

Solar and Cosmic Rays Influence on Winter Temperature Variations in North Siberia

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Abstract.

The global warming is not uniformly distributed over the Earth surface. Some regions are strongly affected by the global warming. The mean temperature of Siberia is rising stronger during last decades. The anthropogenic factors of this rise cause positive linear trend since 1970, while various natural factors, like solar activity, cosmic rays, geomagnetic field, stratospheric ozone, excite periodic oscillations of the temperature and non-linear trends. The time series of winter temperature of North Siberia (65N-75N; 90E-170E) is analyzed by means of the Method of Partial Fourier Oscillations. The cycles of Siberia winter temperature in narrow frequency bands are compared with corresponding oscillations of Total Solar Irradiance (TSI) and Cosmic Rays (CR) in order to determine the existence of common cycles. The warming trend after 1970 is determined by moving average of time series.

Introduction

The aim of this work is to determine changes of temperature of North Siberia, which is the largest reservoir of natural methane. The global warming is not uniformly distributed over the Earth surface. Some regions are strongly affected by the global warming. The mean temperature of Siberia is rising stronger during last decades. The anthropogenic factors of this rise cause positive linear trend since 1970, while various natural factors, like solar activity, cosmic rays, geomagnetic field, stratospheric ozone, excite periodic oscillations of the temperature and non-linear trends. According National Oceanic and Atmospheric Administration (NOAA), the recent temperature trend during last 30 years is not uniformly spread over Earth surface. The maximal effect of global warming is visible in North Africa and close to the North polar circle (Fig. 1). High temperature rate in polar region is danger about future meltdown of permafrost and large amount of methane release. The permafrost stability is connected with the winter temperature variations and its rising to critical level. The time series of North Siberia winter temperature since 1836 is suitable to study possible climatic disaster after sudden methane release.

RECENT TEMPERATURE TRENDS (1990-2019)

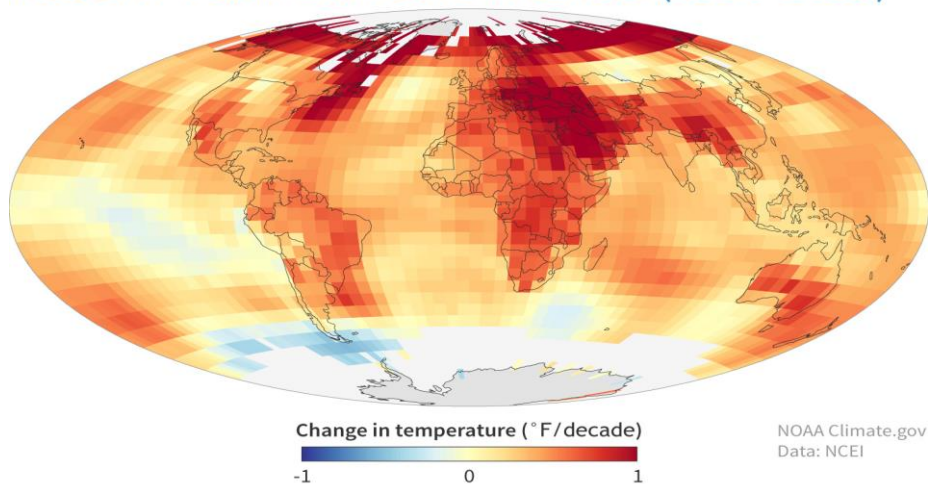


Fig.1. Global temperature trends since 1990 according NOAA.

Data and Methods

a) Cosmic rays and TSI

The TSI and CR data are presented in Fig.2. Solanki et al. (2000, 2002) have reconstructed the open solar magnetic flux for the last 400 years from sunspot data. Using reconstructed magnetic flux as an input to a spherically symmetric quasi-steady state model of the heliosphere, Usoskin et al. (2002, 2005; Alanko-Huotari et al., 2006) calculate the intensity of galactic CR at the Earth’s orbit since 1610.

The daily reconstruction of TSI since 1850 is a composite of SATIRE-T reconstruction from (Krivova et al., 2010) for 1850 to 22 August 1974; and SATIRE-S reconstruction from (Yeo et al., 2014a, 2014b) for 23 August 1974 onwards (Fig. 2, d, yellow color). The monthly values are calculated by the robust Danish Method (Fig.2, d, red color).

