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# ANALYSIS OF CLIMATE CHANGES IN CLOUDINESS AND SURFACE AIR TEMPERATURE FOR 1967-1995 IN RUSSIA

*Abstract:* The analysis of changing climate elements for the period 1967-1995 in Russia allows to reveal special features of long-term variations of the surface air temperature and cloud cover in the night and the day hours for winter and summer in 8 regions over the territory of Russia. Obtained results allowed to discover the total and low-level cloudiness changes in the middle of night and day and to reveal the agreement of long-term variations of cloudiness with air temperature changes and to show atypical features and peculiarities of cloud daily cycle changes in all seasons during the years 1967-1995. A joint analysis of long-term variations in air temperature, cloudiness and frequency of different cloud genera allows to better understand physical processes accompanying the current climate change.

*Key word:* global warming, cloudiness change, cloud genera frequency, air temperature.

## 1. Introduction

The essential indicator of the current climate warming is the increasing of global surface air temperature most clearly seen since the end of the 1970s (Budyko 1974; IPCC 1995). Anthropogenic climate warming was appreciably speeding up in the 1980s and 1990s when record positive global surface air temperature anomalies were observed (Budyko et al.1999).

To better understand physical regularities of natural and anthropogenic climate system changes accompanying the current climate change, detailed observations of meteorological elements are required.

## 2. Long-Term Variations in Air Temperature and Cloudiness at Day-Time and Night-Time in the Winter and Summer Seasons for 1967-1990

Using air temperature observations at different hours the particularities of long-term temperature variations at day-time and night-time were accounted for and compared with total and low-level cloudiness changes, which have been obtained from simultaneous cloudiness and air temperature observations.

The analysis of long-term surface air temperature changes and their relation with cloudiness variations was based on using homogeneous time series of observations at 3 a.m. and 3 p.m. in winter (December, January, February) and in summer (June, July, August) during the 1967-1990 period for 46 meteorological stations located in European part of Russia, Western Siberia and far north-eastern part of the country.

Obtained results (Yefimova et al. 1994) allow to conclude that:

1. The results of analysis of long-term variations in air temperature for the winter and summer seasons during the period 1967-1990 in the western regions and Far North-East of Russia mainly coincide with results obtained in preceding studies about influence of the large volcanic eruptions on temperature causing short-term temperature variations.

In winter the long-term air temperature changes are similar at the night-time and day-time (1.8°C/10 yr. and 1.6°C /25 yr. respectively) and their tendencies are positive. The decrease of tendency in difference between temperatures for the day-time and night-time in winter is equal to 0.2°C/25 yr. and is about 10 times smaller than the increase of air temperature (tendencies were calculated using equations of regression line).

In summer the 5-year moving average temperature changes were not large, moreover trends of temperature were characterized by opposite signs: negative (-0.2°C /25 yr.) for the day-time and positive (0.3°C/25 yr.) for the night-time. As a result of this long-term variations in difference between temperature at day-time and at night-time negative tendencies (-0.5°C/25 yr.) were revealed.

2. In winter and summer changes in total and low-level cloudiness coincide with long-term temperature variations at day-time and night-time. Moreover, the tendencies in total cloudiness for both day-time and night-time were positive and equal to 0.3-0.4 tenths/25 yr. in winter and to 0.1 tenths/25 yr. in summer. Tendencies of low-level cloudiness were characterized by the same absolute values, but opposite signs at day-time and night-time in both seasons. For the period 1967-1990 the value of low-level cloudiness increased in day-time and decreased in night-time in winter (0.1 tenths/25 yr.) and in summer (0.2 tenths/25 yr.).

It is important to notice that the large changes in total and low-level cloudiness hardly exactly agree with long-term temperature variations. Moreover, winter is characterized by direct relation between those elements. In summer long-term variations in air temperature were close to the counter-phase course of cloudiness, specially at the day time.

Particularities of air temperature changes revealed in western regions and Far North-East of Russia for 1967-1990 (Yefimova et al. 1994) were also typical for Eastern Siberia and Far East of Russia (Yefimova et al. 1996). These results were obtained by analysis of additionally generalized data for air temperature and cloudiness at the night-time and day-time in the winter and summer for the period 1967-1990 using the stations in Eastern Siberia and Far East of Russia (Meteorological Monthly USSR 1966-1990).

The real existence of the current climate warming is corroborated by positive air temperature tendencies at the day-time and night-time in winter and summer for 8 large regions of Russia with the exception of a certain decrease in air temperature in the winter season for the North-West and in the summer season for the central and southern part of ETR. The most considerable growth in air temperature (from 3.0 to 3.8°C/25 yr.) was observed in winter for Western and Eastern Siberia.

As the daily meteorological observations from 6 measurement terms have not been published since 1991 it became necessary to use other sources of information for the study of climate change in the 1990s.

