VARIABILITY OF RADIATIVE BALANCE COMPONENTS AND AIR SURFACE TEMPERATURE OVER THE ASIAN TERRITORY OF RUSSIA IN THE PERIOD OF GLOBAL WARMING 1979-2008

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Objective: to investigate and compare the temperature variability over the Asian territory of Russia (ATR, 45−80ºN, 60−180ºE) and variability of factors, which influence on its variations, in particular radiative balance elements and cloud cover.

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/

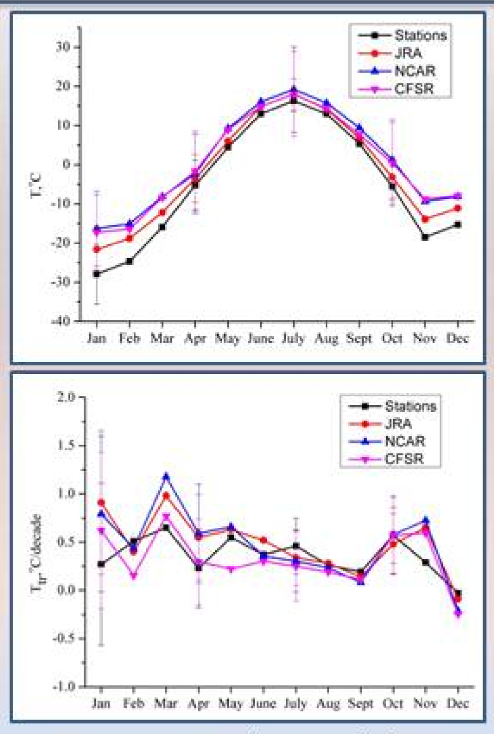
NCEP AMIP/DOE data for 1979-2010
Spatial 2.5° x2.5° with 6-hour temporal resolution
ftp://ftp.cdc.noaa.gov/Datasets/ncep.reanalysis2/

CFSR data for 1979-2010
Spatial 0.3° x0.3° with 1-hour temporal resolution
http://nomads.ncdc.noaa.gov/data/

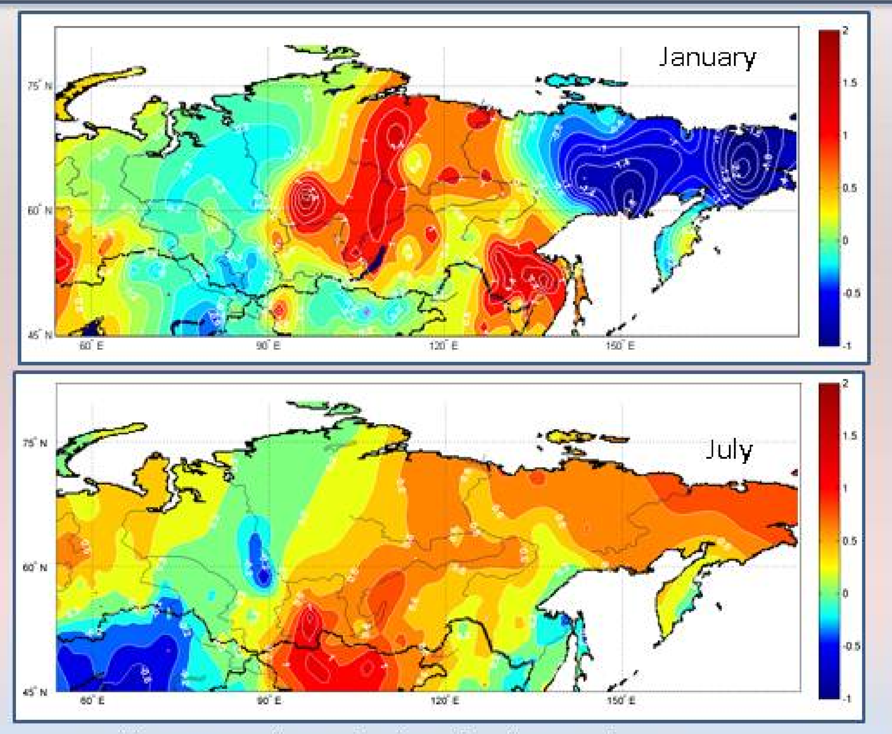
Temperature

Positive trends of annual averaged surface temperature were revealed over all territory of under study. 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).

