Climate change in the Asian part of Russia in the second half of the 20th century: comparison between data of observations and reanalysis

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The temperature, pressure and precipitation fields, and the corresponding linear trends for Asian part of Russia for a climatically significant period from 1975 until 2005 are constructed based on data of observations and reanalysis. The results obtained are compared, and reanalysis capabilities of reconstructing the spatiotemporal changes of climatic parameters are estimated.

IPCC Third Assessment Report[1] notes that it is necessary to study climate changes in different regions to understand the current global changes.

The Asian part of Russia is a vast region of our planet, with the variety of physical and geographic conditions. This region contributes significantly to the climate change in the Northern Hemisphere. According to Refs. 1 and 2, the climate changes are understood here as statistically significant variations of the mean values of climate parameters or their variability (variance, occurrence of extreme events, etc.), stable on the decade-long scales.

Numerous papers (for example, Refs. 3–5) are devoted to the climate changes in the Asian part of Russia. Reference 3 presents, in particular, the calculated coefficients of the linear trends of temperature and precipitation for individual stations over the entire territory of Russia for the period from 1951 until 2000. It is shown that the general tendency of the change in the annual mean air temperature at the Russian territory is characterized by the positive trend of 0.47°C per 10 years in winter and 0.29°C per 10 years in summer, the spatial distribution of the trends is nonuniform, and the regions with maximum warming rates lie in the Central and Eastern Siberia.

In Ref. 4, the calculated distributions over the Asian part of Russia for the same period are characterized by the positive trends of the annual mean temperature varying from 0.2°C per 10 years along the coast of the Arctic Ocean to 0.5°C per 10 years in some regions of Siberia and Far East. Quite close estimates have also been obtained in Ref. 5.

The atmospheric precipitation, according to Refs. 3 and 5, in the second half of the 20th century had the tendency toward a decrease in the annual and seasonal amounts in Russia as a whole and for the eastern regions of Russia, and this decrease was most pronounced at the north-east of the Asian part of Russia.

According the Ref. 4, the pressure of the near-surface air has a tendency toward decreasing at a rate of (–0.1–0.5) hPa per 10 years, and the regions with maximum negative trends are situated at the mouth of the Ob' River and the upper Yenisei and Lena.

In the papers mentioned above and other similar papers, the difficulties in the comparison of the results obtained are connected with a certain arbitrariness in the choice of an analyzed time interval for the territory considered, as well as with the circumstance that it is a problem to determine climate changes at the outer boundaries of the territory. For example, for Asian part of Russia the estimates of the surface air temperature trends along the coast of the Arctic Ocean are based on the data of a relatively small number of stations, and to obtain the correct pattern of trends, one needs for the information about the Arctic sector, which is often unavailable.

The aim of this paper was to find the fields of the mean values and linear trends of climatic parameters on the Asian part of Russia for the climatically significant interval from 1975 until 2005 using data of observation stations and the reanalysis data.[6] The accuracy of reconstruction of the spatiotemporal changes in the temperature, pressure, and precipitation from the reanalysis data is estimated.

Data and the processing technique used

For analysis of climatic changes we used:

– data of daily observations of the surface air temperature, pressure, and precipitation at 454 stations situated to the east from Ural and in the northern regions of Kazakhstan, Mongolia, and China (NOAA Data Distribution Center, ftp://ftp.cdc.noaa.gov);

– NCEP/NCAR reanalysis version 1, daily data for 1948–2005 (ftp://ftp.cdc.noaa.gov), which include the mean values of climatic parameters corresponding to 2.5×2.5° latitude by longitude grid cells.

The data of observations and reanalysis were compared by the following technique. For every observation station, within the time interval chosen,

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the monthly mean and annual mean values and variances of the parameter under study were determined with the use of the least-squares method, the linear trend was determined, and its statistical significance was estimated. The obtained mean values and trends were used to calculate the corresponding fields by the Kriging objective interpolation method.[7] Then the field was integrated within every reanalysis cell, the result obtained was divided by the cell area, and the mean value found in this way was compared with the corresponding reanalysis value. In some cases, when the geographic coordinates of the reanalysis cell center nearly coincided with the coordinates of the observation station, the observed data were directly compared with the results obtained by reanalysis.

