FIRST AND SECOND-ORDER TRENDS OF AIR TEMPERATURE AT THE SURFACE LEVEL FROM GLOBAL RADIOSONDE DATA

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Introduction

The information about temperature trends at the surface level determined from independent datasets is important in studying global climate change and solving practical problems. The paper presents long-term trends in the time series of temperature (T) and its variability (σ) at the surface level (1-st order trends) over the Globe and the estimates of their changes depending on the trend computing period (trends of the 2-nd order).

Data and methods

The calculations are based on the radiosonde data from the CARDS aerological dataset [1] that were updated by current data from datasets AROCTAB [2] and AROCTAC [3] for the observational period of 1964–2018. The data underwent a complex quality control procedure [1]. The necessary condition for including the global aerological network station in the research was 15-year observations for the full period including 2018. The dataset from 774 stations of the global aerological network was formed after several stages of data proceeding. About 18794 thousand observations were used in this research.

The linear approximation $\tilde{T}(t,t_0,t_1)$ for the temperature $T(t)$ in the time interval $t \in [t_0,t_1]$:

$$\tilde{T}(t,t_0,t_1) = a_1(t_0,t_1)\cdot t + b_1(t_0,t_1), \quad t_0 \le t \le t_1$$

minimizes

$$\int_{t_0}^{t_1} \left(\tilde{T}(t,t_0,t_1) - T(t)\right)^2 \cdot dt \to \min .$$

The coefficient $a_1(t_0,t_1)$ is the 1-st order trend. It indicates the average rate of $T(t)$ changes in the studied time interval $[t_0,t_1]$ and corresponds to the classical linear trend. How does the rate of $T(t)$ changes depend on the initial point t_0 as it approaches the fixed end t_1 of the time interval?

The same procedure of linear approximation is applied to the 1-st order trends $a_1(\tau,t_1)$:

$$\tilde{a}_1(\tau,t_0,t_1) = a_2(t_0,t_1)\cdot \tau + b_2(t_0,t_1), \quad \tau \in [t_0,t_1].$$

The coefficient $a_2(t_0,t_1)$ is the 2-nd order trend. It indicates the average rate of the 1-st order trend changes depending on how close is the initial point t_0 to the fixed end t_1 of the time interval $[t_0,t_1]$, i.e. $a_2(t_0,t_1)$ shows the average acceleration of $T(t)$ changes with respect to the fixed end point t_1.

The trends were estimated for each of 774 stations. The monthly anomalies and their variability were calculated with respect to the long-term monthly mean values T for the full period. The values obtained for each station were annually averaged taking into account the area of the station influence.

Results

Figure 1 shows the 1-st order (a) and the 2-nd order (b) trends for the time series of the annual mean temperature anomalies and smoothed approximations of the corresponding time series. The linear trends of the 1-st and the 2-nd order for the entire period are equal to 0.12 C°·Dec^{-1} and 0.054 C°·Dec^{-2}, respectively. Figure 1 also shows the 1-st order (c) and the 2-nd

order (d) trends for the time series of mean annual monthly variability of T, they are equal to -0.053 $C^{o}\cdot Dec^{-1}$ (Figure 1c) and 0.016 $C^{o}\cdot Dec^{-2}$ (Figure 1d). All these trends are determinated with the significance of 99%.

Conclusions

The real global warming at the ground surface (Figure 1a) is detected along with the temperature variability decrease (Figure 1c); the corresponding 1-st order trends are positive and negative, respectively. According to Figure 1b (see blue line), the most significant increase in the warming rate is detected beginning in 2002. According to Figure 1d (see blue line), the 1-st order trends of temperature variability, being negative, turn to positive values beginning in about 1991. As a result, the 2-nd order trend of temperature variability (green lines) becomes slightly positive.

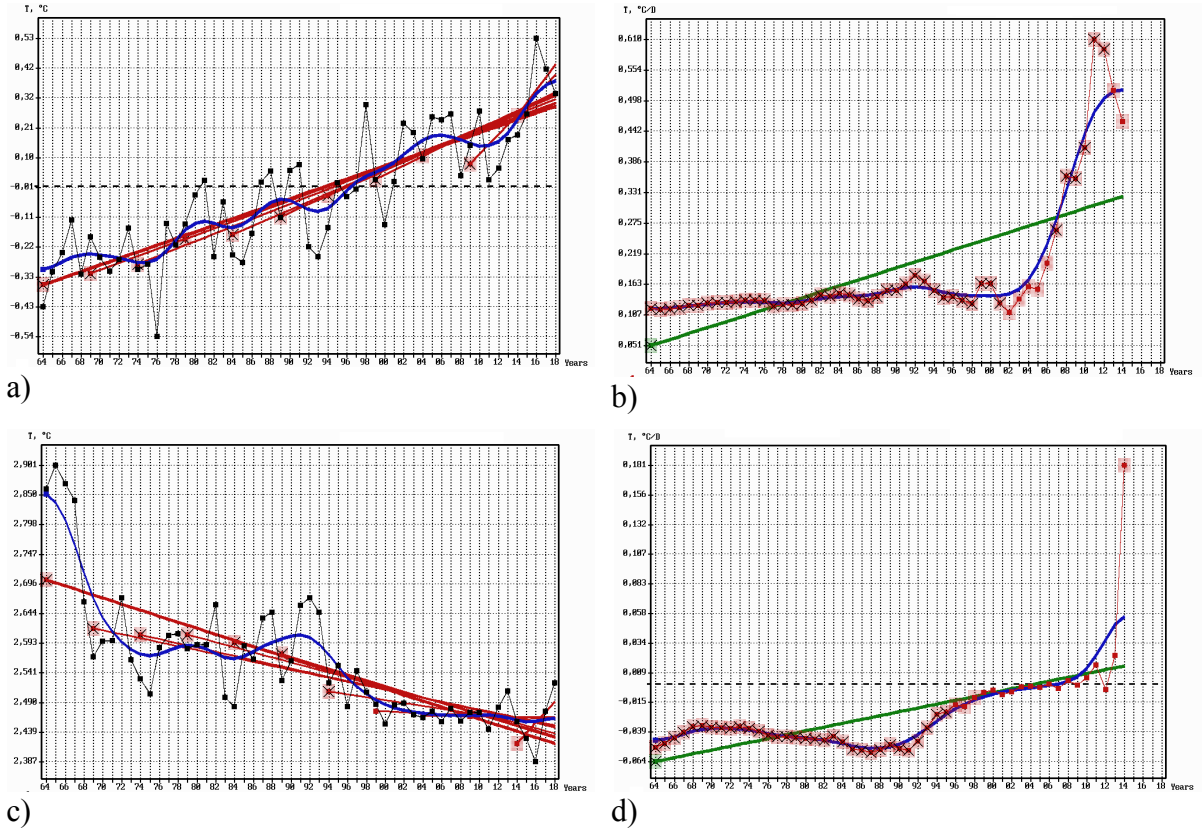

Figure 1. The 1-st and the 2-nd order trends for temperature - (a, b), for temperature variability (σ) - (c, d). Black points (a, c) are the observed annual time series, red lines (a, c) and red points (b, d) are the time series of the 1-st order trends for the corresponding periods with the 5-year step (a, c) and one-year step (b, d), blue lines are the relevant smoothed approximations of the time series, green lines (b, d) are the 2-nd order trends.

References

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