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Short Communication

Response to the comments on 'time trends of daily maximum and minimum temperatures in Catalonia (NE Spain) for the period 1975–2004'

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ABSTRACT: Some comments published recently on a study of time trends of daily maximum and minimum temperatures, T_{max} and T_{min}, have generated certain controversy with respect to a specific property of the Standard Normal Homogeneity Test (SNHT) and the applicability of the absolute and relative versions of this test. New insights to both questions are introduced in the present response. Copyright © 2010 Royal Meteorological Society

KEY WORDS absolute SNHT test; relative SNHT test; transient phenomena

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1. Antecedents

A homogeneous time series is characterized by being submitted only to weather and climate variations, in such a way that it is free from strange signals generated by changes on measurement practices, instrument transitions, environmental changes on station surroundings and station relocations. Many methods and strategies have been proposed to achieve the desired homogeneity of the series, distinguishing between absolute and relative tests, the latter requiring some reference series. A wide variety of methods are summarised by Aguilar *et al.* (2003), while advantages and shortcomings of the different strategies are described by Petterson *et al.* (1998), Ducré-Robitaille *et al.* (2003), DeGaetano (2006) and Reeves *et al.* (2007).

Toreti *et al.* (2009) have introduced in their comments two specific questions concerning the Standard Normal Homogeneity Test (SNHT). On the one hand, on the basis of several numerical simulations, these authors state that performance of the SNHT detecting break points decays at the beginning and the end of the series. This statement could be debatable as Wijngaard *et al.* (2003) assumed a better performance of the SNHT at the beginning and the end of the series, in agreement with Hawkins (1977). On the other hand, the question regarding several aspects of the applicability and main objectives of the relative and absolute SNHT is developed next.

The selection of the optimal test is a decision of the climatologist, who achieves the homogenization of the series by means of a single efficient test (relative SNHT for instance) or tries to detect a break point by comparing the results of applying several appropriate tests, as for instance, absolute SNHT, and Buishand range, Pettitt and Von Neumann tests. These algorithms, widely discussed by Wijngaard *et al.* (2003), were applied by Martínez *et al.* (2009) with the aim of assessing the reliability of detected break points. Very recently, Mourato *et al.* (2009) have applied the same sequence of tests. Whereas the first three tests attempt to locate break points in the series, the fourth checks if data are randomly distributed or time trends are likely. Break points which are likely to be linked to natural phenomena or other causes were accepted by Martínez *et al.* (2009) only if at least two out of the three first tests were in agreement, as Wijngaard *et al.* (2003) proposed. Thus, by using several homogeneity tests, the performance of the absolute SNHT should be notably improved. Only two series were discarded because outstanding break points were not likely to be linked to natural causes.

Two natural phenomena assumed as the main reason for most of break points detected for T_{max} and T_{min} in a narrow range of years are the explosive volcanic eruptions of El Chinchón (Mexico, April 1982)

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and Mount Pinatubo (Philippines, June 1991). Some details should be briefly introduced for a better understanding of the effects of these volcanic eruptions on series of temperatures. For example, after the Mount Pinatubo episode, the average global temperature in July, 1992 decreased by almost 0.8 °C with respect to the 1981–1990 average (Ahrens, 1994). Explosive volcanic eruptions greatly increase the concentration of sulphate aerosols, resulting in a short-lived (2–3 years) negative radiative forcing and cooling global mean climate for a few years (IPCC, 2007). At local and regional scales this cooling process may keep masked by other causes, as wind regimes along the year, without an outstanding decrease of the annual average temperatures. Nevertheless, at large scale the effects of explosive eruptions become evident, as can be observed in the Northern Hemisphere annual combined land-surface air temperatures since 1850 to 2006 (IPCC, 2007; p.249).

An explosive volcanic eruption can be assumed as a transient climatic factor creating step-wise shifts in the climatic series, which are able to be detected by the absolute SNHT, Buishand and Pettitt tests. Detection and identification of these shifts could become complicated if other non-natural phenomena generate more breaking points and, additionally, the probability of detecting a break point is not uniformly distributed along the series, as Hawkins (1977) proved. Assuming a natural phenomenon modifying the global temperature regime for a short period, it has to be accepted that the reference series and those to be verified by the relative SNHT (Alexandersson and Moberg, 1997; Pandžič and Lisko, 2009) must depict quite similar break points due to the mentioned natural phenomenon. Thus, it should be expected that the relative SNHT would not be able to detect the effect of a transient climatic factor. Nevertheless, some examples comparing performance of absolute and relative tests in the next section suggest that a variety of results of the relative SNHT are expected, depending on the characteristics of the checked and the reference series.