Results and discussion

Figure 1*a* shows the distribution of the annual mean temperature over the Asian part of Russia based on data of 454 stations for the period since 1975 until 2005. Figure 1*b* shows the same distribution, but obtained from reanalysis of the NCEP/NCAR data.

One can see that reanalysis gives the qualitatively correct distribution of the annual mean temperature over the territory under consideration. The mean temperature discrepancy, by absolute value, was determined as

$$\delta = \frac{1}{N}\sum_{i=1}^{N}\left|T_i^{\mathrm{o}} - T_i^{\mathrm{R}}\right|,$$

where T_i^{o} is the temperature determined from the observations, T_i^{R} is the temperature determined from reanalysis of data; N is the number of cells used in reanalysis. The value of δ turned out to be 1.25°C, which is quite a satisfactory result, because the dynamic climate models reconstruct the near-surface air temperature with nearly the same error.

A somewhat different situation is observed in the comparison of the corresponding linear trends shown in Fig. 1*c* (observation stations) and Fig. 1*d* (reanalysis).

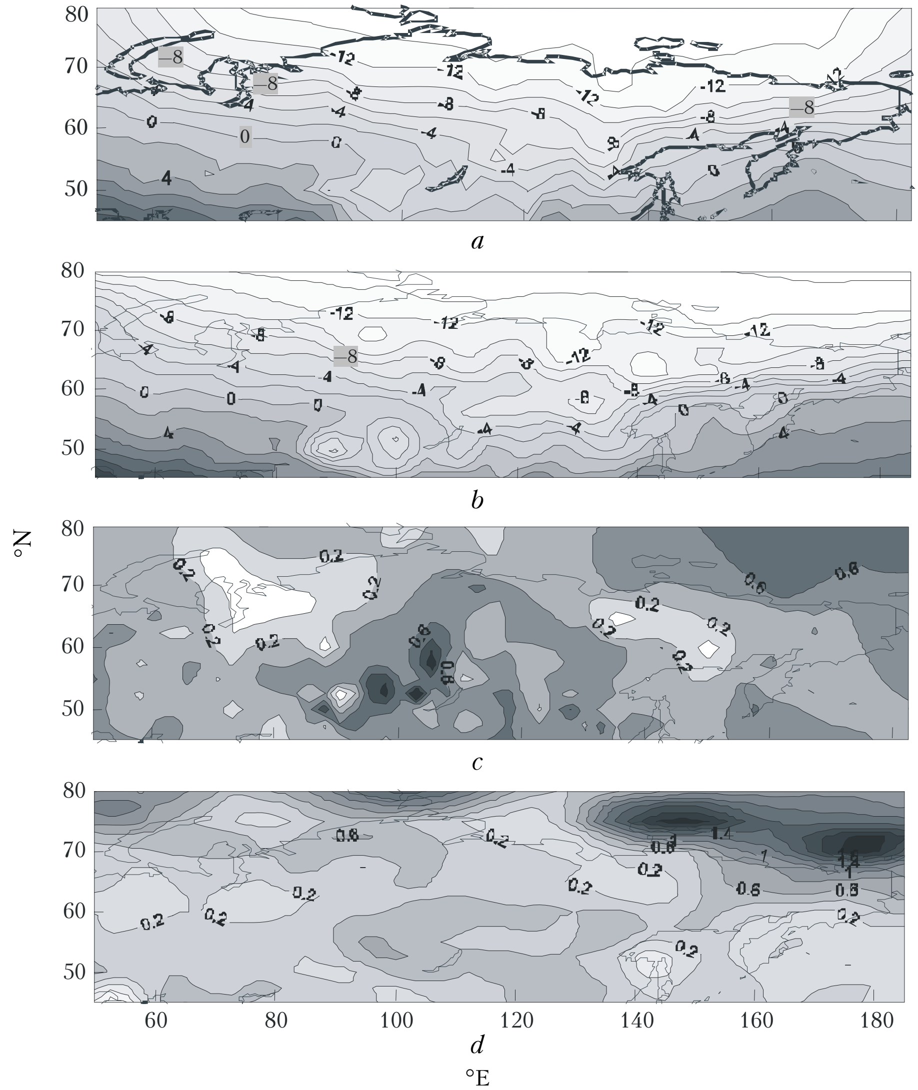

Fig. 1. Fields of the annual mean temperature, in °C, for the period since 1975 until 2005 based on observations (*a*) and reanalysis (*b*), as well as linear trends, in °C per 10 years, from observations (*c*) and reanalysis (*d*).