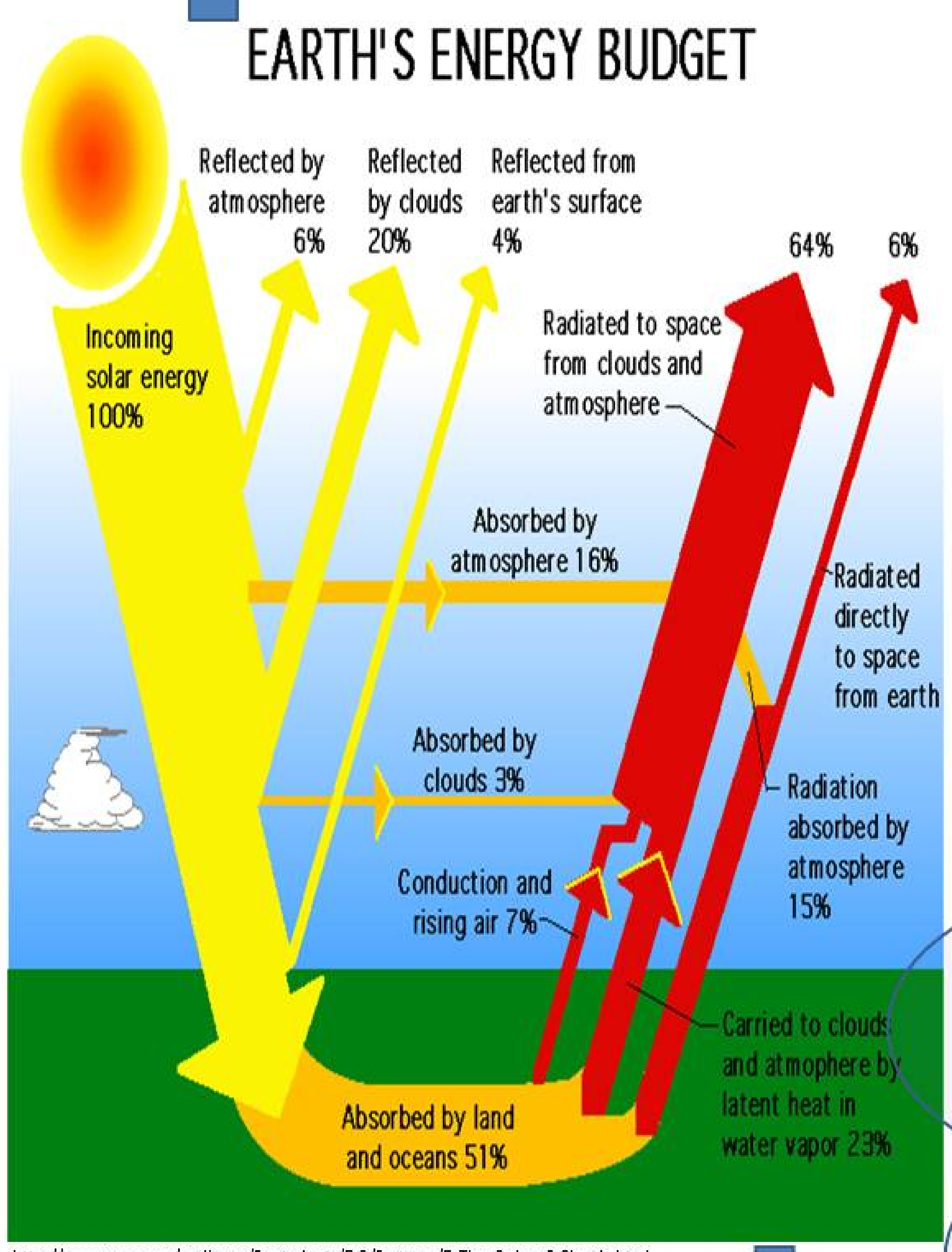
During a year the process of warming was observed in several months: positive significant trends were obtained for February, March, May, June and July. Over Asian territory of Russia temperature field variability is also characterized by significant spatial inhomogeneity