## 3. Empirical Estimates in Surface Air Temperature Changes in the 1990s

Mean monthly air temperature from many meteorological stations in the world have been used to study the further development of the regional features revealed in time variations in air temperature during the 1990s. Using those empirical data, the maps of air temperature anomalies for 1991-1995 from means for 1951-1975 have been obtained for winter and summer, for the continents of the Northern Hemisphere (Budyko et al. 1999). Analysis of maps allows us to show positive air temperature anomalies in winter nearly over the whole territory of Europe and Asia, except Far North-East of Asia. Maximum temperature decrease equaled to 3-4°C is noted in Western and Eastern Siberia. In the winter months air surface temperature were larger by 2-2.5°C above norms in Northern and Eastern Europe, Far East and Habarovsky region. Anomalies in air temperature change from 0.5 to 1.5°C in the north of Siberia.

In summer air temperature anomalies are less than those in the winter months (as a rule they change from 0.1 to 1.0°C).

Revealed regional features of climate change during the period 1991-1995 permit to compare them with predicted air temperature changes from the forecast based on paleoanalogous method for the winter and summer seasons at the beginning of the 21st century (Forthcoming Climate Change 1991). According to this forecast air temperature should increase by 1.5-2.5°C in winter and by 1.0-1.5°C in summer to 2005 in temperate zones of continents in the Northern Hemisphere.

Area-averaged estimates of air temperature anomalies for the large region of Russia (Budyko et al. 1993, 1999) show the stable increase of air temperature in the winter months from the 1980s to the middle of the 1990s. Air temperature significantly increased (by 1.6°C) from decade of the 1980s to the time period 1991-1995 in the European part of Russia and Siberia. In these regions air temperature anomalies (2.3

and 3.3°C) for the 1991-1995 period were close to the predicted ones for 2005 (2.7 and 3.6°C respectively). In the European part of Russia air temperature increased for the period 1991-1995 by 1.5°C, so it was less by 0.9°C than the predicted one. Only in the Northern Siberia the difference between observed air temperature anomalies (1.2°C) for the years 1991-1995 and predicted ones (4.0°C) were large.

The further study of empirical meteorological data for the second part of the 1990s will allow to verify the forecast of climate change for the first quarter of 21st century.

## 4. Cloudiness Variations over Russia for 1967-1995

For the study of cloudiness variations during the 1980s-1990s we used 3-6 hourly observational data from Main Geophysical Observatory's actinometrical archives. Unfortunately, hours of observations at actinometrical stations (every 3 hours from 0 h 30 min. sundial time) do not coincide with observation time at meteorological stations (3 a.m., 9 a.m., 3 p.m., 9 p.m. local time). Consequently, to obtain homogenous cloudiness series we supplemented the aforementioned data with the information about cloud cover and cloud genera for the same hours of observations for the period 1967-1986 (Actinometrical Monthly 1967-1986). Thus we used for the estimation the two series of cloud cover changes, generalized from observations at meteorological stations during 1967-1990 and at actinometrical stations for the period 1967-1995. At the same time, cloud genera frequency (Cu+Cb, St+Sc, Ns) and number of cases with clear sky (by per cent from total number of observations) were calculated from daily cloud observations for the indicated period. Calculations were made for 00:30 a.m., 9:30 a.m.,12:30 p.m. and 3:30 p.m. or 6:30 p.m. for each month of the period 1967-1995. Then seasonal frequency of cloud genera was estimated for different terms of observation and day-time. Statistical analysis of obtained series allows us estimate the cloud cover and genera frequency change tendencies for 32 stations with the most complete series of monthly data. Those estimates show that the long-term variations of total cloud cover agree well in the morning, at midday, in the evening and in midnight for both seasons. Besides, in winter for the period 1967-1995 total cloudiness changes tendencies at 6 from 32 analyzed stations were statistically significant, positive and were equaled to 0.1-0.8 tenths/10 yr. Positive statistically significant tendencies of low-level cloudiness changes (0.1-1.1 tenths/10 yr.) were revealed at 12 stations for this period. Predominant cloud genera for indicated period were St and Sc. Tendencies of those cloud genera frequency were positive and changed from 1 to 8%/10 yr.

In summer, unlike in winter, changes of tendencies of total and low-level cloudiness were negative and changed from –0.1 to –1.4 tenths/10 yr., moreover frequency of St cloud decreased and frequency of Cu and Cb increased. Positive tendencies were revealed only for the territory of Siberia and Central Asia (0.1-1.2 tenths/10 yr.) where increase of St, Sc, Cu, Cb was observed.

Thus, using in analysis 2 series of observations from meteorological (from 1967 to 1990) and actinometrical stations (from 1967 to 1995) allowed us to get independent empirical estimates of cloud cover changes tendencies having the same signs and close values. Consequently, regularities of cloud cover changes revealed during the time period 1967-1990 were retaining for 1991-1995.

Adding the estimates of frequency cloud genera changes to the analysis allowed us to elaborate regional features of cloudiness changes accompanying the current anthropogenic climate warming.

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