Long-term variations of the atmospheric thermobaric field as deduced from NCAR/NCEP Reanalysis data

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ABSTRACT

Using the data from NCAR/NCEP Reanalysis we investigate long-term variations of thermobaric fields for the second half of the 20-th century. Middle and high latitudes are characterized by 10-20-year variations of meteorological characteristics. A most interesting feature of the global variations is the increase (starting in the 1960s) in pressure and surface air temperature in the tropics and subtropics of the northern and southern hemispheres (predominantly in the eastern hemisphere). In the circum-Antarctic depression the decrease in pressure is as significant. Conceivably the other atmospheric circulation variations might all be accounted for by these changes as well as by a gradual enhancement of the influence of the southern processes. The long-term variations in the tropics seem to be caused by the increased recurrence of El Nino events. The physical transport mechanism for disturbances to the region of Central Asia might be represented by the propagation of mixed Rossby-gravity waves; however, results of correlation analysis suggest much higher propagation velocities of disturbances.

Keywords: general atmospheric circulation, climate, thermobaric field.

1. INTRODUCTION

It is well known, that climate variations may be forced in a number of ways. It produces very complicated spatial structure of the long-term atmospheric variations. A given problem is attacked by model calculations, but the results are often uncertain. It might be well for solving this problem to find the main spatial components of observational variability and their interconnections at the different regions. In this paper we examine long-term variations of thermobaric fields differently at the middle latitudes and in the tropics and subtropics of the northern and southern hemispheres.

2. ANALYSIS OF EXPERIMENTAL MATERIALS

Long-term variations of meteorological fields differ quite dramatically for different latitude zones. Fig. 1 presents the smoothed (for 5 years) AT_{500} height variations for January and July along the meridian of 110° E every 10° of latitude. The tropics are dominated by linear trends, whereas 10-20-year variations predominate in middle and high latitudes. In the northern hemisphere long-term variations of climatic characteristics are particularly clearly pronounced in fluctuations of oceanic centers of atmospheric activity. Fig. 2 presents the maps of smoothed (for 5-year intervals) regions of decreased pressure in the northern hemisphere. Contours are drawn at intervals of 2.5 gPm.

The first ten years clearly show an enhancement of the Aleutian Low and a displacement of its center in the eastward direction. The state of the Aleutian Low recovers within the next ten years. After that, the depression again becomes intensified and remains so till the end of the time span under consideration. The Islandic Low shows a less regular behavior during that period, although it is mostly opposite to the variations of the Aleutian Low. It was suggested in [1,2] that the long-term variations in middle latitudes could be caused by the westward drift of the axis of polar intrusions that shows up as a regular change of the types of circulation. The triggering mechanism for the running wave may well involve the atmosphere-ocean interaction in middle latitudes of the Pacific and Atlantic oceans [3].

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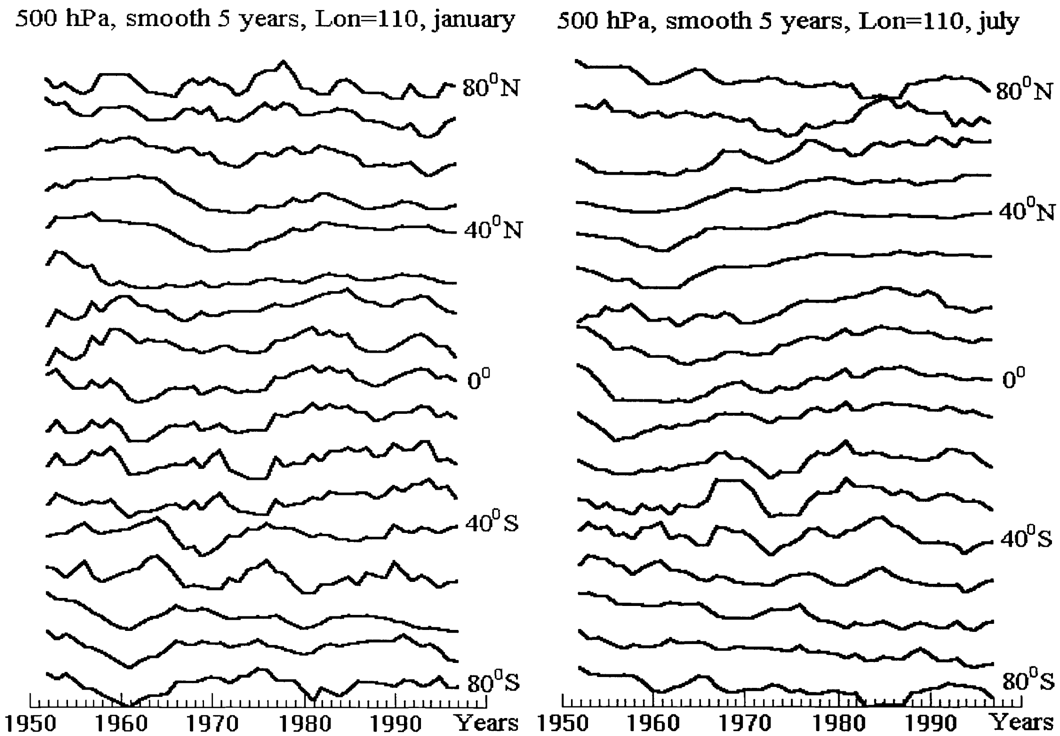


