Concerning the astroclimatological comparison of the Paranal Observatory and El Roque De Los Muchachos Observatory *(Temperature trends)*

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Technical report

1 Introduction

In a recent paper, Lombardi et al. [1] presented an astroclimatological comparison between the Paranal Observatory (Chile) and the El Roque De Los Muchachos Observatory (ORM; Canary Is., Spain). Authors employed two series of meteorological data recorded at both observatories since 1984 up to 2005 to establish some climatic standards and trends. Among other controversial results, Lombardi et al. stated a decadal warming trend for ORM of ($\sim$1.0$\pm$0.3) °C/10yr. However, the Spanish Meteorological Agency[1] has derived a smaller value, $\sim$0.12 °C/10yr ([2], *in spanish*), from a much longer series recorded since 1916 at Izaña station, exactly close to the Teide Observatory, at the same height that ORM and only $\sim$150km away (see Fig. 1). This result is in agree with other global warming trends measurements, for example, $\sim$0.15 °C/10yr for the lower troposphere since 1979 (from the Special Sensor

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[1]http://www.aemet.es

Microwave/Imager –SSM/I– satellite data[2], produced as part of NASA's Pathfinder Program). So, what is actually happen just at ORM? In this report we are going to analyse the statistical significance of the result presented by Lombardi et al. based on the same public data from the ORM employed by the authors.

2 The data

Authors employed the public Carlsberg Meridian Telescope (hereafter CAMC) database[3]. Temperature series were plotted in a point per year approximation. Yearly points were averaged from intermediate monthly averages, in a way that allowed to find lacked months and interpolate them with a mean of the same months chosen between the other years through a closeness criterion. After a linear fit, they calculated averages values and trends.

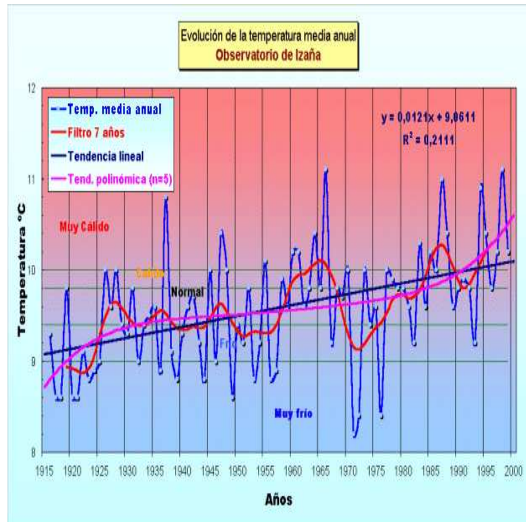

Figure 1: *Temperature series recorded since 1916 at Izaña station, close to the Teide Observatory, at the same height that ORM and only ∼150km away. A trend of ∼0.12 °C/10yr was stated by the authors from the Spanish Meteorological Agency(see ref.[2], in spanish)*

We have followed the same procedure to replicate the plots for CAMC, including the lacked months substitution (that, in fact, only occurs once). A conditioned median filter was also run in the crude series to avoid spurious or artifacted points. Finally, the first and last year data, only partially covered, were rejected. Linear fits were calculated following the Numerical Recipes in C++, §15.2 method [3].

3 Results

We have computed the ten–years–gradient from the fit lines slopes. The results obtained are in Fig.2. The closest result to that of Lombardi et al. is achieved **not considering the statistical fluctuations** of each point (∼0.94±0.4) °C/10yr. In spite of this value assumes no variance at all in the data, we obtain an error of **42**% (12% higher that stated by the authors). Through taking into account only

[2]http://www.ssmi.com/msu/msu_data_description.html#msu_decadal_trends
[3]http://www.ast.cam.ac.uk/∼dwe/SRF/camc.html

$1 \cdot \sigma$ for each point, the result becomes $(\sim 0.77 \pm 1.7)$ °C/10yr, that carries an error of **220**%.

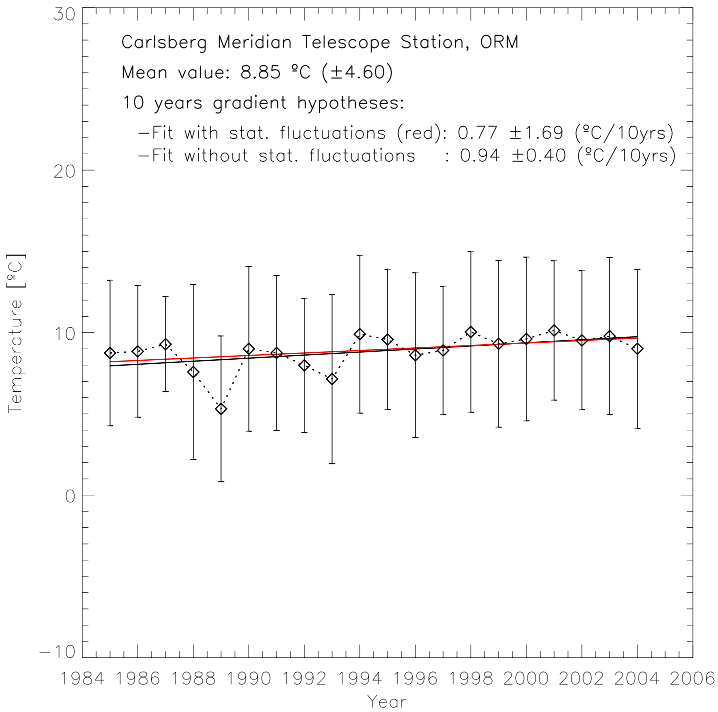

Figure 2: *Temperature series recorded at CAMC station and ten–years–gradients trends with and without taking the statistical fluctuations into account.*