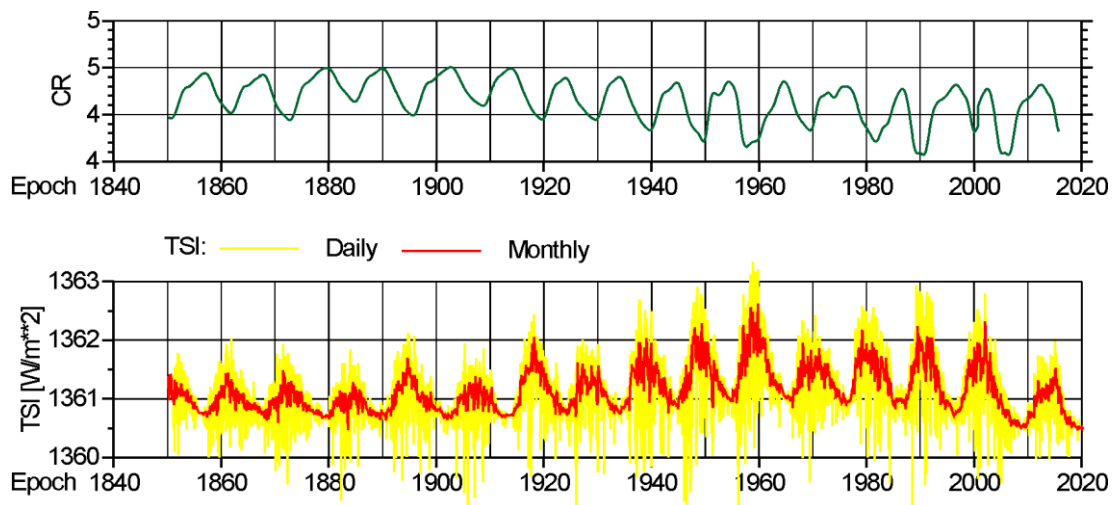


Fig.2. Time series of Cosmic Rays (CR) and TSI. The daily values of TSI are marked by yellow line, their 0.1-year values – by red line.

b) Temperature time series

The North Siberia temperature data are taken from region 65N-75N; 90E-170E (Figs. 3, 4). These data are available from Twentieth Century Reanalysis (20CR) dataset, Version 3.

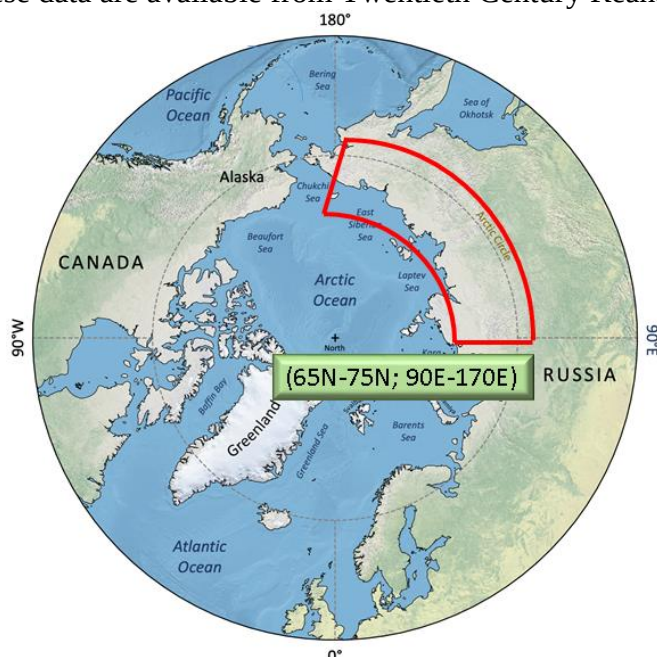


Fig.3. Map of region 65N-75N; 90E-170E of North Siberia.