Figure 1: Plots of the smoothed (over 5 years) variations of the height AT_{500} for January and July along the meridian of 110° E at intervals of 10° of latitude.

The spatial structure of regions with the predominance of linear trends characteristic for the tropics and subtropics is presented in Figs. 3, showing the distribution of correlation coefficients of monthly mean sea-level pressure (a) and surface air temperature (b) with the linear function. In winter, regions of increasing pressure occupy the northern and central parts of Africa, Arabian Peninsula and Hindustan Peninsula, and a region of New Guinea. In a warm period, the region of linear trends in pressure expands to encompass the entire globe with a common band. The band of increasing pressure has its origin in the south of Africa, crosses the tropical and equatorial zones of the Indian Ocean and the Pacific, Central America, the tropics of the Atlantic Ocean, the northern part of Africa, the southern part of Europe, the Middle East, and Central and East Asia. Perhaps, it is the northward spreading of the influence zone of the tropical circulation and the development of southern processes in the warm and transitional seasons that can account for the many recent anomalies of the atmospheric circulation in the central-Asian region.

Antarctica and the adjacent part of the circum-Antarctic depression constitute a stable region of decreasing pressure. In the northern hemisphere pressure during the winter months decreases in the northern and north-eastern parts of Asia, whereas in March and August it decreases in the north-eastern part of America and over Greenland. Noteworthy are the regions of decreasing pressure in the eastern part of the Pacific in the northern and southern hemispheres, i.e. in those regions where the propagation of Rossby waves and vortices excited by anomalous heating in the El Nino zone might be expected. In the southern hemisphere, in the winter months, near the zone of decreasing pressure there is a clearly pronounced band of temperature rise that starts in the central part of the Pacific and ends in the Indian sector of the circum-Antarctic depression. This band spatially coincides with the zone of storm tracks excited by El Nino temperature anomalies.

Regions of elevated surface air temperature in the winter months are characteristic for most of the southern hemisphere, namely, the equatorial and tropical zones of the Indian Ocean and the Pacific, the Indian sector of the circum-Antarctic depression. The trend is the opposite in the eastern sector of Antarctica - it shows a decrease in temperature. Zones of stable linear trends are virtually absent in the northern hemisphere. In March and April, in southern and central Asia and in the northern part of Africa the zones of weak trends (positive and negative) have a zonal character: temperature decreases in the north of Africa and in the south of Asia and rises in middle latitudes. In the summer months, the region of positive temperature trends characteristic for the southern hemisphere spreads to the north of Africa and to the south and south-east of Asia. There is a concurrent temperature rise in the eastern sector of Antarctica.