First of all, significant discrepancies are observed in the region of high (70–80°N) latitudes, for which reanalysis gives higher values of trend than those resulting from the observations. Certainly, the effect of the boundaries, mentioned above, takes place in this region as well, and the comparison of the results for this region makes no sense without the revision of the observation database.

In the region of 50–70°N, reanalysis reconstructs the regions of faster warming in Central and Eastern Siberia with somewhat lower, as compared to the observations, coefficients of linear trends. The causes for the discrepancies in the temperature fields and linear trends obtained from the observations and reanalysis are connected with the quality of the data obtained by reanalysis. The most typical discrepancies, that manifest themselves in the comparison of the data, are demonstrated in Fig. 2, along with the series of monthly mean values of the January temperature for years from 1950 to 2005 for the observation stations Karaganda, Bratsk, and Tarko-Sale, situated just near the nodes of the reanalysis grid.

For Karaganda, the highest discrepancies in the series of the mean January temperature are observed in 1950–1965. The positive trends of the mean January temperature nearly coincide.

For Bratsk, the discrepancies in the temperature series in the period from 1950 to 1965 are quite significant, and just they lead to the opposite trends: positive for the station and negative for the reanalysis node.

Finally, for the station Tarko-Sale, reanalysis overstates the mean January temperature nearly everywhere along the time axis, so that the slight trends although have the same sign, but are shifted with respect to each other.

