Influence of circulation and radiative factors on temperature variability over different regions of the Asian territory of Russia

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Objective: to reveal the reason of temperature variability during last decades over the Asian territory of Russia (ATR, 45−80ºN, 60−180ºE)

DATASETS

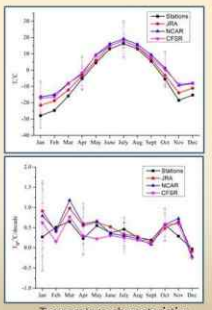
Daily mean temperature data at 450 stations for 1976-2005
ftp://ftp.cdc.noaa.gov/pub/data/gsod/

Reanalysis data
- JRA-25 data for 1979-2010
Spatial 1.25° x1.25° with 6-hour temporal resolution
http://ds.data.jma.go.jp/gmd/jra/
- NCEP AMIP/DOE data for 1979-2010
Spatial 2.5° x2.5° with 6-hour temporal resolution
ftp://ftp.cdc.noaa.gov/Datasets/ncep.reanalysis2/
- CFSR data for 1979-2010
Spatial 0.3° x0.3° with 1-hour temporal resolution
http://nomads.ncdc.noaa.gov/data/
- MERRA data for 1979-2010
Spatial 0.66 ° x 0.66 ° with 6-hour temporal resolution
http://ds.data.jma.go.jp/gmd/jra/

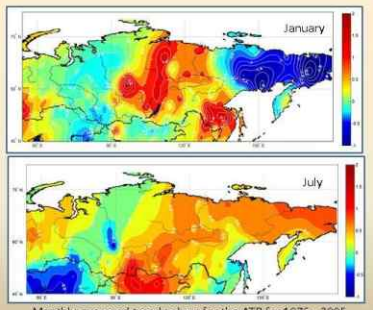
Satellite data
- CERES data for 2000-2010
ftp://ftp.cdc.noaa.gov/Datasets/ncep.reanalysis2/

Temperature

Annual averaged trend value was 0.34°C/decade by observational data, in general, for the period of 1976-2005 temperature increased by 1.0°C, whereas for the period of 1979-2008 by JRA-25 and NCEP/DOE AMIP reanalysis data temperature increased by 0.48°C/decade, 1.4°C for the whole period. For CFSR this value is closer to estimate by observational data 0.96°C (0.32°C/decade). During a year the process of warming was observed in several months: positive significant trends were obtained for February, March, May, June and July. Over Asian territory of Russia temperature field variability is also characterized by significant spatial inhomogeneity



Temperature characteristics



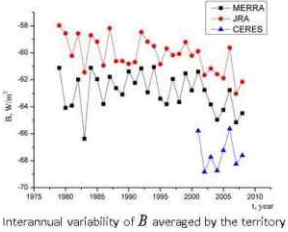
Monthly averaged trend values for the ATR for 1976 - 2005

Radiative factors

TOA Radiative balance

$$B = Q_{\downarrow\theta} - Q_{\uparrow\infty} - L_{\uparrow\infty}$$

where $Q_{\downarrow\theta}$ – downward shortwave radiation,
$Q_{\uparrow\infty}$ – upward shortwave radiation,
$L_{\uparrow\infty}$ - upward longwave radiation



Interannual variability of B averaged by the territory

Heat loss of climatic system due to small $L_{\uparrow\infty}$ trend values (0.5 W/m^2/decade for annual average values) were changed insignificantly, in spite of quite intensive heating (0.48°C/decade by JRA) of low troposphere.

From the beginning of 90s of XX century the growth of $Q_{\uparrow\infty}$coincides with cloud cover dynamics.

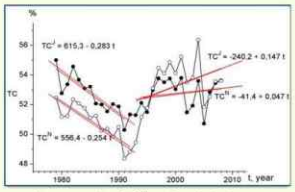
Annual averaged TOA radiative balance values are negative, and values of annual averaged air temperature are also negative. According to JRA-25 data, downward trend of radiative balance is well-marked in the period after the beginning of 90s of XX century. These results were also obtained using other data sources.

In spite of slight decreasing of radiative balance (~2W/m^2), we can suppose that the tendency of regional climatic system cooling is possible; it can decelerate the growth of air temperature at the surface.

Cloud cover

The annual averaged long-term total cloud (TC) cover is 53%. The maximum value is 61% in November and the minimum is 45% in July. In general for the period of 1979-2008 linear trend is negative: -0.02%/decade.

We have found the decrease of total cloudiness and the corresponding growth of downward short-wave radiation at the surface for reanalysis datasets in **subinterval 1979-1992**. In the second **subinterval 1992-2008** the situation is reverse. Temporal variability of middle level clouds and low level clouds has also two subintervals, like total cloudiness variability.



