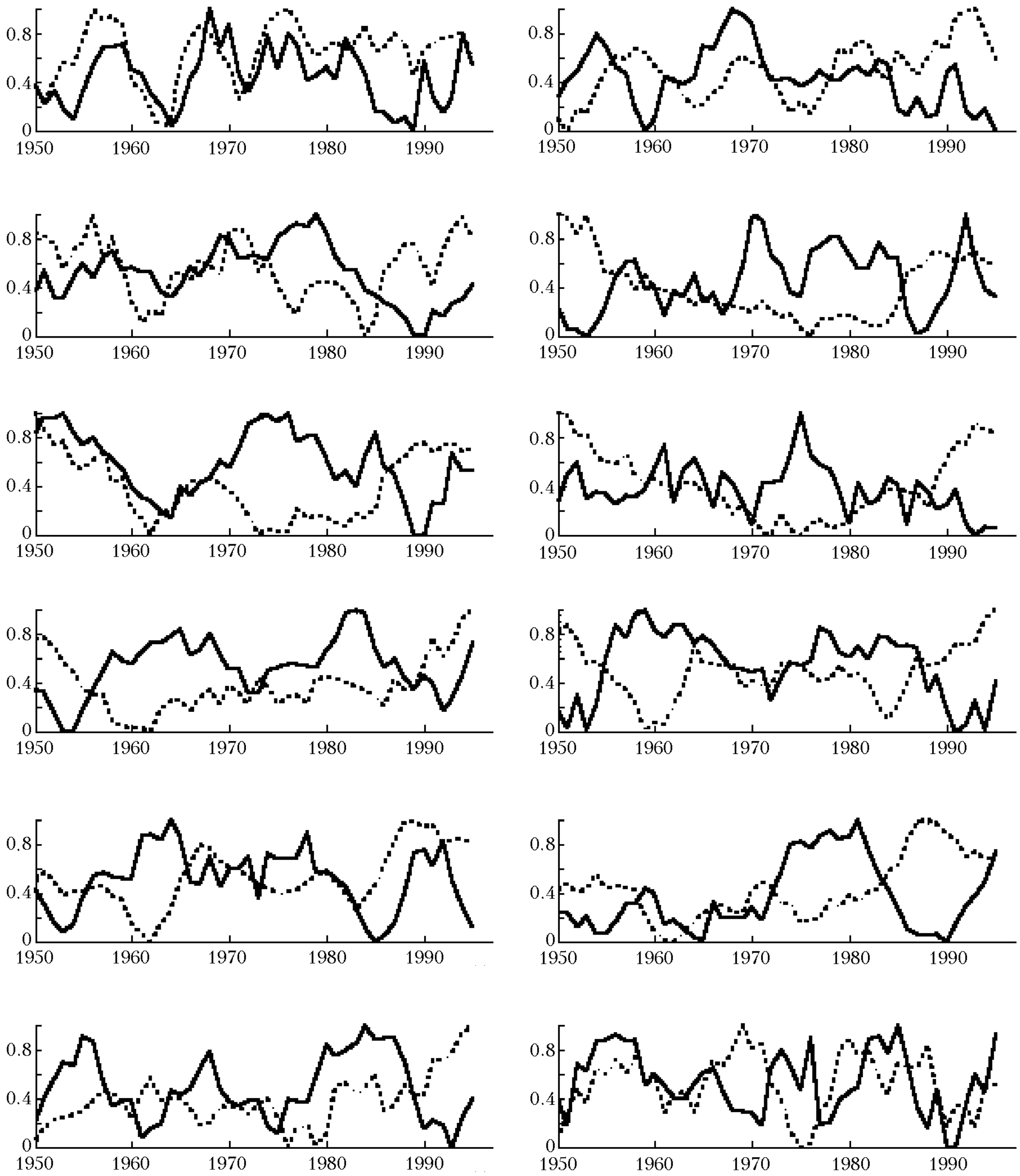

Fig. 2. Time variation of 5-year-smoothed surface pressure, in rel. units, (solid line) and geopotential at the altitude of 500 hPa (dashed line) over Taimyr.

northeastern regions of China. The temperature contrasts in the upper-level frontal zone achieved 8–12°C per 1000 km. The active cyclone formation was also favored by the development of the upper-level ridge oriented to the Amur Region from Eastern China, Korea, or Japan and outflow of warm and moist air along its southwestern periphery.