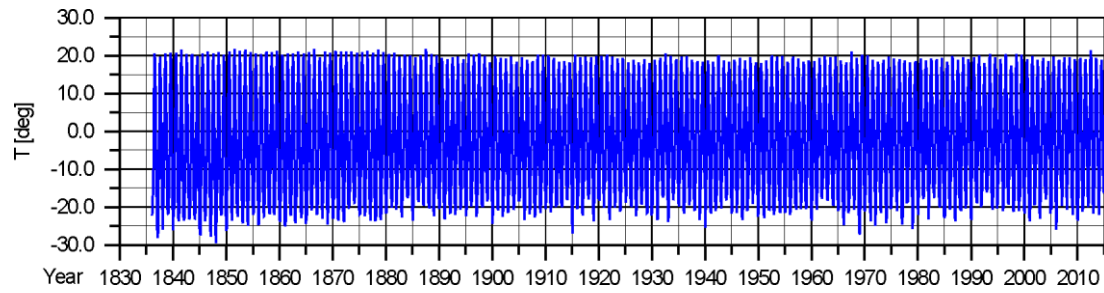


Fig.4. Time series of North Siberia Temperature T for the period 1836-2016.

The time series spectra are calculated by the Fast Fourier Transform (FFT). The time series of oscillations with a given frequency are calculated by the Method of Partial Fourier Approximation (PFA), whose details are described in (Chapanov et al., 2015). The used time series cover 179-year overlapped time interval for CR and T since 1836, and 166-year overlapped time interval for TSI and T since 1850. The PFA performs estimation of 180 harmonics with the accuracy better than 0.0003 for CR, 0.01°C for T , and 5 mW/m^2 for TSI coefficients.

Results

a) FFT spectra

The FFT spectra of the time series (Fig. 5) have some common spectral parts, where the oscillations are with periods around 5, 6, 8, 9, 12, 20-30 and 100 years

