

What we can ask to hourly temperature recording. Part I: Statistical vs. meteorological meaning of minimum temperature

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Abstract: When the lowest temperature in 24-hourly time-spans is attributed to the nocturnal minimum, a systematic underestimation of the latter takes place, due to the missing contribution of warm nights that precede colder ones. This study, illustrated over one station, assesses the incidence of such bias in more than 20% of the cases, with a difference of 0.3 °C between the “standard” way of measuring minima, and the one which restricts the search of minima to the early hours of the day. The application of filters on the time band of search of minima is often mandatory for some temperature data processing, including the matching with meteorological and climate models.

Keywords: minimum temperature, hourly recording

Riassunto: L'attribuzione della temperatura più bassa nell'arco delle 24 ore alla temperatura minima notturna porta ad una sistematica sottostima di tale grandezza, dovuta al mancato contributo di notti calde che precedono notti più fredde. Lo studio, esemplificato in una stazione, quantifica l'incidenza di tale scarto in oltre il 20% dei casi, con una differenza di 0.3 °C tra il modo “standard” di misurare la minima e quello che prevede un'attribuzione limitata alla fascia delle prime ore del giorno. Tale accortezza è un passo spesso necessario per alcune elaborazioni, incluse quelle che richiedano confronti con modelli meteo-climatici.

Parole chiave: temperatura minima, registrazione oraria

According to the World Meteorological Organization, minimum temperature is the “lowest temperature attained during a specific time interval” (WMO, 1992). This definition is rather trivial, but consequences are less obvious when the “specific time interval” is one day. In figure 1, temperatures recorded at the meteorological station of S. Michele (Trento, Italy) during a winter day (27th December 2009) and the following morning are represented. The day began with a cloudy sky, followed by clearings, allowing a temperature rise during daytime. After sunset, strong outgoing radiation resulted in temperature fall, which continued during night. The meteorological database of the Fondazione Edmund Mach (FEM), like many others, records minimum daily temperatures as the lowest temperatures reached in each day, whose first record is taken at 0 AM (local time) and the last at 11 pm, each hourly record referring to measures taken in the previous 60'. The result of this setting, taken as it is, may be undesirable: the lowest value in the 24 hours of the day may be attributed to the (presumed) coldest period of the day - the early hours -, irrespective of the real recording time. In the example of figure 1, the same night (from 27th to 28th Dec.) is

accounted for twice, once for each day: the first at about half of the progressive night cooling, at the latest conventional time of day 27th (11 PM), the second one on the day 28th at 7 AM. On the contrary, the night between 26th and 27th Dec. does not contribute at all.

It may be argued that the case just discussed is an example and that this mechanism can hardly affect a long record. In order to ascertain possible effects of offsetting the measurement of average minimum night temperature, a long period of hourly recording was analyzed (27 years from 1983 to 2009). For each day, the times of occurrence of the lowest temperatures in all the 24-hour periods from 0 AM to 11 PM were calculated. The result is reported in figure 2. It can be seen that the proportion of times (hours) at which the minimum temperature is recorded increases until 7 AM, then decreases to negligible values in the second part of the morning. But after sunset it increases again, due to the presence of cold nights following warmer ones, and it reaches considerable values at 11 PM (in almost 12% of the days).

Now, let's accept the idea that attributing low temperatures that fall in the second part of the day to a day's minimum is incorrect (we will come back on this later). If this is case, the sum of all the incorrect attributions accounts for a non-negligible 22% of the whole dataset. The relevant bias, for the case of S. Michele, 1983-2009, can be

