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A Need to Revisit Air Temperature Measurements in India in the 19th and Early 20th Centuries

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सार– यह शोधपत्र भारत में मौसम विज्ञान संबंधी अवलोकन प्रणाली में हुए दो बड़े बदलावों पर केंद्रित है। पहला 1870 के दशक के अंत में हुआ था जब भारतीय वेधशालाओं में थर्मामीटर शेड स्थापित किए गए थे, और दूसरा 1920 के दशक में जब थर्मामीटर शेड से स्टीवेंसन स्क्रीन में बदलाव हुआ था। शोधपत्र में डेटा में संभावित पूर्वाग्रहों की जांच करने और भारत पर अधिक विश्वसनीय और समरूप 150-वर्षीय तापमान रिकॉर्ड बनाने के लिए सुधार लागू करने की आवश्यकता व्यक्त की गई है।

ABSTRACT. The paper focuses on two major transitions that the meteorological observational system in India has undergone. The first was in the late 1870s when thermometer sheds were set up at Indian observatories, and the second in the 1920s when there was a changeover from thermometer sheds to Stevenson screens. The paper expresses the need to investigate possible biases in the data and apply corrections in order to construct a more credible and homogeneous 150-year temperature record over India.

Key words – Air temperature, historical data, thermometer shed, Stevenson screen.

1. Introduction

Graphs showing the steady increase of the global annual mean surface air temperature are being regularly updated as the years go by. They are also being extended backwards in time as older historical records become newly available. Many of the global warming graphs begin with the year 1900 (IMD, 2024) and some even with years like 1880 or 1850 (WMO, 2024). It is obvious that over such long periods, instruments at an observatory would have had to be replaced, the daily observation timings could have changed, the exposure might have got altered, or the observatory itself shifted to a new location. India is fortunate to possess some of the longest meteorological records in the world which are of immense value in studies of global warming and climate change. It would be of advantage to know the discontinuities that might have occurred in the data series and whether they are serious enough for bias corrections to be applied. The present paper focuses on two major transitions, first in the late 1870s when thermometer sheds were set up at Indian observatories, and second in the 1920s when there was a changeover from thermometer sheds to Stevenson screens.

2. Thermometer sheds in India

When the India Meteorological Department (IMD) was established in 1875, one of its top priorities was to standardize the meteorological instruments and observational practices followed at various observatories in India. At that time, 86 observatories were functioning in India (Blanford 1887). Many of these observatories were located in the sprawling compounds of army cantonments and civil establishments like hospitals, dak bungalows, posts and telegraph offices, colleges or even asylums and jails. So they generally enjoyed a good overall exposure and had greenery around. The staff at these establishments would help to serve as part time observers for a nominal fee. The thermometers were hung either in well-ventilated rooms or in the verandas of bungalows or a little outside in a shaded place. As a result, the thermometers did not always record the true temperature of the air circulating freely and their readings were possibly vitiated by the radiation from walls, floors and other sources. IMD therefore stipulated that all air thermometers be placed inside a shed or hut in the compound of the observatory and the dimensions of the hut should be as per prescribed specifications (Blanford, 1877).