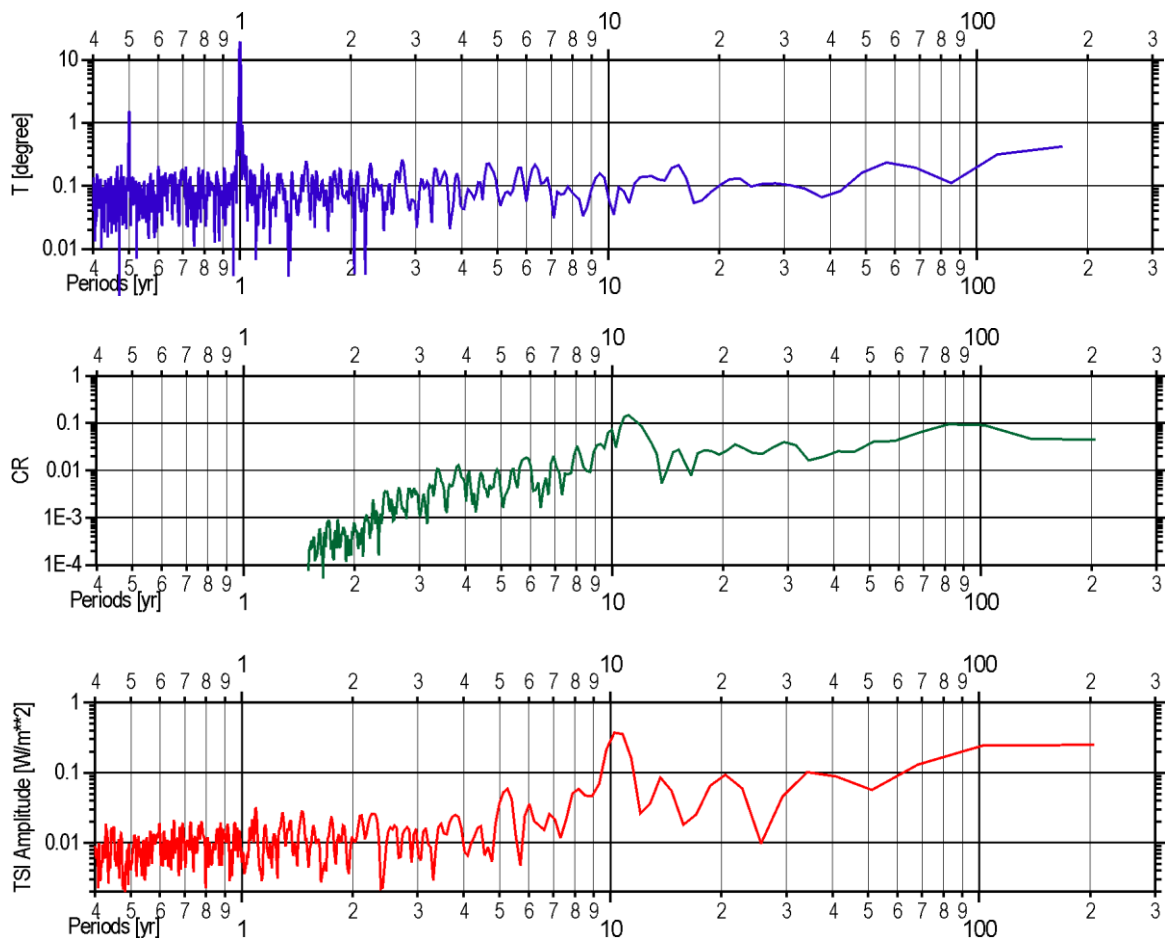


Fig.5. Spectra of CR, TSI and temperature variations, determined by FFT.

b) TSI influence on winter temperature of North Siberia

The TSI influences on oscillations of winter temperature variations in North Siberia are presented in 5 bands, whose periodicity is 6-10 years and 83---163 years (Fig. 6). The TSI drives long-term variations of winter temperature of North Siberia, where the minimal winter temperature rises by 5°C since 1836 (fig. 8).

