VERTICAL MACROSTRUCTURE OF FIRST- AND SECOND-ORDER TRENDS OF AIR TEMPERATURE IN THE 0-30-KM ATMOSPHERIC LAYER FROM RADIOSONDE OBSERVATIONS

O. A. Aldukhov and I. V. Chernykh

Russian Institute of Hydrometeorological Information – World Data Center, Obninsk, Russia, E-mail: aoa@meteo.ru, civ@meteo.ru,

Introduction

The knowledge about a vertical macrostructure of global trends of meteorological values in the atmosphere obtained from observations is necessary to study climate change. The paper presents the series of the first- and second-order trends [1] of air temperature (T) at standard heights in the 0–30-km atmospheric layer above sea level for different months, seasons and for the year as a whole. The goal of the paper and [1-5] is to show the longtime changes in the atmosphere for one period of radiosonde observations for the main aerological values.

Data and methods

Results of observations from the CARDS global aerological dataset [6] that were updated with current data [7] for the period 1964–2018 were used in this research. The required condition for the station to be included in this study was 15-year observations from the full observation period including 2018. The Akima cubic spline interpolation method was used to calculate T values and their standard deviations (σ_T) in the 0–30-km layer above sea level on the basis of standard pressure levels and specific points of vertical profiles. The linear trends were estimated for each station by using least squares method. The anomalies were computed with respect to the appropriate long-term mean values for the period 1964–2018. The statistics obtained for all stations were averaged taking into account the area of the station influence.

Results

The Figure shows a vertical macrostructure of long-term means and standard deviations σ_T, the first- and second-order trends for anomalies of temperature and σ_T in the studied atmospheric layer for different months, seasons and the whole year.

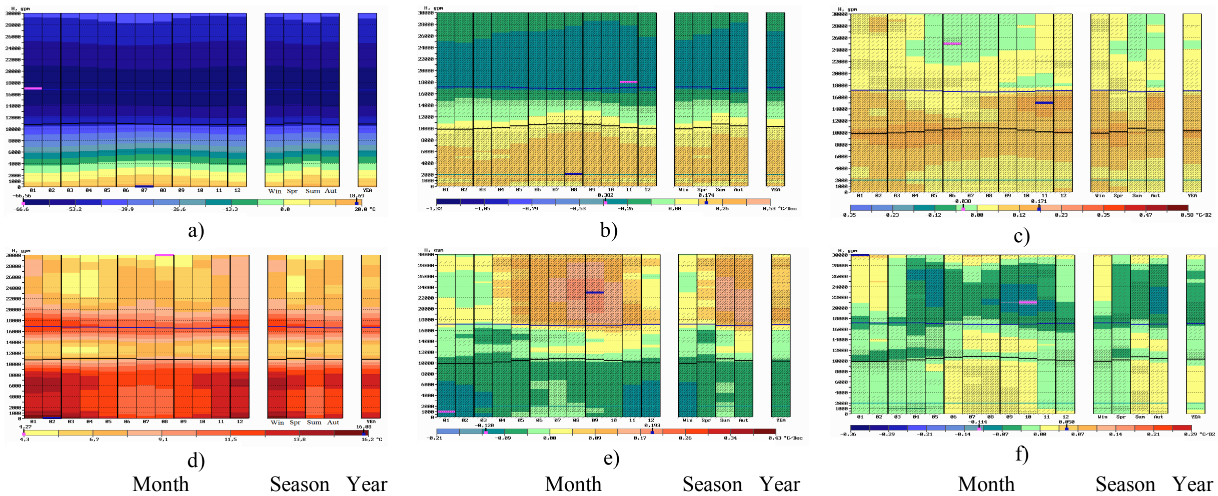

Figure. Long-term means (a, C°), first-order trends of anomalies of long-term means for T (b, C° per decade), second-order trends of anomalies of long-term means for T (c, C° per decade^2), and standard deviations (d), first-order (e) and second-order (f) trends of standard deviations in the 0–30-km layer for the year as a whole, for each month and season. Winter – DJF, spring – MMA, summer – JJA, autumn – SON. Blue and pink segments correspond to maximum and minimum values. The global statistics for months and seasons were subject to twofold smoothing. The three–points smoothing was used. Trends with significance of not less than 50% are marked by the sloping line segments and those with significance of not less than 95% – by lattice. 1964–2018.

The annual changes in the long-term monthly means of temperature T in the studied layer range from -66.56 to 18.69 C°. The minimum value of the monthly means of T was detected at 17 km in January, while the maximum value was detected at 0 km in July.

The annual changes of the first-order trends of the long-term monthly means anomalies in the 0–30-km layer range from -0.382 to 0.174 Cº per decade for T. The minimum value of the first-order trends was detected at 18 km in November, while the maximum value was found at 2 km in August. Warming in the 0–10-km layer and cooling in the 14–30-km layer were determined with significance of more than 95% for all months. The most intense warming was detected mostly throughout the 1–7-km layer for all months, as well as in the entire 0–1-km layer from September to April, and at 7–9-km, from July to August. The largest cooling was detected in the 17–25-km layer for all months and additionally in the 25-26-km, 25–27-km and 25–28-km layers in spring, summer and autumn, respectively. The first order trends (positive as well as negative) were detected only in the 10–13-km layer for all months with significance of less than 95%.

The annual changes in the second-order trends of the long-term monthly means anomalies in the 0–30-km layer range from -0.038 to 0.171 Cº per decade^2 for temperature. Minimum and maximum values of the second-order trends were detected at 25 km in June and at 15 km in November, respectively. The second-order trends of the long-term monthly means anomalies are positive mostly in the 0–17-km layer with significance of more than 95% for all months. This implies the acceleration of warming for cases with positive values of the first-order trends, while this implies the weakening of cooling for case with negative values of the first-order trends with the year 2018 approaching. The second-order trends were detected in the 17–30-km layer with significance of more than 50% and less than 95% for all months. For T, we see both positive values for the second-order trends in 17–30-km layer for winter, spring and autumn, and negative values in the 23–30-km layer from May to August. This means the weakening of cooling in the 17–30-km layer in winter, spring and autumn and its acceleration in the 23–30-km layer from May to August with the year 2018 approaching.

The annual changes in standard deviations σ_T range from 4.27 to 16.08 Cº. The minimum value of σ_T was detected at 30 km in August, while the maximum value was detected at 0 km in February. The annual changes in the first-order trends of σ_T range from -0.128 to 0.193 Cº per decade. The standard deviation decreases in the 0–10-km layer for all months, while in the 18–30-km layer, this increases from May to October with significance of more than 95%. The annual changes in the second-order trends of σ_T in the 0–30-km layer range from -0.114 to 0.050 Cº per decade^2. Negative values of the second-order trends of σ_T at 17-28 km from April to November imply the weakening of σ_T increase in this layer, while positive values of the second-order trends of σ_T in the 0-10-km layer from June to October imply the weakening of decrease σ_T in this layer with the year 2018 approaching.

Conclusions

The vertical macrostructures of the first-order and second-order linear trends of air temperature anomalies are not uniform in the 0–30 km atmospheric layer above sea level. The computations are based on global aerological datasets for the period 1964–2018. Warming at 0–10 km and cooling at 14–30 km were detected for all months. The highest acceleration in T changes was detected at 0-2 km and at 4-17 km in winter, at 0-1 km and at 4-14 km in spring, at 6-12 km in summer and at 6-17 km in autumn, at 5-16 km for the year as a whole with the year 2018 approaching. The corresponding trends were detected with significance of more than 95%.

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