Temperature characteristics



Monthly averaged trend values for the ATR for 1976 - 2005

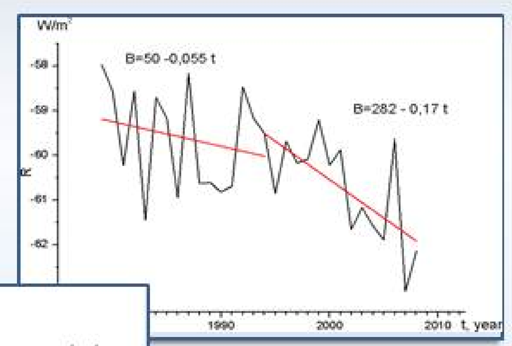


http://www.nasa.gov/audience/forstudents/5-8/features/F_The_Role_of_Clouds.html

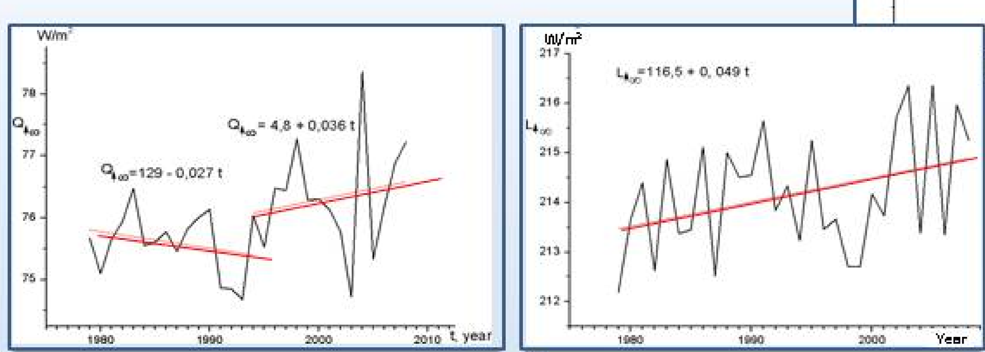
TOA Radiative balance

$$B = Q_{\downarrow 0} - Q_{\uparrow\infty} - L_{\uparrow\infty}$$

where $Q_{\downarrow 0}$ – downward shortwave radiation,
$Q_{\uparrow\infty}$ – upward shortwave radiation,
$L_{\uparrow\infty}$ - upward long-wave radiation



B



$Q_{\uparrow\infty}$ $L_{\uparrow\infty}$

Interannual variability of B, $Q_{\uparrow\infty}$ and $L_{\uparrow\infty}$ averaged by territory, calculated by JRA-25

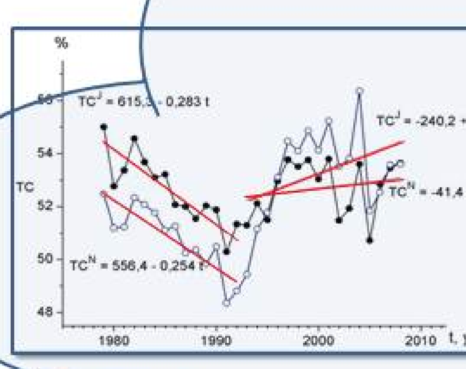
Heat loss of climatic system due to small $L_{\uparrow\infty}$ trend values (0.5 W/m²/decade for annual average values) were changed insignificantly, in spite of quite intensive heating (0.48°C/decade by JRA) of low troposphere.

From the beginning of 90s of XX century the growth of 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.

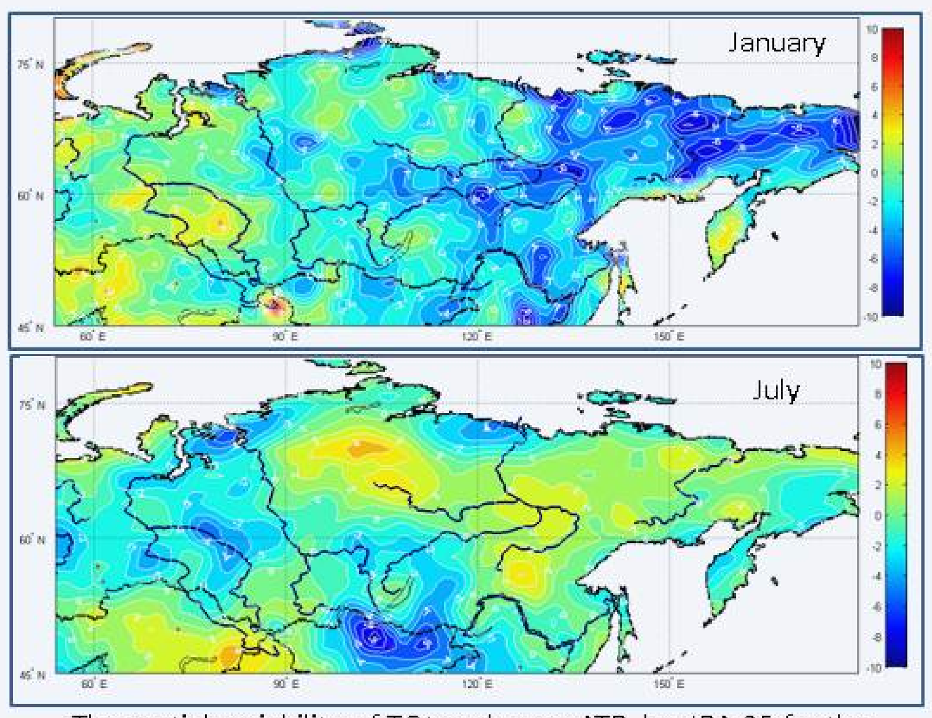
Annual averaged TOA radiative balance values are negative, and values of annual averaged air temperature are also negative. Downward trend of radiative balance is well-marked in the period after the beginning of 90s of XX century.