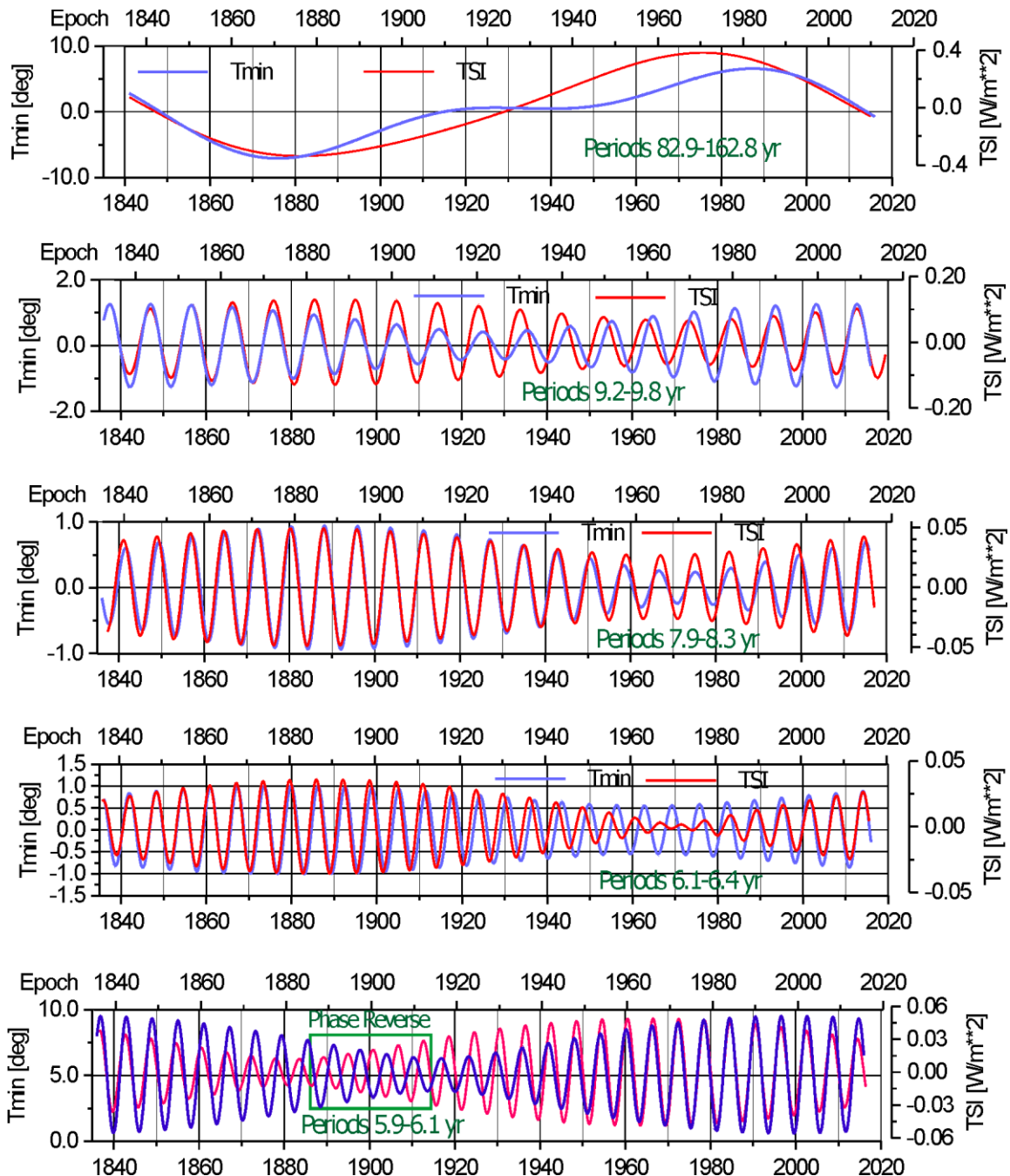


Fig.6. TSI influence on temperature of North Siberia.

c) CR influence on winter temperature of North Siberia

The CR influences on oscillations of winter temperature variations in North Siberia are presented in 5 interannual and decadal bands, whose periodicity is 6-36 years (Fig. 7). The CR and temperature cycles are almost identical for the periodicity below 15 years, while their decadal cycles with periods 30-45 years are partially correlated (Fig. 7).