Another question that deserves consideration is the correction of series in the case of lack of homogeneity. As Petterson *et al.* (1998) propose, "It is better not to adjust than to erroneously adjust, since some adjustments can actually make the data more biased than if no adjustment has been applied". Brunetti *et al.* (2006) share this opinion, pointing out the necessity of metadata and more reference series to validate the estimates as coherent, also requiring a scattering around the mean value lower than the break amount. According to these authors, Martínez *et al.* (2009), after applying absolute SNHT, and Buishand and Pettitt tests, accepted series with breaks very likely associated to transient natural phenomena and small breaks due to other non-climatic factors. In this way, trends deduced by Martínez *et al.* (2009) could partially depend on explosive volcanic eruptions, which are natural phenomena governing short period climate variations, and would be slightly perturbed in some cases by the effect of the accepted small breaks. A revision of the performance offered by the relative SNHT (next section) advises against attempting a homogenization process of the temperature data set, at least for this specific dataset.

2. Examples of relative/absolute SNHT performance

The performance of the relative SNHT for detecting break points is compared with that of the absolute SNHT with the aim of observing if the effects of natural phenomena affecting some temperature series disappear with the relative test. Two stations (Ebro, EBR, and Fabra, FBR, Observatories) have been chosen as reference for the relative SNHT given that their recording continuity is assured, right measurement practices are guaranteed along the whole 20th century and environmental changes around the respective locations are not very remarkable, especially for the Ebro Observatory.

Figure 1 depicts the evolution of the absolute SNHT statistic for the series of T_{max} and T_{min} at EBR (code 75) and FBR (code 77). A notable peak of the statistic immediately after 1991 Mount Pinatubo eruption is detected for T_{max} at EBR. Similarly, the El Chinchón effect is observed after 1982 due to the outstanding peak for T_{min} at FBR. In addition to these two features, other less relevant peaks, also exceeding 95% confidence level, are observed. Thus, the performance of the relative SNHT should be characterised by the lack of break points linked to both volcanic eruptions and, sometimes, the detection of lower order peaks after removing these natural effects. It has to be taken into account that, as Alexandersson and Moberg (1997) showed, signals affected by combined trends and shifts produce a complex evolution of the statistic. The success of the relative SNHT is not guaranteed then. Table I summarises the main features of the relative SNHT performance compared with the absolute SNHT, for T_{max} and T_{min} series from 37 stations. It has to be considered that a total of 35 temperature series with outstanding breaks related to natural phenomena, detected by the absolute SNHT, have been analysed with the relative SNHT. As a result, only 2 out of these 35 peaks remain after the relative SNHT.

Figure 2 shows some examples of the statistic for the absolute and relative SNHT. Whereas for the first two examples the breaks assumed to be linked to the effects of the natural phenomenon of Mount Pinatubo eruption disappear after the relative SNHT, in the third example this break disappears, but the peak close to 1982 remains. Finally, in the last example, the possible effects of the El Chinchón eruption disappear but a possible break before 1980 remains.

In short, given the characteristics of the absolute SNHT statistic for EBR and FBR, a complete success consisting on disappearance of all signs of natural phenomenon effects should not be expected. Additionally, temperature