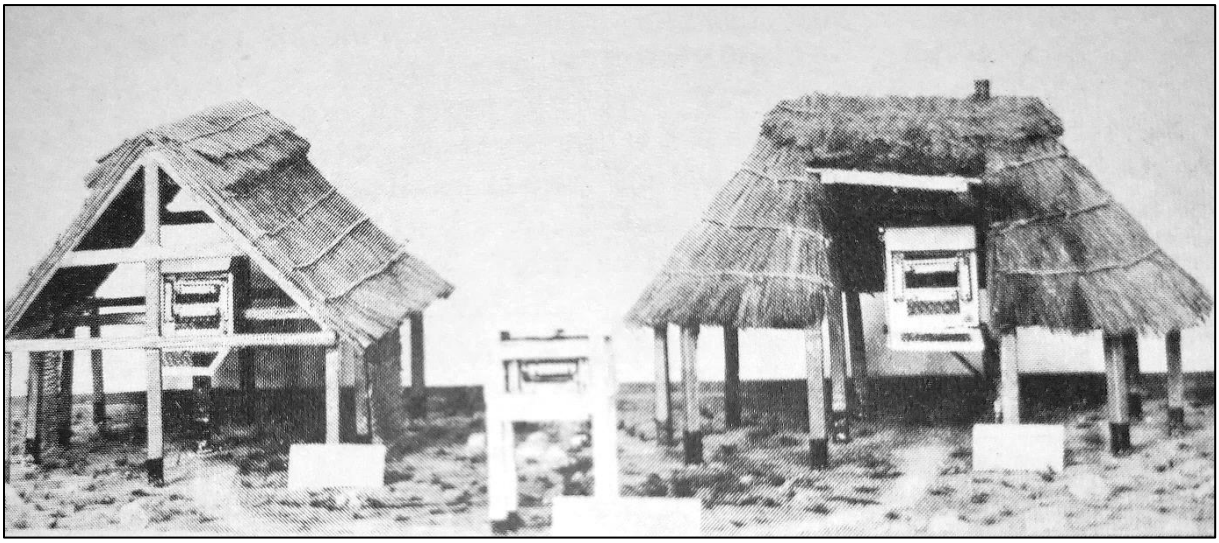

Fig. 1 Vintage photo of Bengal hut and Madras hut

Thermometers used for measuring air temperature must not only meet the usual requirements of instrumental accuracy and reliability but they also need to be placed in a specific type of environment. They have to be located sufficiently away from buildings or structures so that the air around them remains in free circulation. At the same time they have to be protected from the direct rays of the sun, and harsh weather like rain, snow or strong winds. They should not be in contact with or be close to walls or ground or such other external sources of radiation. Keeping all such requirements in view, IMD gave the following detailed instructions for constructing the thermometer shed:

The frame of the thermometer shed would be 18-20 ft (6 m) long and 14-16 ft (5 m) wide, well thatched above and open all round. It was to be erected in an open grassy place, at least 50 ft (15 m) away from any wall or a radiating surface, the ridge pole pointing north and south. It was to have an opening above to allow the heated air to escape. This opening was to be small, in the form of a section of a large bamboo, to serve as a ventilating pipe, inserted through the thatch immediately beyond the ridge pole. The cage containing the thermometers was to be affixed to the southern pole and facing the north. The eaves were to be 5-5.5 ft (1.5 m) above the ground. A vintage photograph of such a temperature shed (IMD, 1976) shows that it actually resembled a small hut with a thatched roof in which an observer would enter to take the readings (Fig. 1).

There were two types of thermometer sheds in use in IMD, known as the Bengal Hut and the Madras Hut, and while details are not available, the design differences between them may be assumed to have been inconsequential with regard to the temperature recorded. By 1885, the number of observatories in India and neighbouring territories under British rule had grown to 134 and most of them had proper thermometer sheds installed (Blanford, 1887).

3. Stevenson screen

At the time when British meteorologists were busy erecting thermometer sheds in India, efforts were being made in their home country to design a thermometer enclosure that would meet the required exposure conditions but would be much more compact and convenient. Thomas Stevenson, a civil engineer, and the father of the celebrated writer, Robert Louis Stevenson, had envisaged such a screen (Stevenson, 1864). It remained a subject of debate for a long time and it underwent several modifications and validations before earning its rightful place in British observatories (Mawley, 1884). By the end of the 19th century, observatories in several other countries had adopted the Stevenson screen, as it had come to be known after its designer. In the decade of the 1920s, IMD replaced all its thermometer sheds by Stevenson screens in keeping with global trends.