Heavy rains in the cases considered were favored by joining of the Okhotskii cyclone with the particular cyclones moving from Yakutiya or Mongolia. The process of cyclone joining is clearly seen in Fig. 1*a*. The particular cyclones were either at the stage of young cyclone or at the stage of maximum development. The cyclone joining resulted in the formation of a deeper depression, which became stationary at the time of maximum precipitation in Blagoveshchensk.

The *second group* incorporates air-mass processes in the unstably stratified air mass that occurred on June 6 and July 4 and 17 of 2002. The thermobaric field at the time of precipitation was characterized by the development of the ridge from the Eastern China to the Amur Region and the related upper-level trough

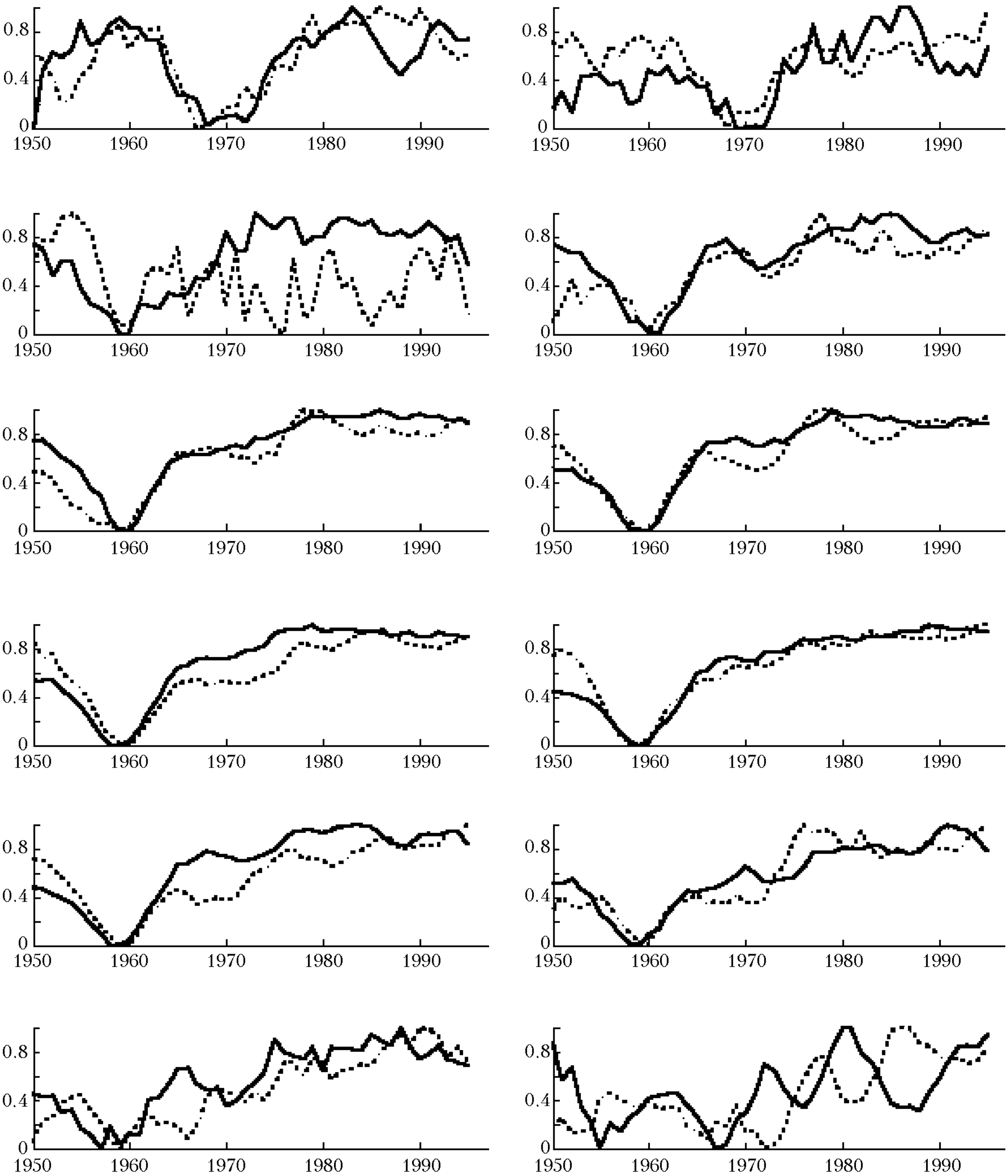

Fig. 3. Time variation of 5-year-smoothed surface pressure, in rel. units, (solid line) and geopotential at the altitude of 500 hPa (dashed line) over Tibet.

oriented from the East Siberian Sea to the lower reach of Yenisei (Fig. 1*b*). The conditions near the surface in the low-gradient baric field at active intrusion of cold from the north were favorable for the formation of dense cumulus clouds and showers often accompanied by thunderstorms. In these cases, the more intense was the advection of cold, the heavier were the rains. Thus, on July 17, which was characterized by the maximum diurnal amount of precipitation (41 mm) for the considered period, the center of the pressure increase, to the north from Blagoveshchensk, was also maximum and equal to +2.8 hPa.