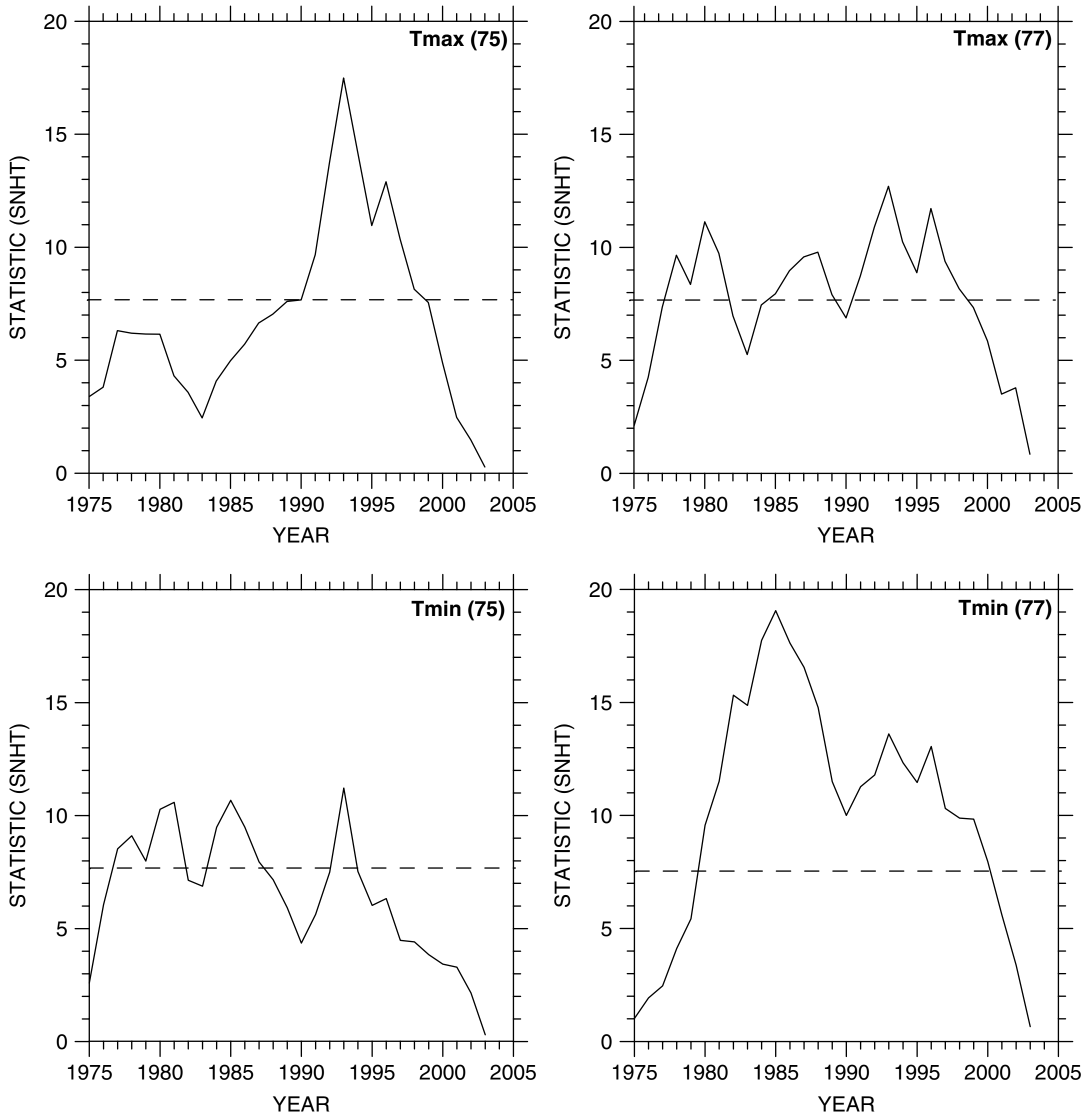

Figure 1. Annual evolution of the absolute SNHT statistic for stations EBR (code 75) and FBR (code 77). Dashed lines depict the 95% confidence level for the statistic.

Table I. Number of relevant break points linked to El Chinchón and Mount Pinatubo eruptions.

	T_{max}		T_{min}	
	El Chinchón	Mount Pinatubo	El Chinchón	Mount Pinatubo
Detected according to the absolute SNHT	3	12	15	5
Removed	2	8	8	2
Remaining	1	0	1	0
Shifted to another year after the relative SNHT	0	4	6	3

series could be locally affected by natural phenomena as well as wrong instrumental practice, environment changes and other disturbances. Nevertheless, the ratio of peaks detected by the absolute SNHT which can be related to natural phenomena that disappear after applying the relative SNHT is remarkable (Table I), especially for Mount Pinatubo on T_{max} and for El Chinchón on T_{min}.

