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Atmospheric Research 37 (1995) 3–9

ATMOSPHERIC
RESEARCH

Maximum and minimum temperatures: a backward and a forward look

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Accepted 17 November 1994

Abstract

The effects of changing exposure of thermometers at land stations are reviewed, and the documented influences of instrumental changes in the late ninteenth and early twentieth century are presented, as well as some more recent cases. In general, the effect of improved thermometer exposure has been an apparent reduction in the diurnal temperature range, of several tenths °C. Careful intercomparisons, lasting several years, are therefore needed between present and proposed future instrumentation, if further artificial changes are to be avoided. Past data should be carefully compensated for changes of instrumentation and observing practices.

The analysis of monthly mean maximum and minimum temperatures is an insufficient basis for an understanding of current changes in diurnal range. Concomitant changes of cloudiness and wind strength should be analysed. Ideally, daily data should be stratified by cloud amount and wind strength so that radiative and advective influences can be assessed. Changes in diurnal range in calm, cloudless conditions may indicate changes in radiative balance owing to greenhouse gases and aerosols.

1. Introduction

Many of the papers published in this issue have extended the analyses of trends in maximum and minimum temperatures summarized in the 1992 IPCC Supplement (Folland et al., 1992). However, owing to limitations on availability of the data, most of this work has been confined to data for the last 50 years. But a 50-year period is inadequate for the assessment of long-term trends because there have been substantial natural climatic fluctuations on multidecadal to century timescales. Fig. 1 illustrates this problem for a variety of types of data. For some data, e.g. those from satellites, the brevity of the record remains unavoidable, but maximum and minimum temperatures were recorded worldwide back into the 19th century. These data are therefore of potentially great value, so long as they can be homogenised. The earlier data, taken in non-standard exposures (Parker, 1994) will require adjustment. This paper presents an overview of the task involved.

SSDI 0169-8095(94)00062-X

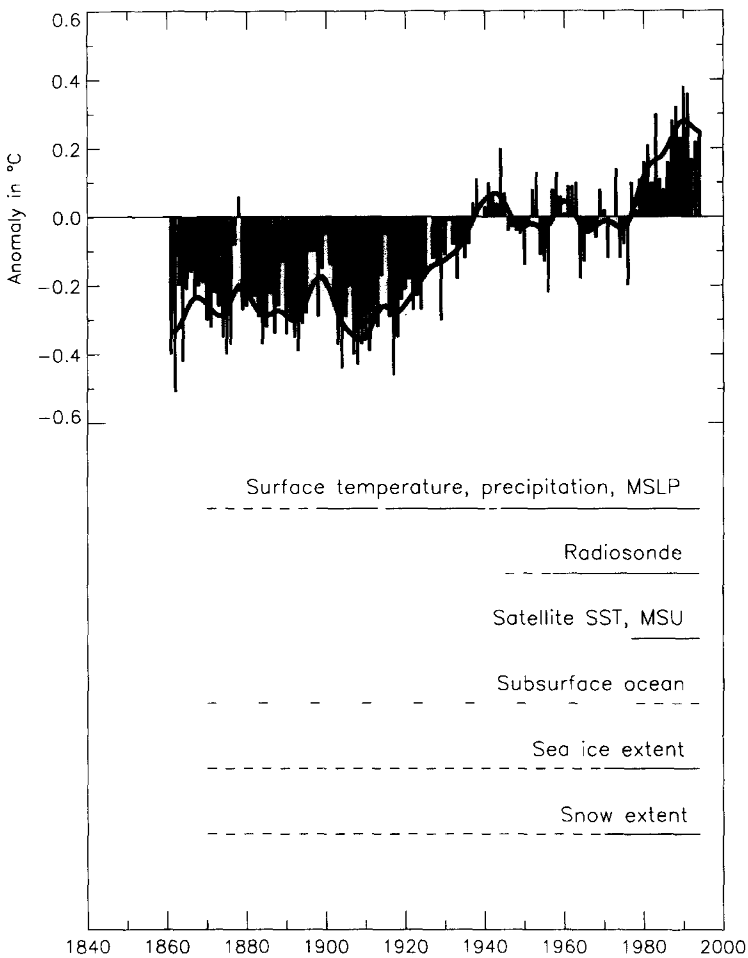

Fig. 1. Length of major data bases versus timescales of climatic variation. The time series is a revised update (to September 1994) of the IPCC (Folland et al., 1992) global surface temperature series. The smooth curve on the time series was created using a 21-term low-pass binomial filter. Dashes in the data-base histories represent sparser data. *MSLP* = mean sea level pressure, *SST* = sea surface temperature. *MSU* = microwave sounding unit.