In spite of slight decreasing of radiative balance (~2W/m²), 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 temporal variability of total cloud cover



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

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. The maximum variability of cloud cover corresponds to the cold season.

In general for the period of 1979-2008 linear trend is negative: -0.02%/decade.

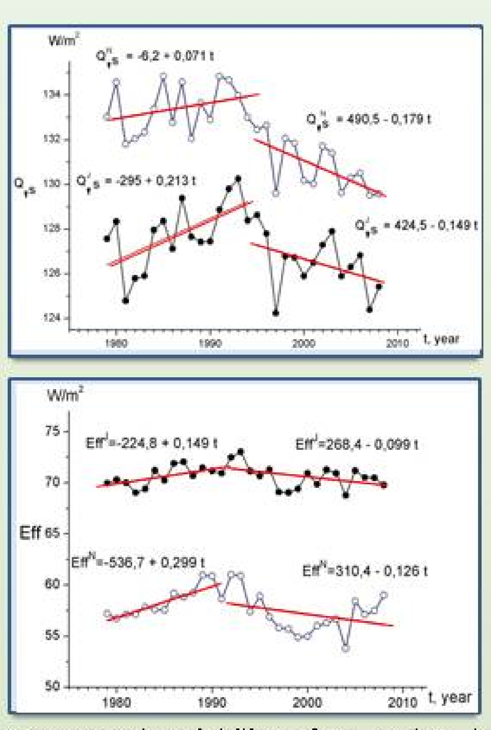
We have found the decrease of total cloudiness and the corresponding growth of downward short-wave radiation at the surface for reanalysis datasets in subinterval 1979-1992. In the second subinterval 1992-2008 the situation is reverse. Temporal variability of middle level clouds and low level clouds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

In general, for the period of under study over ATR the following tendency was observed: the contribution of high level clouds was increased (15% from its annual averaged value), of middle level clouds was slightly decreased (1%), and most markedly decreasing was observed for the part of low level clouds (20%)