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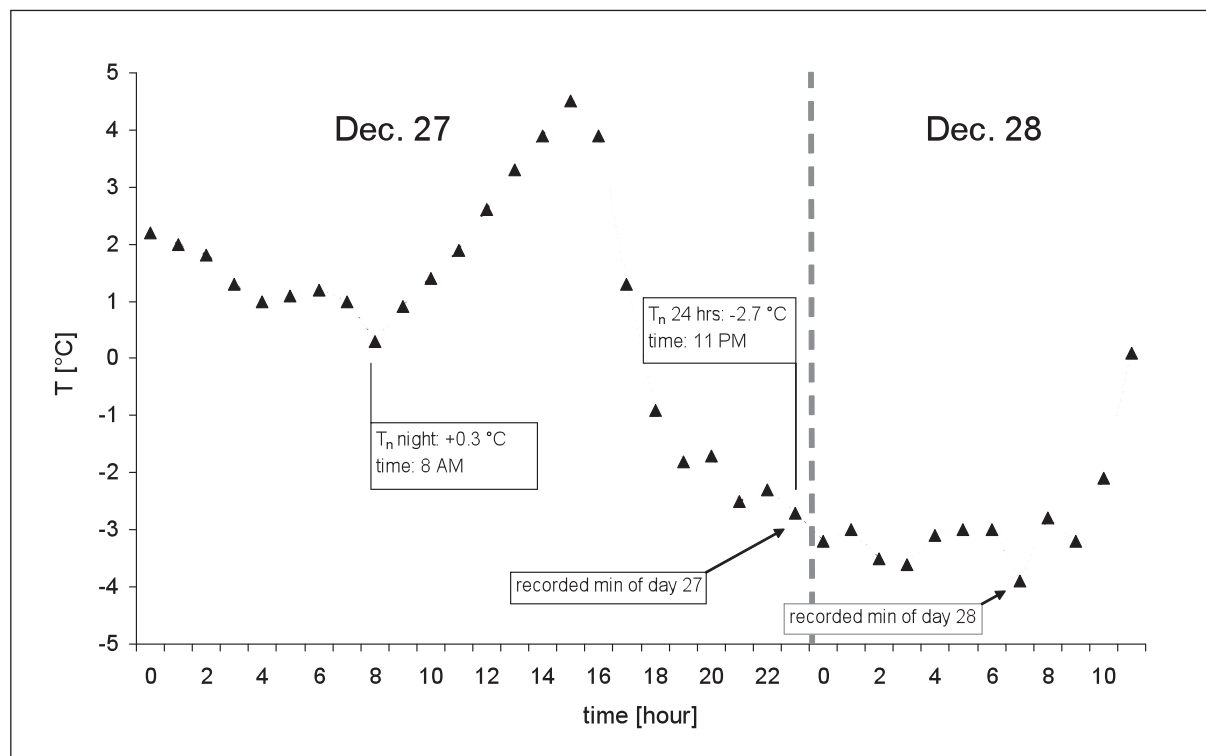


Fig. 1 - Mean hourly temperatures at S. Michele, 27th – 28th December 2009.
Fig. 1 - Temperature medie orarie a S. Michele, 27 – 28 dicembre 2009.

assessed in an average underestimation of minimum temperature of 0.3 °C. But single differences can be much larger, as shown in figure 3a, representing the departures from the “correct” estimation of minimum temperatures, that is, the

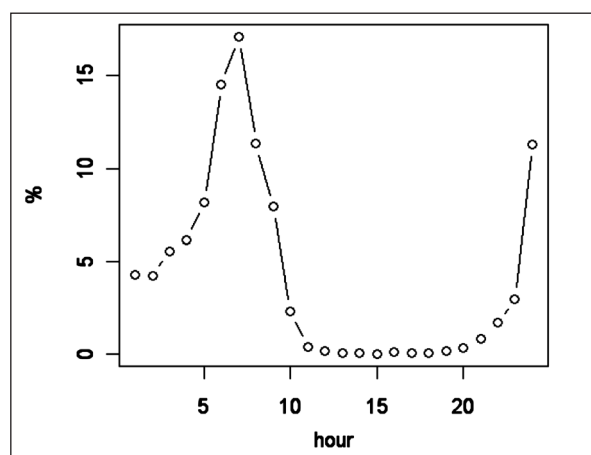


Fig. 2 – Station of S. Michele: mean times of occurrence of the lowest daily temperature calculated over the fixed 24-hour periods “0 AM – 12 PM”, 1983-2009.
Fig. 2 – Stazione di S. Michele: ore medie di registrazione della temperatura minima giornaliera calcolata su periodi prefissati di 24 ore “0 - 23”, 1983-2009.

differences in minimum daily temperatures measured according to the two standards (search either over the whole 24-hour period or over early morning hours). The graph in figure 3a is quite impressive, even if it includes a few cases for which only a few hours of recording were available; the latter is the cause of an error of attribution of minimum daily temperatures, irrespective of the lack of recording during the expected cold band of hours in the day. The boxplot of differences (Fig. 3b) shows that the Inter-Quartile Range (IQR) of bias is flattened onto values little different from zero, even if it displays a good number of cases well below the lower IQR boundary.