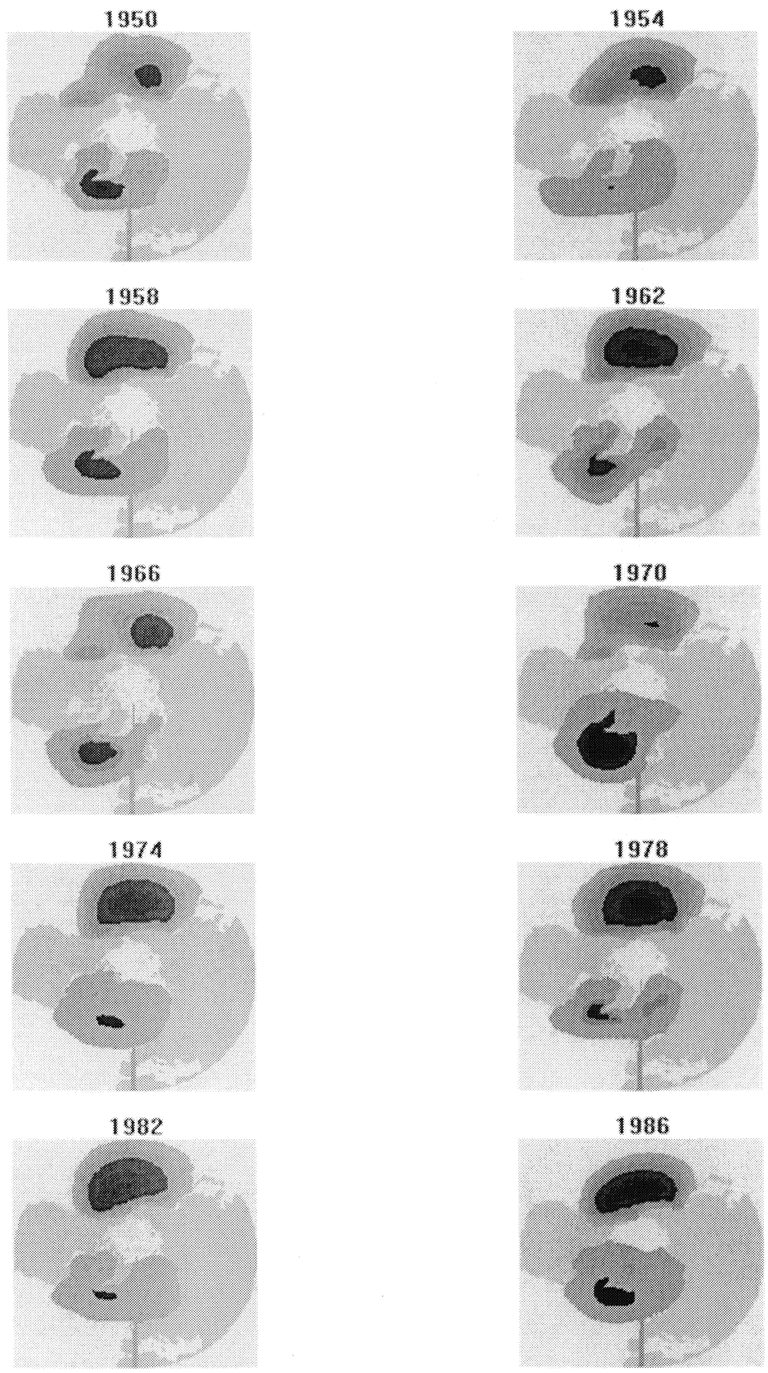