3. Conclusions

Questions regarding the absolute and relative SNHT could be summarised as follows:

1. The performance of the absolute SNHT for detecting break points at the beginning, the end and in the middle of the series is debatable and decisions taken

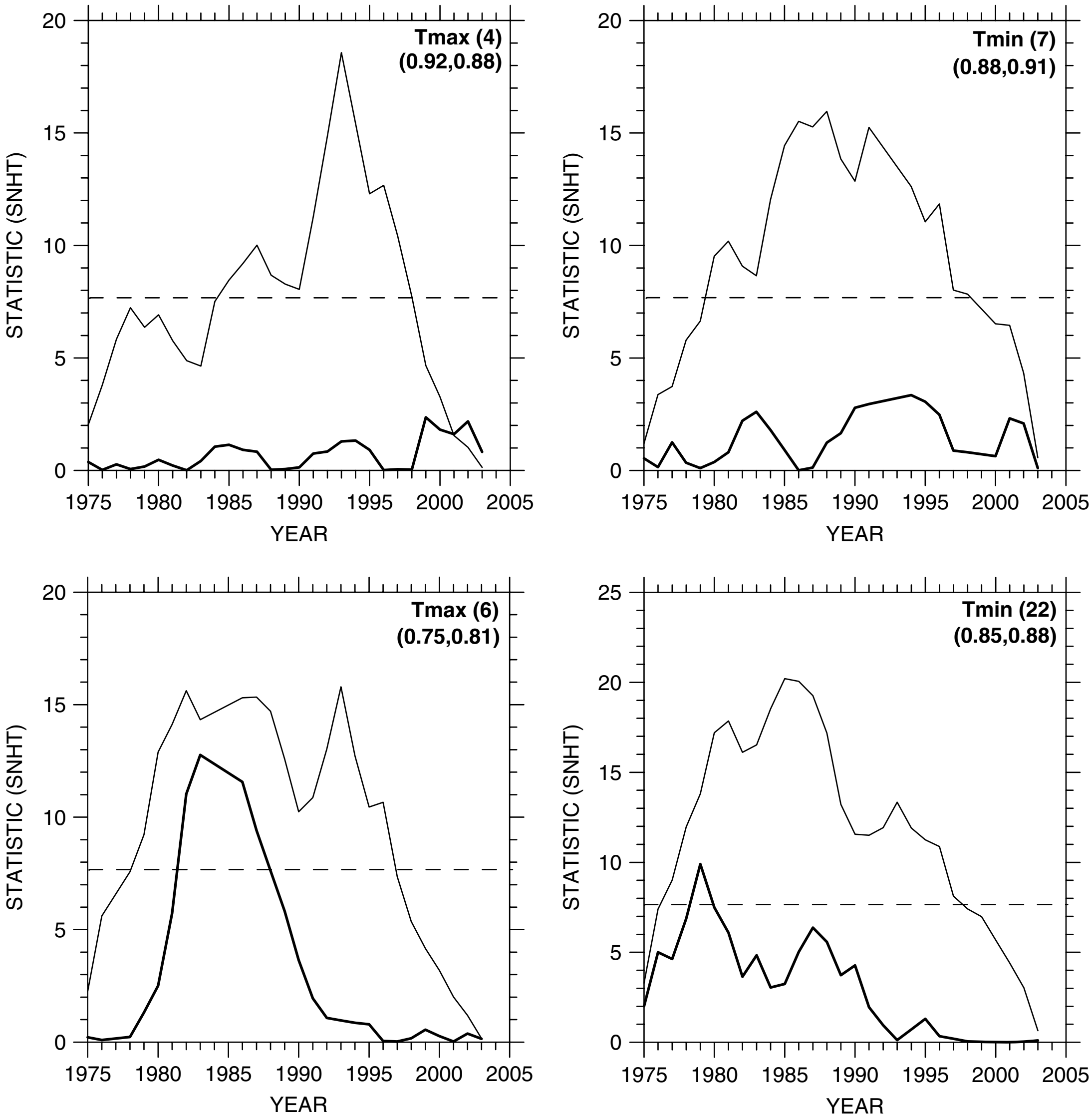

Figure 2. Four examples of the annual evolution of the absolute (thin line) and relative (thick line) SNHT statistic. Dashed lines depict the 95% confidence level for the statistic. Correlation coefficients with observatories EBR and FBR are included within parentheses.

with the absolute SNHT should be confirmed or rejected by the Buishand and Pettitt tests.