Other papers in this issue also consider the need for joint analysis of maximum and minimum temperatures with other types of data. Only in this way can the results be verified and interpreted. In this paper, a few recommendations for future work are made.

2. Historical data

Many of the typical thermometer exposures used in the late nineteenth and early twentieth centuries are reviewed by Parker (1994), and fuller details for particular countries and locations are given in the bibliography cited therein. Parker (1994) also tabulated a variety

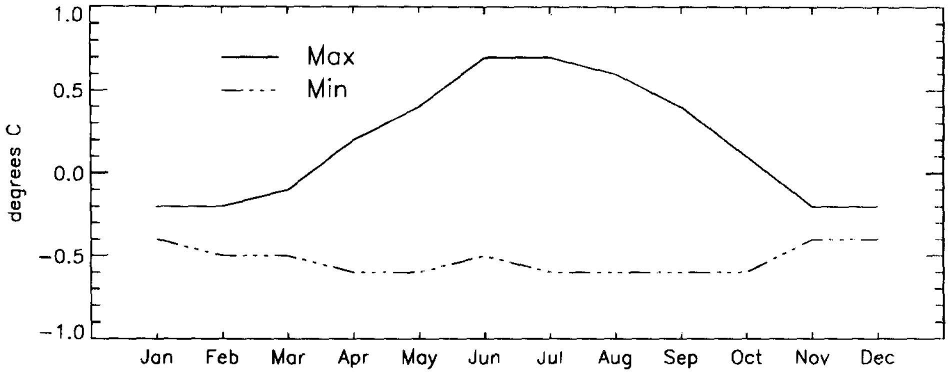

Fig. 2. Temperatures, Glaisher stand minus old-style Stevenson screen, London, 1881–1915 (Margary, 1924). The old-style Stevenson screen had an open base.

of experimentally-determined biases of historical exposures relative to Stevenson screens. Here, some of the same findings are presented graphically to emphasise the effects on diurnal ranges in recorded temperatures. The results can be used to estimate approximate adjustments to the early records.

Many early thermometer-stands were open to poleward, allowing reflected solar radiation to affect the thermometers by day, and permitting radiative heat-loss at night. As a result, recorded diurnal ranges were enhanced relative to what would have been measured in Stevenson screens (Figs. 2 and 3). The effect was greatest in summer. There were differences between types of thermometer-stand: for example, the night-time cooling evident in the Glaisher stand (Fig. 2; Margary, 1924) was not found in the French stand (Dettwiller, 1978). Also Young (1920) only found generally small biases in the USA's fruit-region shelter. His sample, however, was small.

Wild's apparatus, common in Russia and eastern and central Europe in the late nineteenth and early twentieth centuries, was more complex, consisting of a cylindrical shield inside a

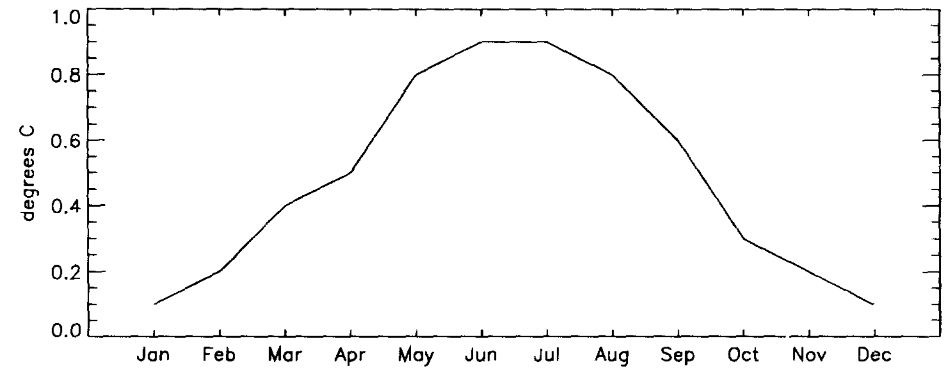

Fig. 3. Maximum temperatures, French screen minus new-style Stevenson screen, Paris, based on 50 years' data (Dettwiller, 1978). The new-style Stevenson screen has a base of staggered boards to limit radiation transfer while permitting ventilation. The performance of new and old style Stevenson screens differed very little (Parker, 1994).