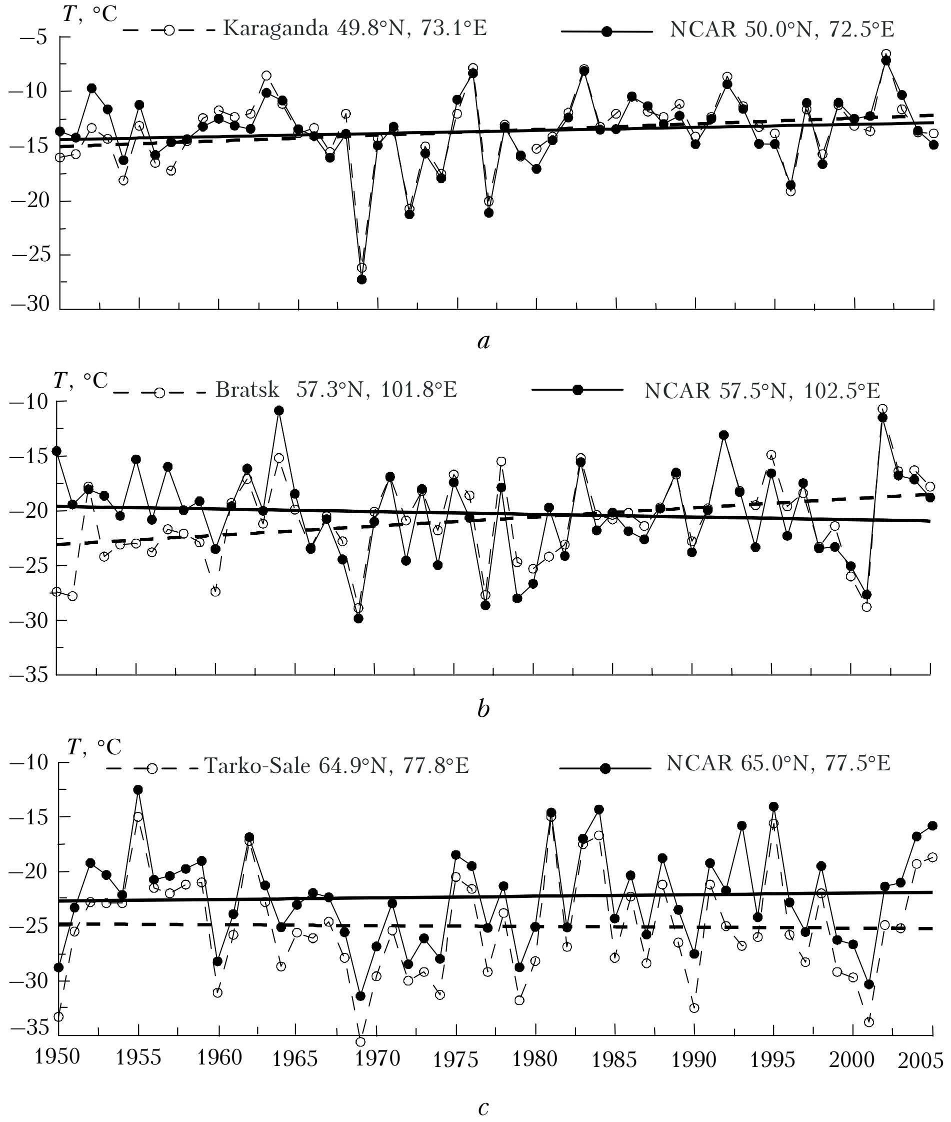

Fig. 2. Comparison of the observations and NCEP/NCAR data reanalysis for the meteorological stations Karaganda (*a*), Bratsk (*b*), Tarko-Sale (*c*). Mean January temperature for years from 1950 to 2005.

It follows from the previously mentioned that although reanalysis gives quite correct warming pattern, the quantitative pattern, especially as applied to territories poorly covered by observations, can differ widely from the actual one.

The winter Siberian High affects most significantly the formation of the near-surface pressure field over the Asian part of Russia. The north-west and south-east of this territory are influenced by the Icelandic and Aleutian Lows.

Figure 3*a* shows the field of the annual mean pressure, averaged over the period from 1975 to 2005. It is characterized by the low-pressure area centered above the Kara Sea. This formation is not deep; the pressure in its center is 1008 hPa.

It follows from the January pressure maps, available in climatic atlases, that the trough of the Icelandic Low covers the regions of the Barents Sea and, partly, the Kara Sea.

However, the comparison of the annual behavior of the pressure in this formation and in the Icelandic Low[4] gives grounds to consider this region as a central cyclone, whose existence was noticed by S.P. Khromov in Ref. 8. Another low-pressure (1008 hPa) area, lying to the east of Sakhalin, is a trough of the Aleutian Low.

