Objective time-scale-dependent homogenization of early instrumental temperature series

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With 13 Figures

Received August 31, 2000
Revised October 22, 2001

Summary

An objective method for homogenization of early (pre ~1850) instrumental near surface air temperature records is developed. The method is grounded on the same variational principle as used in the objective analysis of meteorological fields; i.e., the method consists of a statistically optimal spatial-coherence-based adjustment of nearby station temperature records. The adjustments are made for several different ranges of time scales, where the wavelet transform is used for the decomposition. The method takes into account that early instrumental temperature records are supposed to contain observational disturbances which are more or less smooth functions of time as a result of summations of numerous sources of biases. The method differs from traditional homogenization techniques in that corrections are not only made for a discrete number of abrupt or linear changes, but for continuously changing errors. The power of the method is illustrated with an example of homogenization of three very long temperature records from Sweden.

1. Introduction

Early European instrumental near surface air temperature records, beginning in the 18th century, are important sources for our knowledge of the past climate. A few tenths of such long temperature records have been reconstructed from the observation registers by various climatologists, and have generally been published at monthly resolution. These records have been used in numerous studies of climate change (e.g., Jones and Bradley, 1992), although many problems with the homogeneity of the records remain unsolved. In particular, a consideration of the spatial coherence of the decade-to-century scale variations in the records give grounds for doubts about the data consistence. Because these low-frequency temperature variations are of considerable interest in the climate change problem, further efforts are needed in order to adjust the spatial coherence of the records, particularly at the low-frequency range in their earlier parts.

To develop a low-frequency adjustment technique, it is essential to take into account how temperature variations are interconnected in time and space. From numerous studies of the spatial structure of near surface air temperature fields (e.g., Gandin, 1965), we know that the spatial correlation of instantaneous temperatures decays down to 0.50 at distances of about 500–700 km. One can expect that the correlation-decay distances increase with an increased temporal smoothing of the data, i.e., the spatial coherence is larger at lower time frequencies. Unfortunately, rather few estimates of the spatial correlation of temporally averaged temperatures have been published. Schuurmans and Coops (1984) showed some results of between-station correlations
of seasonal mean temperatures estimated from data for 13 European stations for the period 1875–1975. One can conclude from their publication that the spatial correlation of seasonal temperature generally decreases down to 0.50 at distances of about 1000–2000 kilometers. The correlation-decay distance was also found to be smallest in summer, and largest in winter. Only mountain stations like Geneva showed essentially shorter correlation-decay distances of about 500 km. Briffa and Jones (1993) measured the spatial coherence of temperature changes around the globe using 5° lat × 5° long grid box annual and seasonal temperature anomalies for the period 1901–1990. Compared to other parts of the globe, spatial coherence was found to be relatively low in all seasons over the mid to high latitudes of the Northern Hemisphere and especially low in summer over the North Atlantic Region. They also found the correlation-decay distances to be generally higher for annual rather than seasonal data. Their results for Europe are in general agreement with those of Shuermans and Coops (1984). Jones and Bradley (1992) estimated the between-station correlations for 12 selected annual temperature records from stations in Europe, Asia and North America and with an average for the whole Northern Hemisphere. Correlations were calculated for the three periods 1851–1915, 1916–1980 and 1851–1980. For the longer period, correlations were also calculated for low-frequency temperature variations resulting from 10-year Gaussian filtered records. It turned out that correlations tend to be higher for the overall period and they are generally markedly higher for the low-pass filtered records. This fact may be considered as evidence of a rule, which we postulate; that the spatial temperature correlation increases with the degree of temporal smoothing. Another corroboration of this rule can be evidenced from a consideration of patterns and dynamics of the decadal temperature anomalies since the late nineteenth century (Parker et al., 1994). According to the results of Parker et al. (1994), the characteristic extent of the domains of the decadal temperature anomalies is of a subcontinental scale, and the period of their life-time is about 2–3 decades. It seems that only 6–8 domains of temperature anomalies over the whole Northern Hemisphere are preserved after a 40-to-50-year low-pass filtering of the temperature fields (see also Jones and Kelly, 1983).

With the aid of a wavelet-based technique Datsenko et al. (2001) estimated, using several central European temperature records for entire period (~250–300 years) of instrumental observations, that the distance for the decay of correlation down to the value 0.50 is about 1500 km, or even more, for 1-to-4-year long temperature variations. However – and this is important – the correlation-decay distances for interdecadal-scale temperature variations in these very long records turned out to be shorter. This contradiction to the rule postulated above is especially evident in the seasonal low-frequency variations of the earliest temperature observations for Central England and De Bilt (in The Netherlands). A similar decrease of the correlations with the Northern Hemisphere low-pass filtered temperature is also seen for some long station temperature records, for example Berlin (Jones and Bradley, 1992).

From the discussion above, one may conclude that; firstly, decade-to-century scale variations of the real temperature fields are more strongly correlated in space than instantaneous ones, and secondly, the reliability of low-frequency temperature variations as represented by early instrumental records (before ~1850) are questionable. Therefore, it is necessary to develop a method that can perform an adjustment of early instrumental temperature records, such that their between-station correlation with neighbouring records become more realistic, particularly at the low-frequency range. It seems natural to us that a decomposition of the temperature records of interest into several components, each depicting temperature variations at different time scales, is a useful prerequisite for such a method. For this purpose, the wavelet transform of the temperature series is an appropriate choice. To our knowledge, such a temporal scale-by-scale decomposition has not been used earlier for the purpose of homogenization of long instrumental records.

In a recent review, Peterson et al. (1998) summarized and discussed the most widely used homogenization methods. Different teams have developed different philosophies regarding data adjustment as their requirements and missions have been different. Several techniques, however, have in common that the isolation of the effects