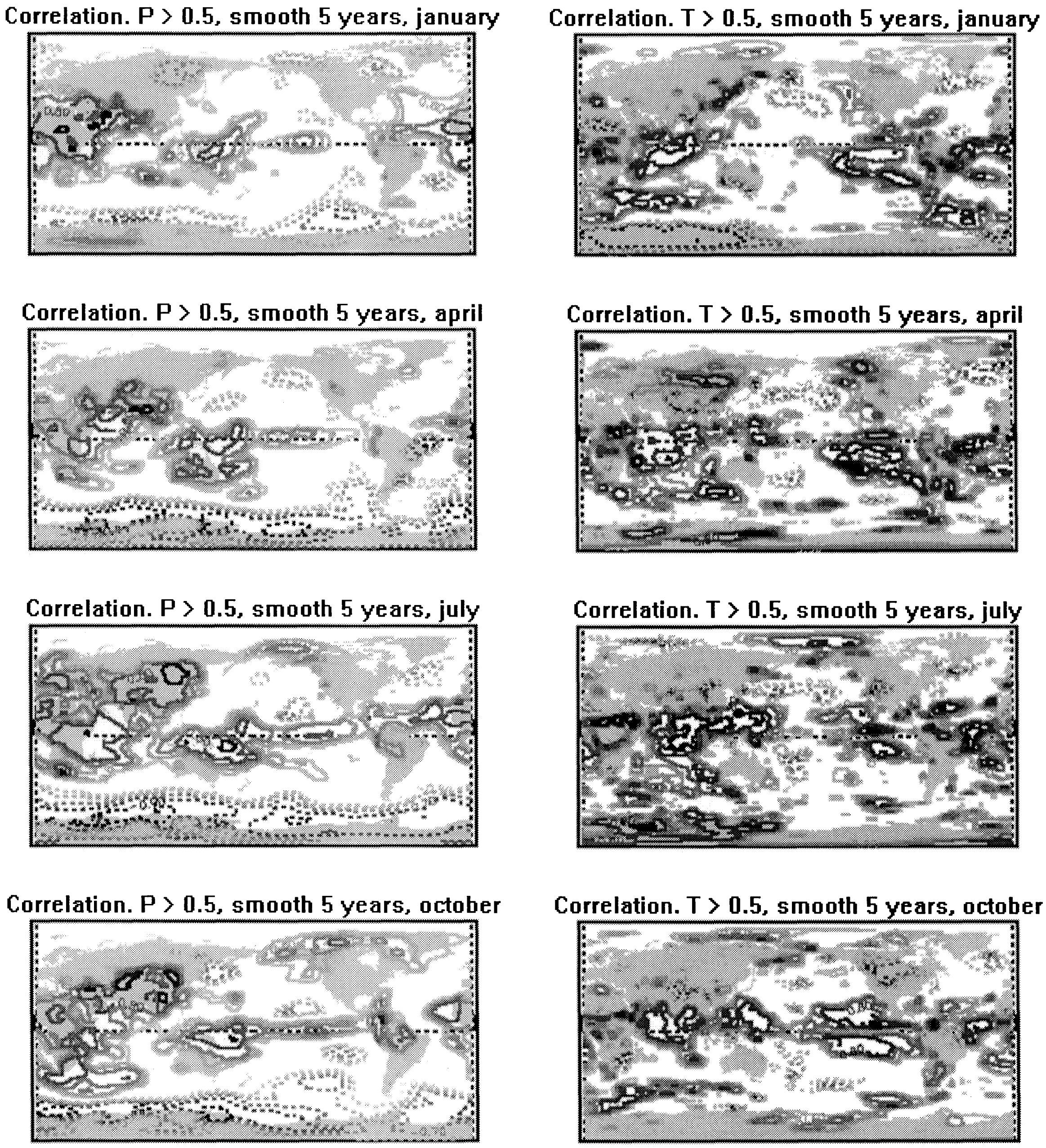