The Stevenson screen is like a wooden box standing on wooden pillars on a grassy patch of land. It is painted white in order to reflect sunlight. The sides have slits to allow air to enter and leave the box. The thermometers are installed vertically or horizontally on a frame inside. The box has a door that can be opened for taking the readings. It is so oriented that when the door is opened, the sun's rays will not fall on the thermometers. The recommended height of the screen (WMO, 1975) is around 4-6.5 ft (1.2-2 m), which keeps it beyond the reach of the ground radiation and

Fig. 2. A Stevenson screen

Fig. 3. Louvred screen in an automatic weather station

is also physically convenient for a human observer. Currently, Stevenson screens are installed at all surface meteorological observatories where the readings are taken manually (Fig. 2). In automatic weather stations which are set up in remote places or left unattended, digital sensors such as thermistors or platinum resistance thermometers, are likewise shielded by compact louvred covers (Fig. 3) which serve as miniature Stevenson screens. The Stevenson screens may vary slightly in their design from one country to another and louvred enclosures from one manufacturer to another, but their basic design concept is common to all.

4. Hong Kong Observatory

In the decade of the 1930s, temperature sheds got phased out of all observatories around the world. However, there is at least one place where a temperature shed still continues to be in operational use and that is at the Hong Kong Observatory (HKO, 2024). The Hong Kong Observatory was established in 1883 but even at that time it had thermometers mounted in a Stevenson screen (Lee,

Fig. 4. Thermometer shed at Hong Kong Observatory

2016). However, around 1889, a double roof palm-leaf thermometer shed, which was said to follow an Indian pattern, was constructed. The shelter covered 25 x 20 ft (7.6 m x 6.1 m), was 3 ft (0.9 m) high at the eaves, 9 ft (2.7 m) at the ridgepole, and had about 6 inches (15 cm) air space between the two roofs. This shed was destroyed by a typhoon in 1913 and another similar shed was erected at a different site in the observatory compound.

In 1933, a new thermometer shed was constructed again on the original site. It was a 20 x 15 ft (6.1 x 4.5 m) shelter with double palm-leaf roof extending to within 3 ft (0.9 m) of the ground on all sides except the north, which was left completely open. In 1959, the double palm-leaf roof of the open shed was replaced by a roof made of two separated layers of matting. In 1978, the shed was rebuilt and the Stevenson screen was also brought back. Since then, although the shed has been re-thatched or repaired periodically, its configuration has remained practically unchanged (Fig. 4). Currently the shed houses two sets of platinum resistance thermometers for measuring dry bulb and wet bulb temperatures. It is possible to have a virtual tour of the temperature shed of the Hong Kong observatory via the internet (HKO, 2024).

5. Implications and suggestions

Comparisons made in 1978 at the Hong Kong observatory (Chen, 1979) have shown that in tropical climates, the palm leaf shed readings are more representative than those made in a Stevenson screen. During these limited comparisons over a few months, the Stevenson screen readings were found to be systematically higher than the shed readings in daytime and lower at night. On days of bright sunshine and light wind, the screen temperatures were up to 1 deg C higher than the shed temperatures and 0.5 deg C lower on clear calm nights.

Since thermometer sheds were discontinued everywhere, such comparisons are not available for any other place. Chenoweth (1993) who examined the nonstandard exposures of thermometers in the U.S. in the 19th century estimated a positive bias of 0.2-0.3 deg C in the observations. Parker (1994) also found that the earliest extratropical data may have been biased typically 0.2 deg C warm in summer and by day, and similarly cold in winter and by night, relative to modern observations and there was a likely warm bias in the tropics in the early 20th century.

The effect of the changing exposure conditions of air thermometers remains a matter of lingering uncertainty when historical temperature data are merged into a long data series. The compatibility of air temperature measurements made in temperature sheds in the 19th and 20th centuries in India with present day Stevenson screen measurements has never been systematically assessed.

It may be worthwhile to carry out a field experiment in which a thermometer hut is newly built at a suitable site as per the IMD specifications of 1877 and simultaneous observations are taken in the hut as well as in a Stevenson screen in its vicinity over say a year or longer. A good site to do this may be the Atmospheric Research Testbed in Central India (ART-CI) set up recently at Bhopal by the Indian Institute of Tropical Meteorology, Pune. An analysis of the simultaneous observations may reveal whether there are any systematic differences. If any bias is indeed noticed, it will be worthwhile to revisit the temperature records of the 19th and early 20th centuries and apply the bias corrections to them to construct a more credible, continuous and homogeneous 150-year temperature record over India.

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