The discussion above stems from the assumption that minimum temperatures should be measured on a meteorological (i.e., physical) ground, rather than just on a statistical one. Namely, they have to represent the lowest temperatures attained during the cold period of the day. Spotting the lowest record over a 24-hour period is formally (and statistically) correct, but it clashes against the purely conventional definition of a “day” as the period from 0 AM to 12 PM – a convention that is very useful for the sake of organizational aspects in human life, but not for measuring nocturnal,

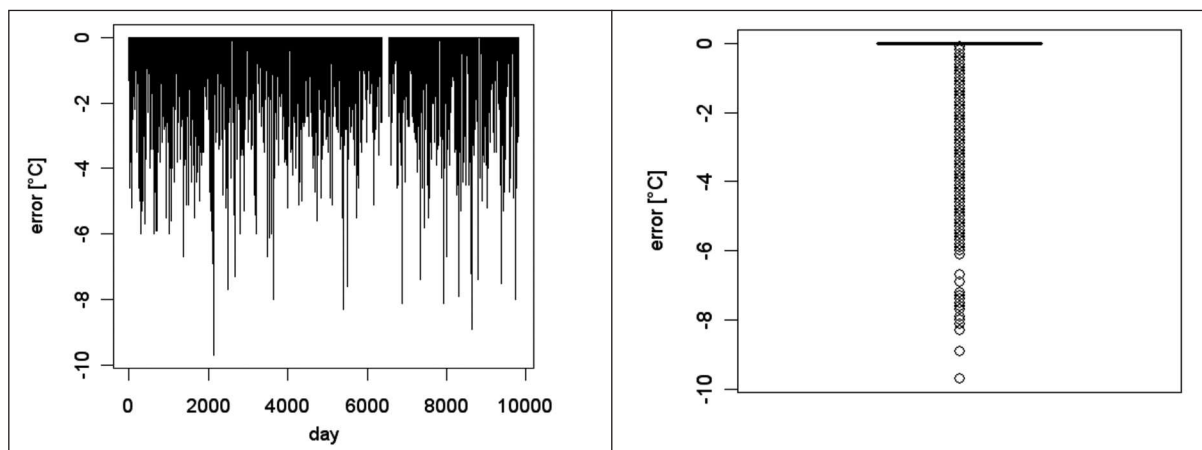


Fig. 3 – Station of S. Michele, 1983-2009. Bias of estimation of minimum temperatures when no filtering on hours is carried out, compared to the estimation in which the search of the minimum is restricted to the early hours of the day. a) Daily time series. b) Boxplot of the bias.

Fig. 3 – Stazione di S. Michele, 1983-2009. Scarto della stima della temperatura minima in assenza di filtri sulla fascia oraria, comparata con la stima in cui la ricerca della minima è limitata alle prime ore del giorno, 1983-2009. a) Serie giornaliera. b) Boxplot dell'errore.

natural phenomena, where the night should be kept as an unbroken unit.

Moreover, it must be remembered that, before the introduction of thermographs, temperatures were measured twice a day, minimum daily temperatures being recorded at morning; whether the minimum had been reached in the late hours of the previous day, or in the early hours of the current day, remained unknown to the observer, but the case was excluded of a minimum temperature of the day falling after midday. In long climatic series, neglecting this aspect may lead to a systematic underestimation of minima since the instrumental change. Finally, the choice of a minimum temperature really representing the lowest value of the cold period of the day is

mandatory when measured values are compared with model outputs, as is the case of calibration of models based on the match between observed and modelled temperatures.

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REFERENCE

WMO, 1992. International meteorological vocabulary. Geneva (CH), 784 pp.