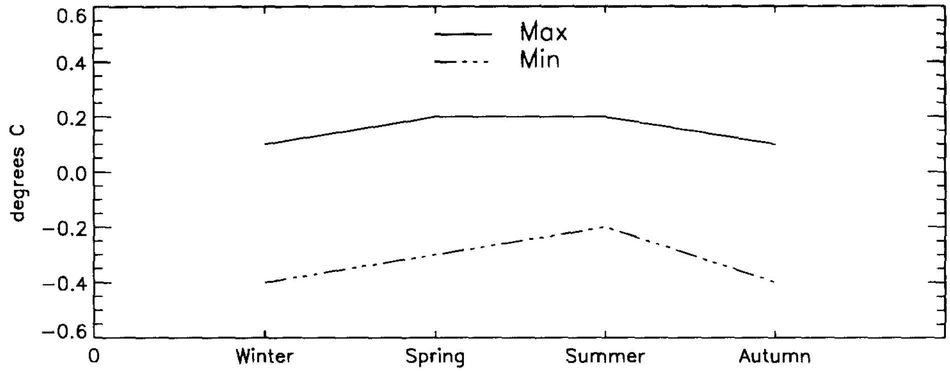

Fig. 4. Temperatures, Wild's screened shield minus old-style Stevenson screen, London, 1879–1881 (Whipple, 1883).

louvred screen. Parker (1994) provides illustrations. However, its biases also enhanced the recorded diurnal ranges (Fig. 4), though with less of an annual cycle than for the open stands.

In the tropics, thatched or felted sheds were common until the 1920's, the thermometers being suspended from the eaves in a cage, or fixed to a trellis in the shed. Receipt of reflected solar and emitted longwave radiation from the ground outside the shed made maxima too high relative to a Stevenson screen, and minima were also too high owing to retention of heat by the roofing material. According to the results of Field (1920) (Fig. 5a) diurnal ranges were slightly reduced on an annual average, but with some seasonal variation; Bamford (1928), however, obtained an enhanced diurnal range throughout the year (Fig. 5b). The biases will have been affected by the material used in the shed, by the reflection and emission properties of the ground outside it, and by the radiation and advection (wind) climate of the site. The results of all instrumental comparisons must be to some extent site-specific.

North-wall screened exposures yield reduced diurnal ranges (Fig. 6; Marriott, 1879). These exposures were common in much of central, northern and eastern Europe in the late nineteenth and early twentieth century, Russia before the 1870's, USA until 1890, Canada in the late nineteenth century (Parker, 1994).

Hazen (1885) examined unscreened north-wall exposures, which were common in the USA and Prussia until the early 1890's. His results were for fixed hours (as opposed to maxima and minima) and suggest a slight enhancement of the diurnal range. However, the results will have been dependent on the particular sites used, and generalizations must be made with caution.

Some old exposures have never been compared with Stevenson screens. A particular example is the Canadian screen and shed described by Kingston (1878) and illustrated by Parker (1994). Reconstruction of the apparatus, and a series of comparative measurements, have been recommended (Parker, 1994).

The above results show that in most, but not all, cases, apparent diurnal ranges were reduced by the introduction of new instrumentation.