Figure 2: Maps of the smoothed (over 5 years) distributions of low-pressure regions in the northern hemisphere for the time interval from 1950 to 1986. Isohypses are drawn at intervals of 2.5 gPm.

Overall, the spatial structure of the regions with predominant linear trends of pressure and temperature resembles that of the regions of the strongest atmospheric response to El Nino events [4,5]. Changes in the atmospheric circulation at the time of the El Nino event have a zonal character and are the largest in the equatorial zone of the Pacific and in the tropical zone of the Indian Ocean. The recurrence of El Nino events has indeed increased for the last 50-100 years. This is illustrated by Fig. 4, showing the plot of yearly mean sea surface temperature (SST) anomalies of thermobaric fields at the equator at the point of 260° E, based on NCAP/NCER SST Kaplan data. More accurate comparisons have to use the general atmospheric circulation model specifying the actual SST behavior.



a) b)

Figure 3: Distributions of the correlation coefficients (> 0.5) of monthly mean ground-level pressure (a) and air temperature (b) in the nodes of the spatial grid with the plot of a linear function.

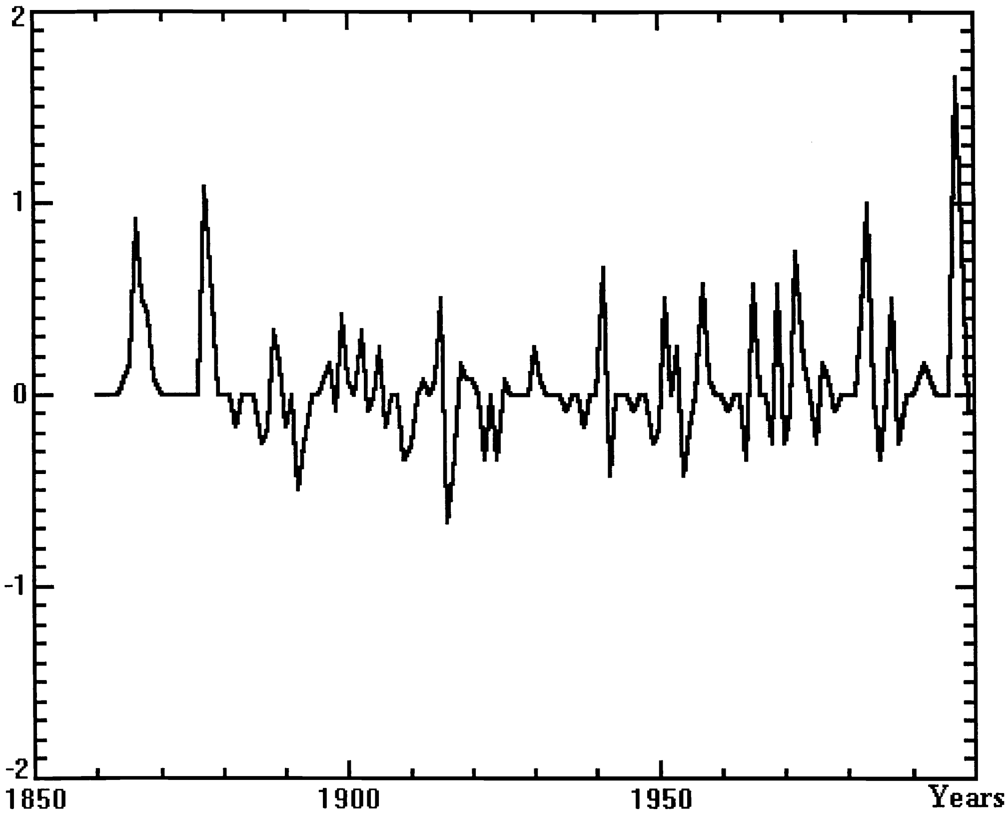


Figure 4: Plot of yearly mean OST anomalies at the point of 260° E according to NCAR/NCEP SST Kaplan data.

Of special interest for the study of weather anomalies on the Asian continent are the formation conditions of the Tibetan anticyclone and of the height ridge over Central Asia. In the summer season these features, on the one hand, determine the transport directions of air masses over Asia; on the other, they are most closely associated with the Asian monsoon that provides the influx of latent heat to the region of anticyclogenesis. The Asian monsoon, in turn, represents a complex weather phenomenon, a role in which is played by wave and vortex disturbances propagating both eastward and westward, as well as by circulation characteristics in middle latitudes, such as periods of formation and decay of the Okhotsk anticyclone. Observations provide important evidence in favor of the influence of the tropical circulation on extratropical latitudes. The problem of forcing coming from the tropical latitudes was addressed in a number of theoretical studies [6-9]. One of the influence mechanisms is the northward propagation of Rossby waves. If the excitation source is the anomalous heating in the El Nino region, then the greatest response should be expected in eastern parts of the Pacific and of North America [10]. The Central Asian region, in turn, can be influenced by disturbances propagating in the westward direction. An analysis of the dynamics of such disturbances is made in [11]. A wave packet (most probably, a packet of mixed Rossby-gravity waves) is generated and enhanced in the region of active convection associated with the Madden-Julian Oscillation, drifting slowly in the eastward direction. To the west of 150° E, some of the disturbances with a scale of 2300-3000 km and the velocity of 3.5-4 m/s deviate in the north-westward direction and transform to off-equatorial easterly waves, now often called tropical depression (TD)-type disturbances, with predominant periods of 3-6 days. This mechanism can, in principle, ensure the energy influx to the region of formation of the height ridge over Tibet.

To verify this hypothesis we constructed distributions of correlation coefficients for daily mean values of the height AT_{500} for 60 days for the period of the summer Asian monsoon with sea-level pressure variations at the points with coordinates 90° E, 35° N (Fig. 5).