The *third group* includes the processes occurring on July 31 and August 1 that are characterized by a deep southern intrusion of the troughs from the Taimyr Peninsula and the East Siberian Sea and by the development of the ridge to the north, whose axis was shifted toward Blagoveshchensk (Fig. 1*c*). At the close interaction of air masses of the polar and marine origin in the Southern Transbaikalian region and Eastern Mongolia, old cyclones coming to the central and downstream Amur River are actively regenerated.

At frontal showers near Blagoveshchensk the isohypse pattern at the steering flow altitude became

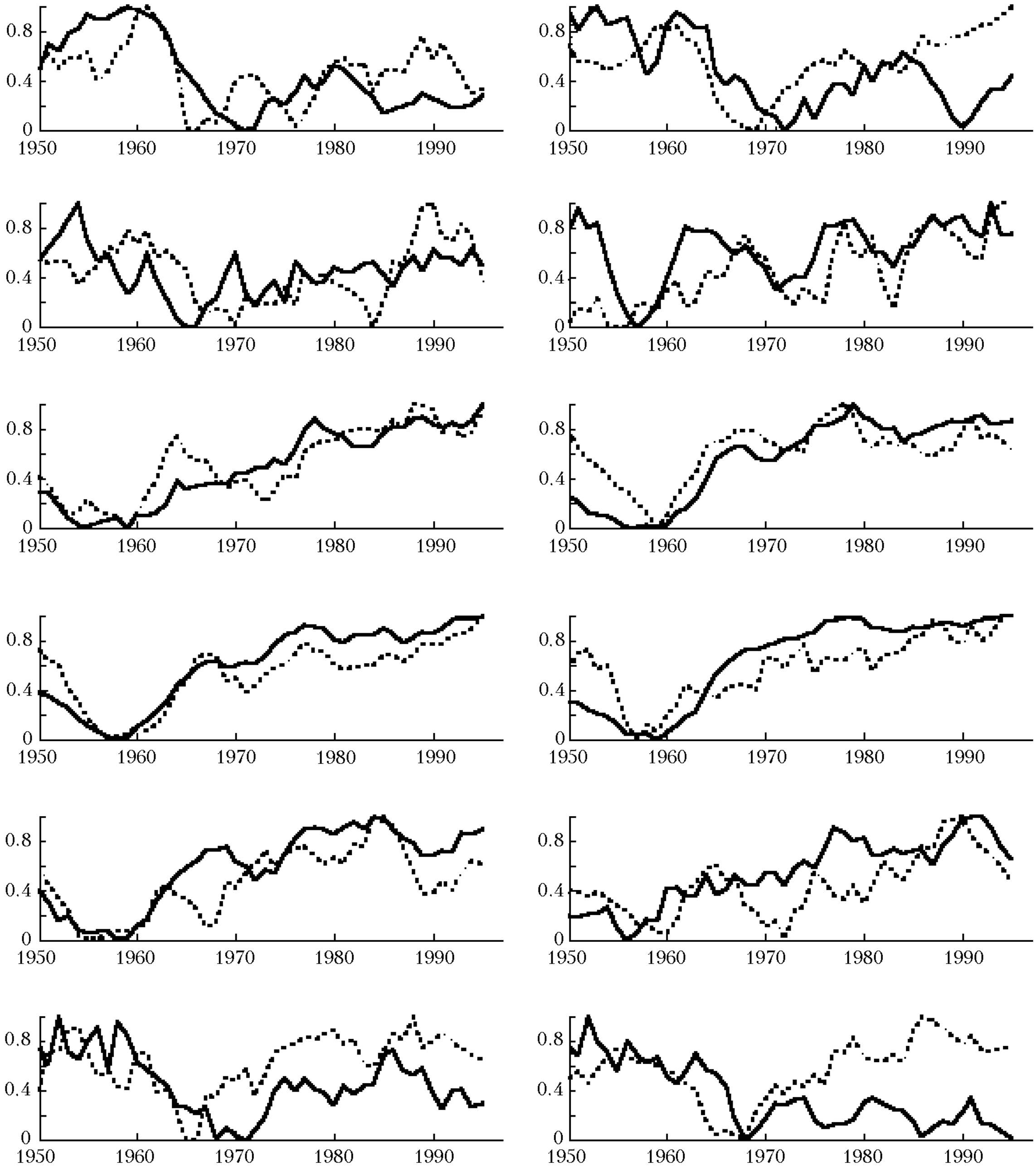

Fig. 4. Time variation of 5-year-smoothed surface pressure, in rel. units, (solid line) and geopotential at the altitude of 500 hPa (dashed line) over Ulan-Bator.

far denser, and at air-mass showers the deformation of the upper-level field occurred along with the formation of northwestern and northern flows 2–3 days before the precipitation, which confirms the leading role of dynamic factors in the formation of precipitation during warm periods.

In our opinion, the AT_{500} level is most useful for precipitation forecast in the Amur Region, because the configuration of the upper-level baric fields and the directions of air mass transport are clearly seen at this level. In particular, at the level of 5 km we can clearly see the deformation of the high-altitude ridge over the Japan and Yellow Seas due to deepening of the upper-level troughs from the northwest or northeast. The contribution of the advective factors of cyclone formation was also pronounced in the case, when, at the development of the upper-level ridge from China, Blagoveshchensk turned out to be at the interface between the cold trough from the north and the warm ridge from the south. At the peak of their development (July 17), the amount of precipitation was the highest too.

The amount of precipitation near Blagoveshchensk has increasing in recent years. Taking into account that the synoptic processes are closely related to the configuration of the large-scale thermobaric fields, we can assume that this tendency is caused by the long-term changes in the intensity of upper-level troughs and ridges in the region under study. The upper-level ridges can be considered as indices of the development of thermal ridges, while the upper-level troughs can be considered as indices of the development of the cold troughs not only near the surface, but also at high altitudes.