2. The absolute SNHT is able to detect the effects of transient natural phenomena, as well as changes on measurement practices or devices, and environmental changes on station surroundings.
3. The capability of the relative SNHT for removing natural phenomenon breaks would be strongly dependent on the behaviour of the absolute SNHT statistic of the reference series and on the correlation coefficient between checked and reference series. Thus, the success of the relative SNHT removing transient natural phenomena is conditioned by the selected reference series and their quality.

In short, if the goal is to apply a homogenization process to the series, an appropriate option could be the relative SNHT, in spite of some shortcomings. Nevertheless, if the objective is accepting or rejecting a climatic series for additional analyses, the absolute SNHT, together with the Buishand and Pettitt tests, would be the recommended procedure because the effects of transient natural phenomena would be detected and preserved.

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References

Aguilar E, Auer I, Brunet M, Peterson TC, Wieringa J. 2003. *"Guidelines on Climate Metadata and Homogenization"*, World Meteorological Organization: Geneva, WCDMP-No. 53, WMO-TD No. 1186.

Ahrens CD. 1994. *Meteorology Today*. West Publishing Co.: Minneapolis/St. Paul, 591.

Alexandersson H, Moberg A. 1997. Homogenization of Swedish temperature data. Part I: homogeneity test for linear trends. *International Journal of Climatology* **17**: 25–34.

Brunetti M, Maugeri M, Monti F, Nanni T. 2006. Temperature and precipitation variability in Italy in the last two centuries from homogenised instrumental time series. *International Journal of Climatology* **26**: 345–381.

DeGaetano AT. 2006. Attributes of several methods for detecting discontinuities in mean temperature series. *Journal of Climate* **19**: 838–853.

Ducré-Robitaille JF, Vincent LA, Boulet G. 2003. Comparison of techniques for detection of discontinuities in temperature series. *International Journal of Climatology* **23**: 1087–1101.

Hawkins DM. 1977. Testing a sequence of observations for a shift in location. *Journal of the American Statistical Association* **72**(357): 180–186.

IPCC. 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds). Cambridge University Press: Cambridge, United Kingdom and New York, NT, USA, 996.

Martínez MD, Serra C, Burgueño A, Lana X. 2009. Time trends of daily maximum and minimum temperatures in Catalonia (NE Spain) for the period 1975–2004.*International Journal of Climatology*. DOI: 10.1002/joc.1884.

Mourato S, Moreira M, Corte-Real B. 2009. Interannual variability of precipitation distribution patterns in Southern Portugal. *International Journal of Climatology*. DOI:10.1002/joc.2021.

Pandžič K, Lisko T. 2009. Homogeneity of average annual air temperature series for Croatia. *International Journal of Climatology*. DOI: 10.1002/joc.1922.

Petterson TC, Easterling DR, Karl TR, Groisman P, Nicholls M, Plummer N, Torok S, Auer I, Boehm R, Gullet D, Vincent L, Heino R, Tuomenvirta H, Mestre O, Szentimrey T, Salinger J, F´ørland E, Hanssen-Bauer I, Alexandersson H, Jones P, Parker D. 1998. Homogeneity adjustments of *in situ* atmospheric climate data: a review. *International Journal of Climatology* **18**: 1493–1517.

Reeves J, Chen J, Wang XL, Lund R, Lu QQ. 2007. A review and comparison of changepoint detection techniques for climate data. *Journal of Applied Meteorology and Climatology* **46**: 900–915.

Toreti A, Kuglitsch FG, Xoplaki E, Della-Marta P, Aguilar E, Prohom M, Luterbacher J. 2009. Comments on “Time trends of daily maximum and minimum temperatures in Catalonia (NE Spain) for the period 1975-2004”. *International Journal of Climatology* (in press).

Wijngaard JB, Klein Tank AMG, Können GP. 2003. Homogeneity of 20th century European daily temperature and precipitation series. *International Journal of Climatology* **23**: 679–692.