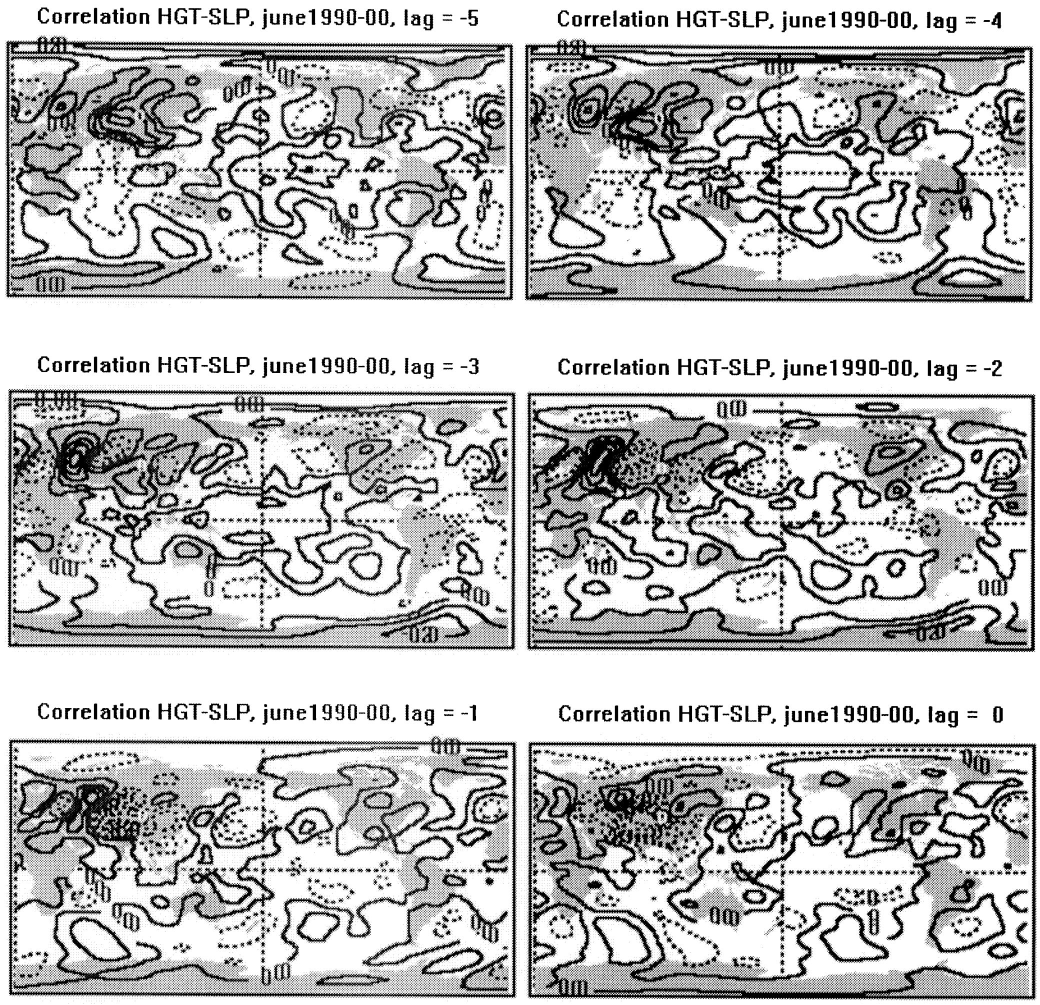


Figure 5: Distributions of the averaged (over 10 years, from 1990 to 2000) correlation coefficients of daily mean values of the height AT_{500} for 60 days during the summer Asian monsoon with ground-level pressure variations at the point with coordinates 90° E, 35° N. Correlation fields are calculated with time shifts from -5 to 0 days.

Correlation fields were calculated with different time shifts from -5 to 0 days and averaged over 10 years for the time interval from 1990 to 2000. The correlation fields were found to be highly stable and, with some exceptions, to recur from year to year. Five days before the increase of AT_{500} over Tibet, the central part of the Pacific develops a region of opposite sign. This region is displaced relatively rapidly in the westward direction, and in five days reaches the central part of the Indian Ocean. The high pressure ridge is intensified over Tibet at that time, and the depression deepens over the area of Middle Asia. The velocity of the disturbance was unexpectedly high, which exceeded nearly by a factor of ten the velocity of mixed Rossby-gravity waves. A similar result is also obtained by comparing the height field over Tibet with the height AT_{500}. The origin of such disturbances still remains unclear and demands further investigation.

3. CONCLUSIONS

Using the data from NCAR/NCEP Reanalysis we investigate long-term variations of thermobaric fields. Middle and high latitudes are characterized by 10-20-year variations of meteorological characteristics, perhaps, caused by the atmosphere-ocean interaction. In the northern hemisphere long-term variations of climatic characteristics are particularly clearly pronounced in fluctuations of oceanic centers of atmospheric activity. A most interesting feature of the global variations is the increase (starting in the 1960s) in pressure and surface air temperature in the tropics and subtropics. In the circum-Antarctic depression the decrease in pressure is as significant. Conceivably the other atmospheric circulation variations might all be accounted for by these changes as well as by a gradual enhancement of the influence of the southern processes. The long-term variations in the tropics seem to be caused by the increased recurrence of El Nino events. The physical transport mechanism for disturbances to the region of Central Asia might be represented by the propagation of mixed Rossby-gravity waves; however, our results suggest much higher propagation velocities of disturbances.

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