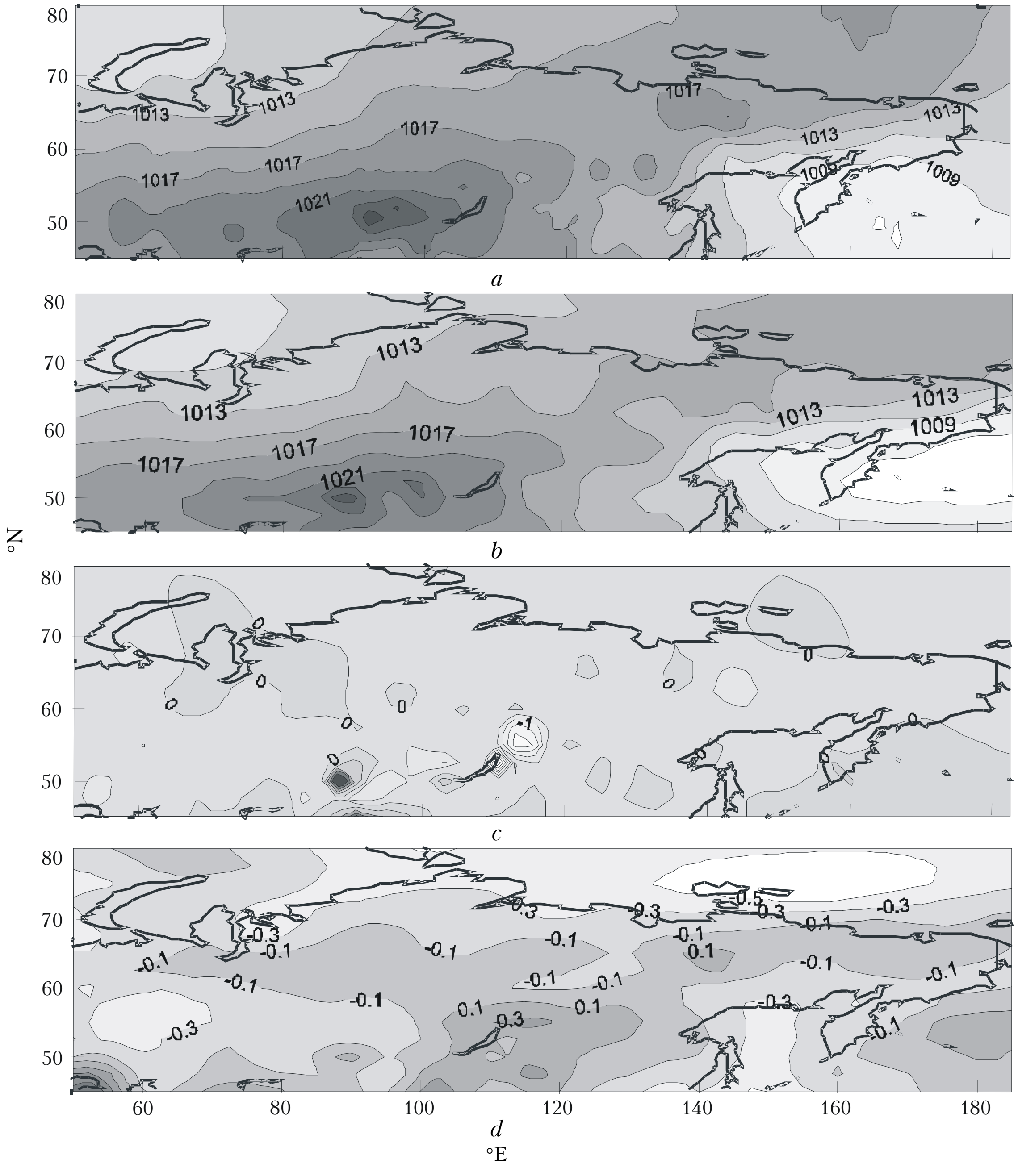

Fig. 3. Fields of the annual mean pressure, in hPa, for the period from 1975 to 2005 obtained from the observations (*a*) and from reanalysis (*b*) and the linear trends, in hPa per 10 years, obtained from the observations (*c*) and from the reanalysis (*d*).

In the synoptic meteorology, the 1015 hPa isobar is commonly considered as a boundary between the cyclonic and anticyclonic pressure fields.

It is seen from Fig. 3*a* that the processes of anticyclogenesis prevail over the major part of the Asian part of Russia. The Siberian High with the pressure of 1025 hPa in its center serves the main regulator. Its center lies over the Tuva Hollow, and a branch is extended to the north-east toward Chukchi and the East-Siberian Sea. The independent nucleus of the Siberian High lies to the east of the Chersky Range.