As indirect evidences of these formations, we used the values of the surface pressure and the altitude of the AT_{500} surface. This was done according to the 5-point-smoothed NCAP/NCER Reanalysis data for the regions where troughs of the circumpolar vortex near Taimyr and in the region of the East Siberian Sea are developed, as well as the upper-level ridge over Northern China. Figures 2–4 show the plots of variation of the pressure reduced to the sea level and the AT_{500} altitude in these regions.

The variations of the baric field in the regions of trough and ridge formation turned out to be different. For the troughs, the prevailing characteristics were 10–20-year variations typical of oceanic centers of action of the atmosphere in the Northern Hemisphere (Fig. 2).

The trend towards the increase of the surface and upper-level baric fields in the region of the formation of the upper-level ridge oriented from China turned out to be more regular in time. The plots drawn for the northern part of Tibet (Fig. 3), where this ridge is formed, Ulan-Bator (Fig. 4), and the northeastern part of China, through which the axis of the ridge passes as it moves to the east, turned out to be very similar. In all the plots starting from the 1960s, for all months (except for March) the increase in the AT_{500} geopotential altitudes is observed. Since March and until October, also starting from the early 1960s, the surface pressure increases, and this occurs against the background of the decreasing surface temperatures in warm periods and the increasing surface temperatures during cold periods. Farther to the north, the tendency toward the increase of the pressure and the AT_{500} geopotential is noticeable only in warm periods (April–October), but the time of beginning of the increase remains the same (the 1960s).

Thus, starting from the 1960s, a distinctly pronounced tendency exists in the development of the upper-level ridge oriented from the south, while no tendency has been revealed in the dynamics of the related upper-level troughs from the north. It should be noted that in summer periods, as compared to the winter ones, the circumpolar vortex is weak and long waves in the troposphere are weakly pronounced. Therefore, the development of the upper-level ridge from the south indicates the growing role of the southern processes, in particular, intensification of the orographic anticyclone formation in Tibet region.

Tropical monsoons of Southeastern Asia likely play a certain role in activation of the southern processes, whose development is accompanied by the increase in the flux of latent heat released upon condensation of water vapor in the process of forced lifting to the southern slope of the Himalayas. This can favor the increase of the heat flux to the north and development of the upper-level ridge or upper-level anticyclone formation, as well as the growth of the surface temperature.

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