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



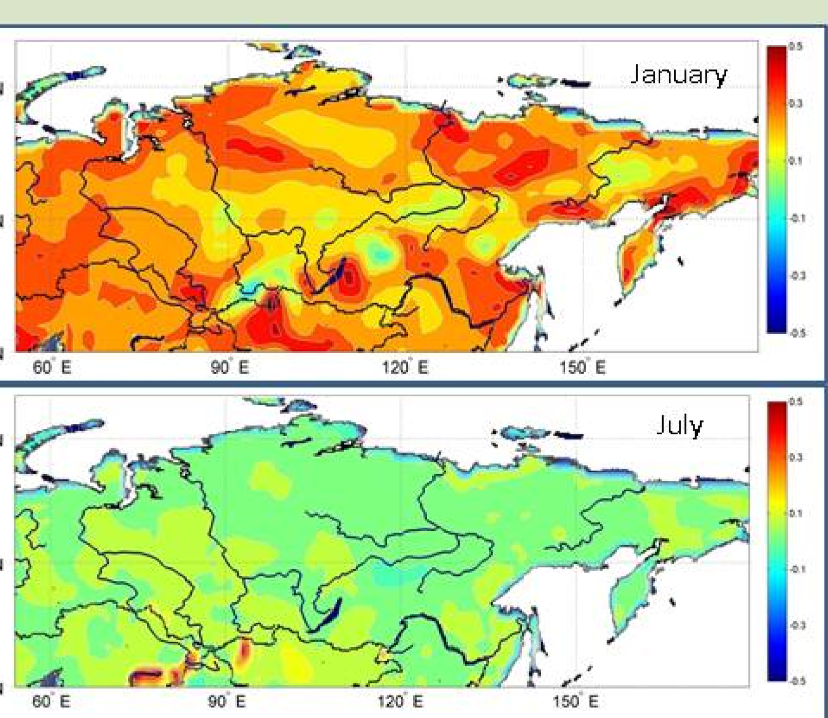
$Q_{\downarrow S}$ E_{eff}

The temporal variability of $Q_{\downarrow S}$ and E_{eff} by JRA-25 and NCAR/AMIP

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.

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.



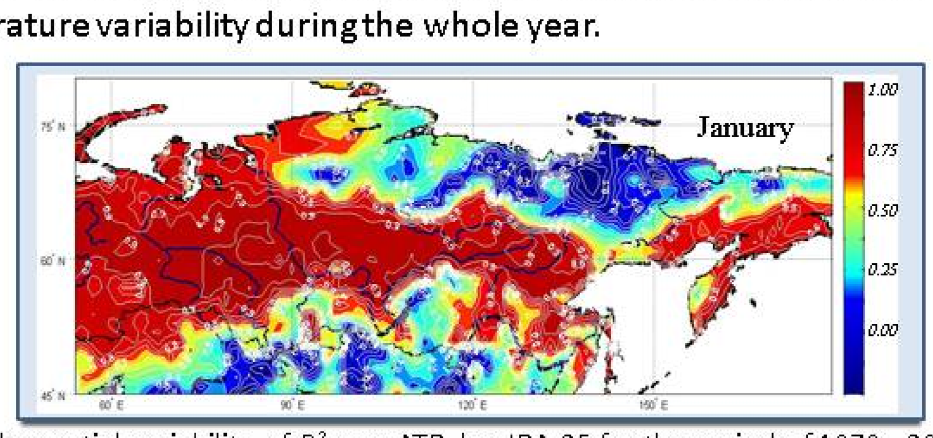
The spatial variability of B trends over ATR by JRA-25 for the period of 1979 - 2008

Regression analysis

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

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

The contribution of each predictor in the regression analysis to the total variability of air temperature was calculated. In January, the largest contribution belongs to the effective long-wave radiation. Probably, this is due to total clouds in this season. Clouds impact on the temperature regime of the territory in spring and autumn. The influence of latent and sensible heat fluxes, and heat flux in the ground prevail only in winter. In general, anomalies of shortwave and longwave radiation play a major role in the air temperature variability during the whole year.



The spatial variability of R^2 over ATR by JRA-25 for the period of 1979 - 2008

Determination coefficient values (R^2) is changed from 0.53 to 0.80 for the period 1979-2008. We also investigated two subintervals, revealed in temporal variability of parameters of under study. The value of R^2 slightly varies within a year: for the first subinterval 1979-1992, from 0.76 to 0.9; for the second subinterval 1992-2008, from 0.69 to 0.87.

Estimations of predictors' contribution

Month	δQn	δE$_{eff}$	δEg	δTC
Jan	26.8	37.2	20.2	15.8
Feb	20.0	41.3	21.5	17.3
Mar	21.5	42.1	15.3	21.1
Apr	50.6	14.9	6.4	28.1
May	53.8	17.9	6.5	21.8
Jun	43.8	32.0	10.8	13.4
Jul	45.3	23.3	15.5	15.9
Aug	39.7	30.4	19.0	10.9
Sep	35.0	36.4	14.1	14.5
Oct	20.2	31.6	17.2	31.1
Nov	7.3	35.9	24.4	32.4
Dec	19.5	36.8	25.7	18.0

Conclusion

✓**Regional variations of solar radiation flux obtained by reanalysis data are mainly conformed to total cloudiness and air temperature changes. In general, anomalies of short-wave and longwave radiation play a major role in the air temperature variability during the whole year.**

✓**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 short-wave 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/m2), we can suppose that the tendency of regional climatic system cooling is possible; it can decelerate the growth of air temperature at the surface.**

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