The temporal variability of total cloud cover

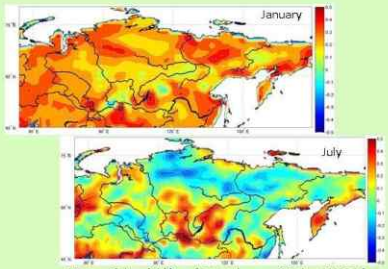
In general, for the period of under study over ATR the following tendency was observed: the contribution of high level clouds was increased (1%), of middle level clouds was slightly decreased (1%), and most markedly decrease was observed for the part of low level clouds (2%)

Heat balance at the surface

$$B_S = Q_{\downarrow S} - Q_{\uparrow S} + L_{\downarrow S} - L_{\uparrow S} - LE - P - G$$

here $Q_{\downarrow S}$ - downward shortwave radiation at the surface,
$Q_{\uparrow S}$ - upward shortwave radiation at the surface,
$L_{\downarrow S}$ - downward longwave radiation at the surface,
$L_{\uparrow S}$ - upward longwave radiation at the surface,
LE – latent heat, P – sensible heat, G - heat flux in the ground

Signs before LE, P and G depend on heat flux direction. Positive turbulent fluxes are directed away from the earth surface whilst positive net radiation is directed towards the earth surface.



The spatial variability of B trends over ATR by JRA-25 for the period of 1979 - 2008

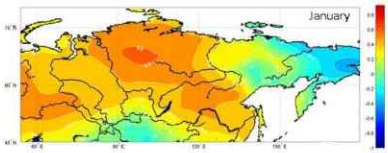
Heat exchange between surface and atmosphere takes place through longwave radiation fluxes, and sensible and latent heat fluxes. In temporal dynamics of the effective longwave radiation E_{eff}=$L_{\uparrow S}$ - $L_{\downarrow S}$ two periods with the change of gradient in the beginning of 90s are distinguished. The interval 1990-1996 is also marked out in the temporal dynamics of sensible and latent heat fluxes. For ATR heat balance trends are insignificant for the period 1979-2008.

Circulation factors

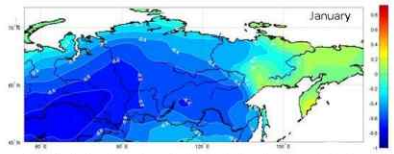
Teleconnection indices

NAO - North Atlantic Oscillation
AO - Arctic Oscillation
SOI - South Oscillation Index
SCAND - Scandinavian Pattern

In general, basic circulation mechanism, forming temperature regime over ATR for the period 1979-2008, is described by SCAND almost during a year. NAO has significant influence on the air temperature variability over the territory under study only in several months of cold season.



Spatial distribution of correlation coefficient between NAO and air surface temperature over the Asian territory of Russia



Spatial distribution of correlation coefficient between SCAND and air surface temperature over the Asian territory of Russia

Correlations of temperature with SCAND and AO describe the same process, which leads to temperature increase when west transfer is enhanced and to temperature decrease when it becomes weaker. We did not obtain statistically significant relationship between temperature variability and pressure changes in equatorial Pacific (SOI).

Regression analysis

Only radiation

$$\delta T = \beta_1 \delta Q_n + \beta_2 \delta E_{eff} + \beta_3 \delta Eg + \beta_4 \delta TC$$

Only circulation

$$\delta T = \beta_1 \delta SCAND + \beta_2 \delta NAO + \beta_3 \delta SOI + \beta_4 \delta AO$$

$\delta Qn = \delta Q_{\downarrow S} - \delta Q_{\uparrow S}$ – clear sky shortwave radiation anomalies
$\delta E_{eff} = \delta L_{\uparrow S} - \delta L_{\downarrow S}$ – clear sky longwave radiation anomalies
$\delta Eg = \delta LE + \delta P + \delta G$ – anomalies of latent, sensible heat, heat flux in the ground
δTC – cloudiness anomalies

WP (West Pacific) index was added to this equation for Far East

Regions

R^2	West Siberia	East Siberia	Far East	ATR
R^2 circulation	0.45	0.33	0.46	0.38
R^2 radiation	0.54	0.33	0.40	0.51
R^2 circulation + radiation	0.68	0.63	0.63	0.65

Determination coefficient R^2 of temperature linear regression models. Period from 1979 to 2008. JRA-25 reanalysis data

The largest contribution belongs to radiative balance elements due to large values of R^2 for West Siberia. The influence of circulation and radiative factors on temperature variability over East Siberia are almost equal. For Far East circulation factors are dominant. Regression analysis has shown, that in general, from 30 to 60% of surface air temperature variability over ATR is described by variability of global circulation processes. With heightening such relation becomes weaker and contribution of described dispersion decreases.

Conclusion

✓From the beginning of 90s of XX century the growth of solar radiation, reflected by earth's atmosphere is observed. This growth coincides with cloud cover dynamics and downward shortwave solar radiation coming to the surface. Annual averaged radiative balance values at the top are negative, and values of annual average air temperature, averaged by the territory, are also negative.

✓Hence, in spite of slight decreasing of radiative balance (~2W/m^2), we can suppose that the tendency of regional climatic system cooling is possible; it can decelerate the growth of air temperature at the surface.

✓Regression models allow to describe up to 65% of temperature variability if we take into account both circulation and radiative factors. Relative part of these two groups is varied for different regions of ATR.

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