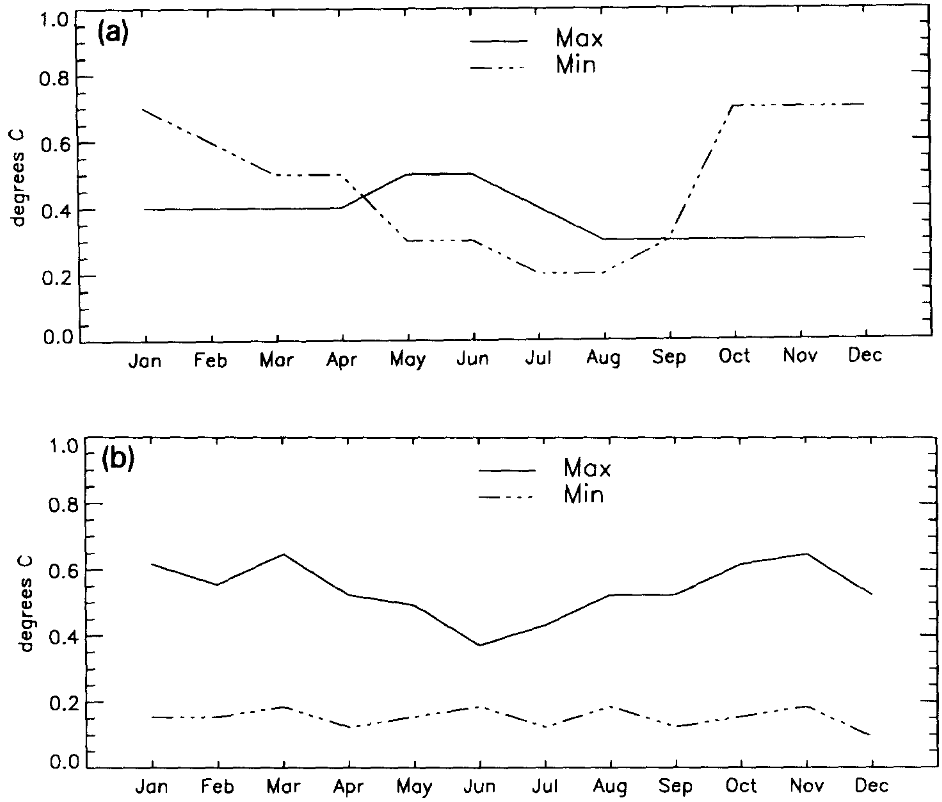

Fig. 5. (a) Temperatures, cage suspended beneath thatched shed minus new-style Stevenson screen, Agra (India), 1917–1918 (one year's data only) (Field, 1920). (b) Temperatures, trellis under felted shed minus open-based Stevenson screen, Colombo (Sri Lanka), 1923–1926 (Bamford, 1928).

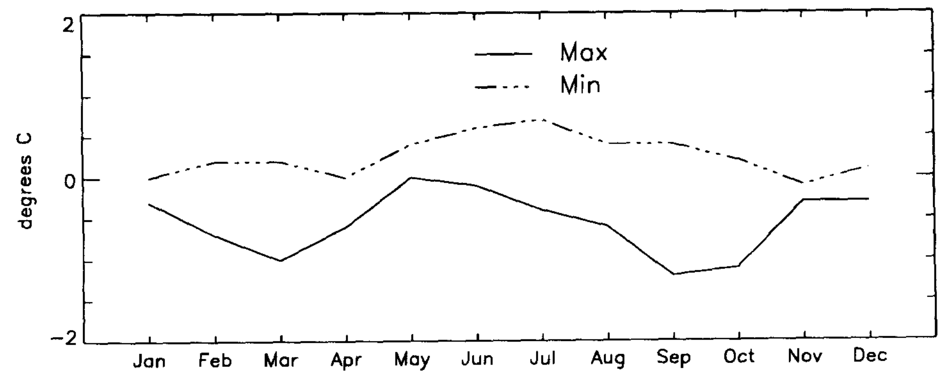

Fig. 6. Temperatures, north-wall screen minus old-style Stevenson screen, London, 1878–1879 (one year's data only) (Marriott, 1879).

3. Looking to the future

Not only historical data have been affected by instrumentally-induced biases. Quayle et al. (1991) presented a recent example: when thermistors were introduced at stations in the USA, observed diurnal ranges were reduced by 0.7°C. In contrast, Gall et al. (1992) ascribed recent extremely high maximum temperatures observed in Arizona to instrumental effects. Therefore, careful intercomparisons, lasting several years, are needed between present and any proposed future instrumentation, to avoid or compensate for such artificial changes.

Further verification of changes of diurnal range can be obtained by analysing concomitant changes of other variables, especially cloudiness, wind strength and humidity. Considerable work has already been done in this area (Karl et al., 1993; other papers in this issue). Ideally, daily data should be stratified by cloud amount and wind strength and humidity, so that radiative and advective influences can be assessed. Changes in diurnal range in calm, cloudless conditions may indicate changes in radiative balance owing to greenhouse gases and aerosols, so long as instrumental effects have been taken into account. The data-processing burden for this task will, however, be substantial; the cloud, wind and humidity data will require careful quality-control. Urbanization tends to reduce diurnal ranges: this will need to be taken into account, possibly with the aid of satellite data (Gallo et al., 1993).

The relationship between diurnal range and elevation could be investigated using a combination of conventional and satellite data (Johnson et al., 1993). Because the clear-sky greenhouse effect decreases with elevation, the results could be used to bound estimates of the direct influence of anthropogenic increases in the greenhouse effect on diurnal range. This would, of course, exclude indirect effects via changes in the atmospheric circulation, and other effects such as the increasing aerosol burden.

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