The pressure field obtained for the same period from reanalysis is shown in Fig. 3*b*. Despite of quite good qualitative agreement between the fields in Figs. 3*a* and *b*, there are some discrepancies. Reanalysis understates the pressure in the northwestern and southeastern cyclonic areas (1004 and 997 hPa) and significantly (1035 hPa) overstates the pressure in the region of the Siberian High.

The distribution of the pressure trends obtained from the observations is shown in Fig. 3*c*, while that obtained from the reanalysis is shown in Fig. 3*d*.

The comparison of these figures demonstrates quite significant discrepancies. According to observations, the annual mean surface pressure over the major part of the territory under study decreases with the rate from 0.2 to 0.5 hPa per 10 years.

The areas of the weak (0.1–0.5 hPa per 10 years) positive trend of the pressure lie in the Lower Ob', in the region of the New Siberian Islands and to the south-east in the zone of action of the Aleutian Low. This circumstance can be indicative of the tendency of filling the Aleutian Low in 1975–2005.

In the zone of action of the Siberian High, the observation stations are situated in the mountainous area. These stations are characterized by both high positive (Khamar-Daban, +6 hPa per 10 years) and negative (Zamokta, –7 hPa per 10 years) pressure trends, so that they give no grounds to speak about the intensification or weakening of the Siberian High, although the tendency toward intensification is observed in the winter months.[9]

The reanalysis gives a qualitatively different distribution of the pressure trends (Fig. 3*d*). The first difference consists in the very high values (up to 20 hPa per 10 years) of the positive trends in the region of the Aleutian Low. Further, the trends of the decreasing pressure in the northwestern part of Asian part of Russia are also high (up to –10 hPa/10 years) as compared to the observations.

Thus, reanalysis shows the more pronounced dynamics of the pressure change over the territory studied than that following from Fig. 3*c* and other published data.[10]

The distribution of the precipitation amount over the Asian part of Russia was calculated based on data of 454 observation stations for years from 1975 to 2005, for a year as a whole and for the warm and cold periods separately.

The results calculated for the warm period from the observations are shown in Fig. 4*a*, while those obtained from reanalysis are depicted in Fig. 4*b*.

The fields are in a satisfactory agreement in both the precipitation distribution and in the precipitation amount. The smoother Reanalysis field is a natural consequence of the method, which is used in it to set the initial data in the cells, covering uniformly the Asian part of Russia.

The zone of the maximum precipitation amount lies in the 50–65°N latitude belt, but the precipitation distribution within this zone is not uniform. In Western and Central Siberia, the precipitations are mostly formed due to the Atlantic moisture transport, weakened by the Urals. Here the precipitation amount in the southern zone is 600–700 mm for the warm period.

In the Central Amur and Kamchatka, the precipitations are formed under the effect of the Pacific Ocean, and the precipitation amount in the warm period achieved 700–900 mm.