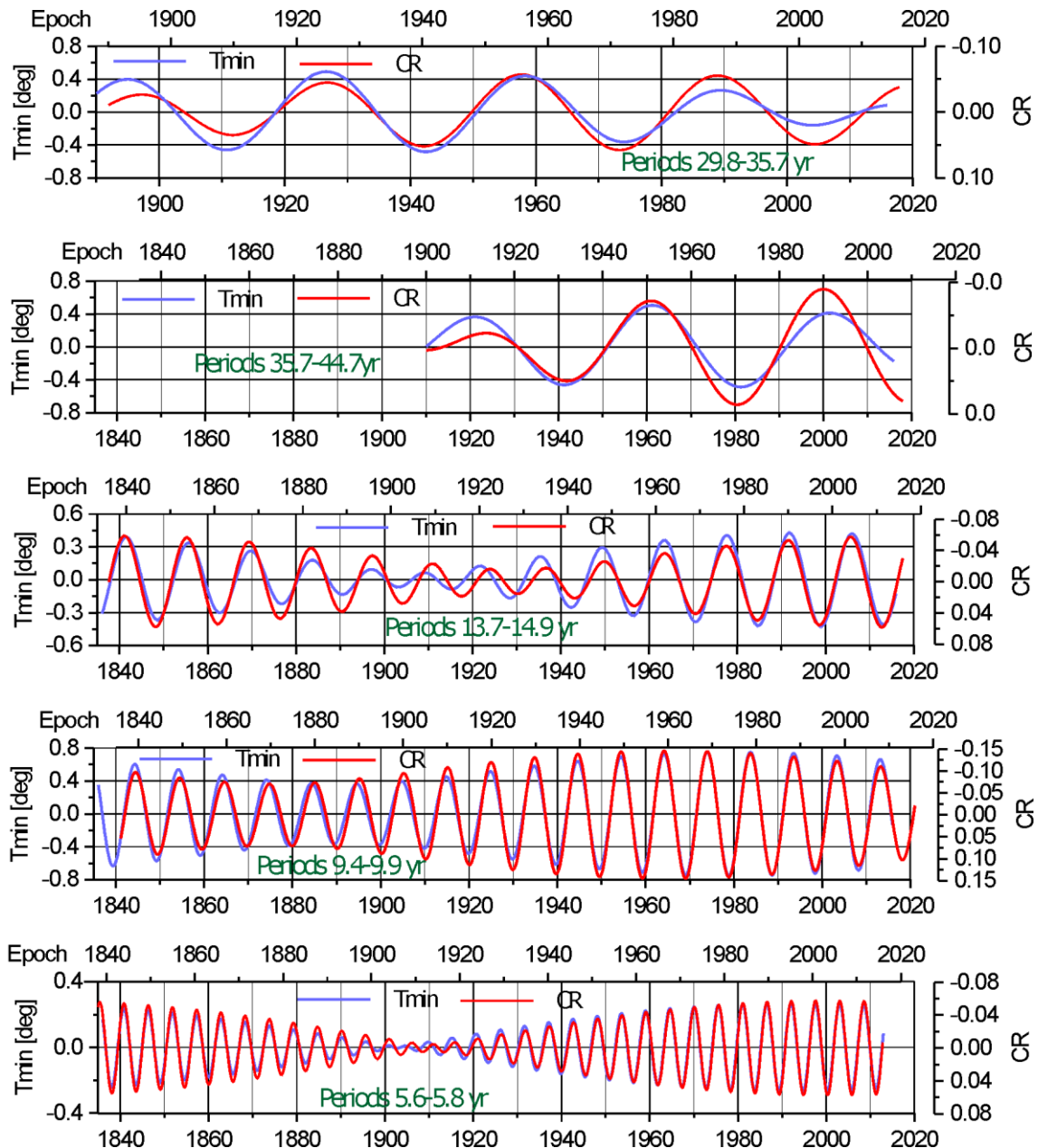


Fig.7. CR influence on temperature of North Siberia.

d) Minimal winter temperature variations and Earth orbit influence

By the definition the TSI represent the total solar energy falling orthogonally to the solar direction over 1 square meter in vacuum, outside the atmosphere in the space near the Earth orbit. The TSI depends on the distance between Earth and Sun, so it varies with annual period, because the Earth distance to the Sun are different at Perihelion and Aphelion. These distances are slowly change in time, due to eccentricity variations of Earth orbit. Laskar et al., (2011) determine that the Earth orbit eccentricity decreased by 0.0004 for the last 1000 years, so it is changed by -7.2×10^{-5} for the period 1836-2016. The Perihelion increased and the aphelion decreased by 0.0072% for this period, and corresponding change of TSI at these points is 0.014%, or 196 mW/m^2 . The Earth pass the Perihelion in the beginning of January and Aphelion – in the beginning of July, so, the TSI slowly decrease by 0.2 W/m^2 during the Winters since 1836. Nevertheless, the minimal Winter temperature increase by $+0.03 \div +0.06^\circ\text{C/yr}$ and this rate is not connected with the eccentricity change. The summer temperature is less changed, so

the visible decrease of annual amplitude of North Siberia temperature is mostly due to winter temperature rate (fig. 8).

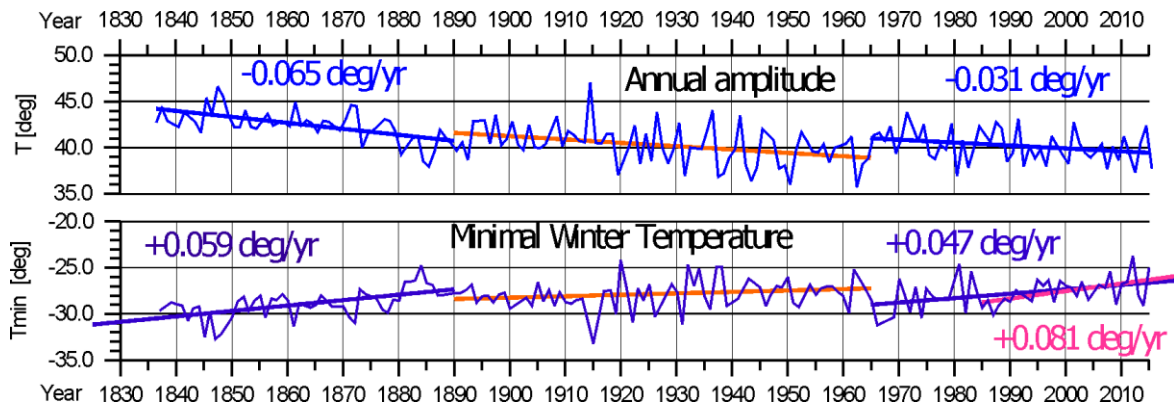


Fig.8. Time series of annual amplitude and minimal winter temperature variations in North Siberia..

Conclusions

The solar activity affects the temperature of North Siberia by means of TSI and cosmic rays variations. The TSI variations affect centennial cycle of Winter Siberia temperature and 4 sbdecadal cycles, while the CR variations affect 4 decadal and 1 subdecadal cycle. The TSI value decreases by 0.2 W/m^2 during the Winters since 1836, due to eccentricity and Perihelion change of Earth orbit, but this value is not essential for the positive trend $+0.03 \div +0.06^\circ\text{C/yr}$ of winter temperature. This trend, plus additional 0.08°C/yr since 1985 due to anthropogenic global warming, leads to 5°C/yr temperature rise up for the last 180 years without possible direct damage on methane from permafrost for next decades.

Acknowledgements

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