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Temperature trends in the middle atmosphere as seen by historical Russian rocket launches: Part 2, Heiss Island (80.6°N, 58°E)

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Abstract

Long-term changes of the temperature of the middle atmosphere are investigated using a data bank obtained by Russian rocketsondes at Heiss Island (80.6°N, 58°E). The major interest of the data series is that it is one of the longest and uninterrupted records obtained at high latitudes in the northern hemisphere over 25 years, from 1969 to 1994. Previous estimates using this dataset has shown the largest trends. The revised analysis performed here took into account all possible discontinuities in the data series, such as a change in the time-of-measurement, T_0, and in the type of sensor. For this purpose, some data were filtered out, and a statistical model based on multiple regression analyses included step functions to take into account such discontinuities. The temperature responses to different sources of variability (solar activity, volcanic aerosols) were retrieved for summer and winter periods. The response to the 11-year solar cycle in the winter period is found to be largely positive in the stratosphere ($\sim+4$ K) and largely negative in the mesosphere (~-8 K), with a smaller and opposite response in summer. This response depends on the phase of the QBO, as already shown by previous studies. The response to volcanic aerosols is found to be significantly positive in the upper mesosphere, in good agreement with numerical simulations and with observations above France. The long-term trend resulting from this reanalysis indicates a cooling of the middle atmosphere, increasing with altitude from -2 K/decade at 40 km to a maximum of -6 K/decade around 65 km. This result is slightly larger than the trend observed at mid-latitude but quite smaller than previous estimates.

Keywords: Atmosphere; Temperature; Trend; Rockesonde; Solar-cycle

1. Introduction

Global change occurring in the Earth's upper atmosphere is attracting the attention of the research community in connection with the growing concern regarding its anthropogenic origin. The temperature of the middle atmosphere is expected to cool on a long-term basis due to the additional effects of the increase of greenhouse gases and ozone depletion. Several international efforts have been pursued to assess the quality of long-term temperature data series in order to quantify this

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cooling and to compare it with numerical models (Ramaswamy et al. (2001) for the stratosphere, Beig et al. (2003), for the mesosphere).

Historical rocketsonde series, extending over several decades, are unique to derive temperature profiles from the upper stratosphere to the mesosphere; several such series have been obtained by the US, Japan and USSR. These datasets have however exhibited limitations due to the changes of the sensor and of the time of the measurement (Keckhut et al., 1999; Keckhut and Kodera, 1999; Kubicki et al., 2006). Most of the available data series were obtained in the equatorial–tropical regions or in the mid-latitudes of the northern hemisphere. However, a valuable series has been obtained from January 1969 to March 1994 by the Central Aerological Observatory (CAO), at Heiss Island (80.6°N, 58°E) and has already been the object of several analysis (Kokin and Lysenko, 1994; Golitsyn et al., 1996). The major interest of the Heiss Island series is the fact that it is the only one located at high latitude in the northern polar region and this fact justifies this reanalysis. Because previous trend estimates are larger than the one observed at mid-latitudes and tropical latitudes, and it is quite an issue to understand if such an amplitude is real or can be caused by discontinuities in the series. A major effect that has not been taken into account previously is the one connected to tidal effects and changes of the time of the measurement. The other one is the instrumental discontinuities that have been corrected before using an a priori calculation. Here, we have applied an a posteriori estimate permitting an independent comparison with the previous calculations.

Similarly to the Volgograd series investigated in a previous companion paper (Kubicki et al., 2006), Heiss temperature series can be biased by tidal interferences (including instrumental bias related to solar zenith angles) due to numerous changes in the time of rocket launches, which has not been taken into account in the previous analysis . In this study, to eliminate such biases some data were filtered out, and a statistical model based on multiple regression analysis, including step functions to take into account potential discontinuities, was used to estimate the long-term changes of the temperature of the middle atmosphere over Heiss Island. In the first sections, the dataset and the analysis are described. Then the results concerning the different retrieved responses are presented. It includes temperature changes associated with stratospheric volcanic aerosols, the solar cycle and a linear trend. In the last section, results are discussed and compared with other results.

2. Data description

The dataset investigated in this study was obtained by temperature sensors flown on board the M-100B meteorological rockets, launched on a regular basis to provide atmospheric temperature profile above Heiss Island. The data archive extending from January 1969 to March 1994 (Fig. 1) includes more than 2200 vertical profiles (more than in the Volgograd series). The altitude range covered is 30–85 km and the vertical sampling is given at intervals of 1 km.

The datasets have been corrected using an altitude-dependent radiative correction. The values of the correction were provided from 50 to 75 km by CAO, and a linear interpolation was used to obtain temperature data at the other levels. However, the modification of the payload (both the size of the wire in the sensor and the way it was mounted), which occurred in October 1978, has induced a systematic difference that has not been taken into account in this correction. To take into account such a change, the time series for the first period (before the modification) needs to be adjusted to the

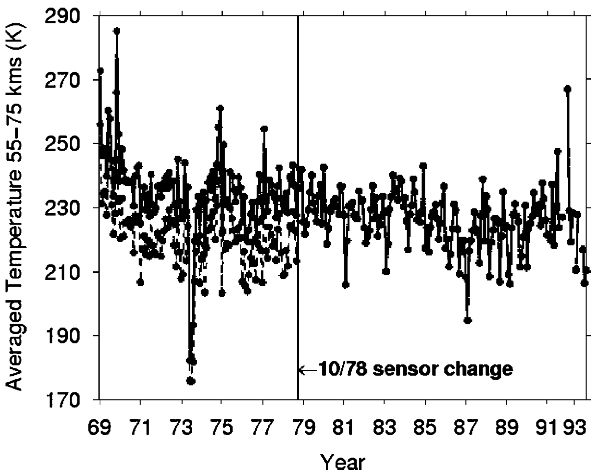

Fig. 1. Time series of the averaged temperature over the altitude range 55–75 km at Heiss Island from January 1969 to March 1994. A sensor change has occurred in October 1978. The raw dataset before the sensor change is plotted as a dashed line, and the corrected dataset suggested by CAO (Kokin and Lysenko, 1994) as a solid line. After the sensor change, no other correction has been applied.