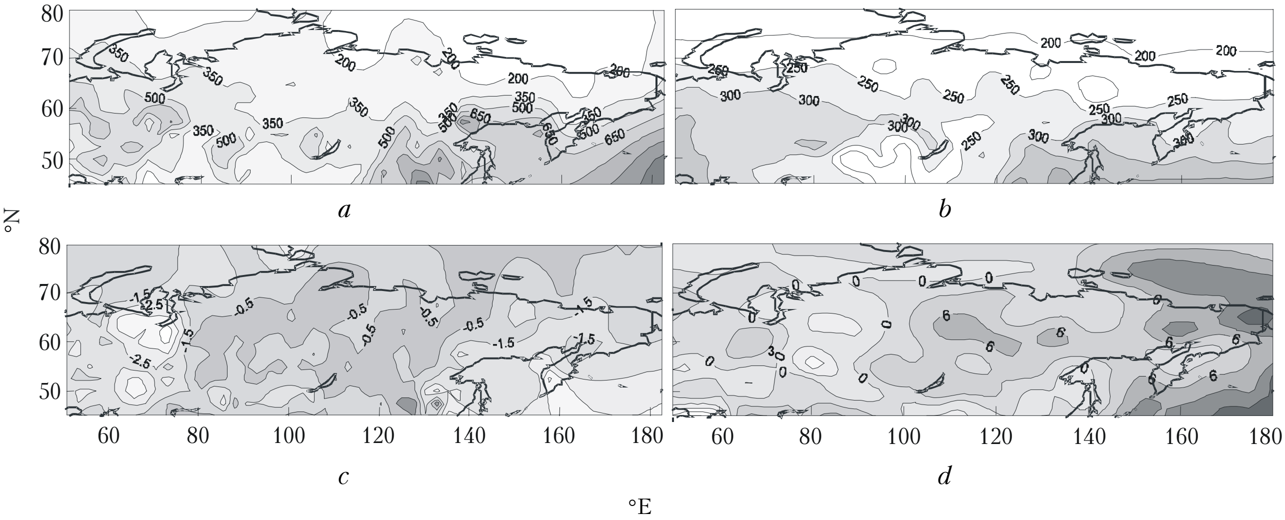

Fig. 4. Distribution of the average precipitation amount in the warm period from 1975 to 2005, in mm, from the observations (*a*) and from the reanalysis (*b*) and the linear trends, in mm per 10 years, from the observations (*c*) and from the reanalysis (*d*).

In the northern part of the Asian part of Russia, the precipitation amount in the warm period decreases down to 200–300 mm, which is connected with the convection suppression by the cold Arctic seas. In the cold period, the regions of the maximum precipitation amount lie in the south-west (300–600 mm) and south-east (400–800 mm) zones of the Asian part of Russia.

Figure 4 shows the trends of the precipitation amount in the warm period calculated based on the observations (Fig. 4*c*) and by reanalysis (Fig. 4*d*).

It follows from Fig. 4*c* that for the 30-year period under consideration the trends of precipitation in the warm period are negative (2–5 mm per 10 years) for the entire Asian part of Russia.

Nearly the same situation takes place for the cold period as well, and the highest trend values are observed in the regions with the maximum precipitation amount.

As to the precipitation dynamics obtained from reanalysis (Fig. 4*d*), it leads to the conclusion opposite to that following from the observations: the precipitation amount increases over the entire Asian part of Russia with the positive trend of 2–5 mm per 10 years.

Conclusions

The permanently updated reanalysis databases contain the extensive information about the climate parameters at different levels in the troposphere and lower stratosphere. This information allows the temperature, pressure, humidity, wind, and other fields to be reconstructed with the high time resolution both on the global and regional scales.

The restrictions are the low (2.5×2.5°) spatial resolution and the relatively short (starting only from 1948) length of the time series.

Such information available provokes the natural wish to use reanalysis in solving various problems, associated with the description of the global or regional climate.

However, the results of this study show that the problem on verification of the results obtained by reanalysis calls for special care.

The examples considered above show that the linear trends of climate parameters calculated by reanalysis reconstruct the data of observations with the different degree of confidence. At the same time, the example with precipitation demonstrates the possibility of obtaining, from reanalysis, the results, which are wrong in principle.

The linear trends give the quantitative characteristics, describing the largest time scale of variability of the studied series. Therefore, there are some grounds for hope that reanalysis will describe smaller-scale changes, such as the quasibiennial and quasidecade variability, with higher quality.

This statement is based on the comparison of the wavelet spectra of the temperature and pressure observation series for several stations with the corresponding wavelet spectra obtained based on data of reanalysis. The high coherence and the absence of the phase shift are observed for oscillations with the scales shorter than, roughly, 15 years whereas the larger scales are reconstructed unsatisfactorily.

Nevertheless, in the absence of other data, the use of reanalysis is a necessary and quite justified first approximation.

It should also be noted that the quality of data obtained by reanalysis has significantly improved since early 1970s, when the arrays of the initial data began to be complemented with the information acquitted from space-borne platforms.

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