4 Statistical significance estimation

Statistical significance, understood as how likely a result is not due to chance, is an important concept concerning the validity of the results. The problem would not be making a numerical treatment of a set of data and honestly pointed out the final *number*, but special care must be applied when connecting with a physical quantity. What it is actually chance is that CAMC started recording in 1984. In this sense, if we assume the hypothesis of the calculated gradients are in agree with reality, we may expect no significant variations if moving ahead the series start point up to present. In Fig.3 we have plotted such an evolution up to a 1995, being consistent with the *TEN*–years–gradients calculated. Contrary as predicted, gradients show an apparently highly sparse behaviour. Even more, if the oldest available data were come from 1994, an almost null warming could have been early interpreted. But this kind of conclusions may be probably misled by low significance.

To quantitative approximate the statistical significance of the result presented by Lombardi et al. we have assumed the hypothesis of no significant variations are expected in the ten–years–gradient series evolution and we have also assumed the

40% of error. After a χ^2 goodness–of–fit test, the probability[4] Q of a well fitting to the hypothesis is $\sim$ 2.6 e−02. Under normal errors, a believable goodness of fit is assumed when Q is larger than $\sim$ 1 e−01. If we half reduce the error to 20%, the probability will not reach $\sim$ 1 e−11 (see Fig.3).

Therefore, we may conclude that the model has to be rejected and **the stated ten–years–gradients have a null statistical significance**. This result is in agree with the highly sparse behaviour previously observed and it seems to keep clear that not enough points are being considered for such trend determinations.

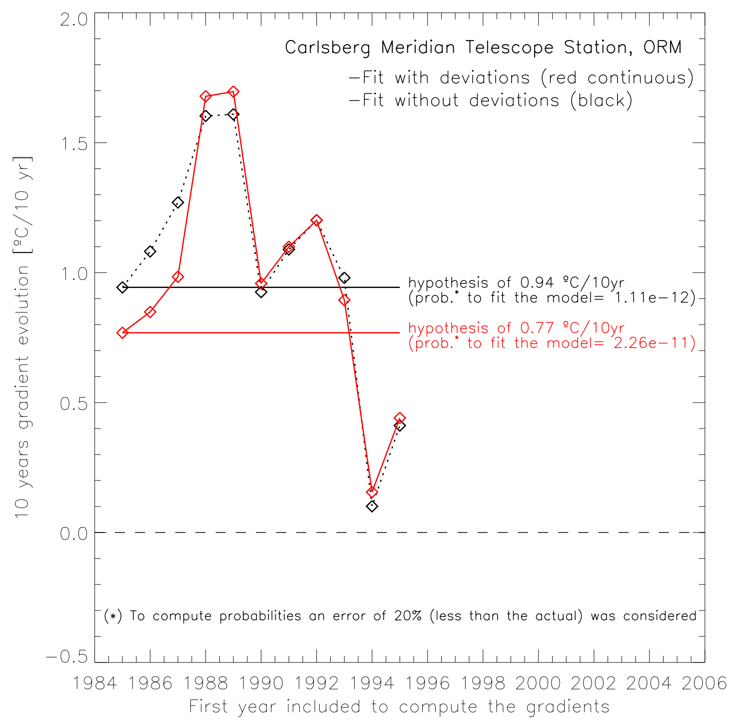

Figure 3: *Ten–years–gradients evolution if moving ahead the temperature series start point. The hypothesis that the first value was accurate (as stated by Lombardi et al.) was subjected to a χ^2 goodness–of–fit test, leading to a very low probability.*

5 Enough number of years?

The number of points available it is also an important consideration that must to be taken into account. It becomes more evident if we imagine a limit case with, for example, only two points. In such a case, and depending on what pair of points, almost any trend conclusion is possible. But no significative information could be extracted. To guarantee the possibility of comparisons between different stations,

[4]Expressed as the incomplete gamma function Q –see Numerical Recipes in C++[3], §6.2–

climatologists (i.e. World Meteorological Organisation[5]) have adopted rigorous criteria for standards (or normals). Such a criteria typically impose a minimum of 30 years, to eliminate year to year fluctuations, and a set of rigid restrictions to the continuity[6]. In the case of climatological trends research, different phenomena with time periods from tens to thousands of years (like glaciations, e.g., see ref.[4]) are playing a role. Therefore, many tens of years or hundreds, if possible, are desired.

Our data series are **10 years sorter than the WMO criteria** demands. And, even more, after applying the WMO continuity rules, **only 8 of the 20 years** have all its months included. This result may be understood because the CAMC station was though to give the operation conditions service to the telescope and not as a climatic station. This means that the telescope operation was the priority. For example, only from 1987, a dedicated PC were used to record the meteorological data, regardless of whether observing was in progress. Even so, no readings were available when any one of the computers was down, or during periods of routine maintenance or when the telescope was being modified.

6 The importance of one point

In a shortage of data scenario, the weight of each point becomes highly significative in the final result. Therefore, singular points must to be carefully analysed before considering the statistical significance of the result. For example, after a first view to Fig.2 it seems clear the presence of a singularity in 1989. Although solar cycles and atmospheric index repercussions in the climate goes beyond this report, we may try to put in context that kind of points. In the case of 1989, one of the mainly accepted climatic index, as the North Atlantic Oscillation Index –NAO–, reached a strong maximum in 1989 (see Fig.4), that agrees with a cold year at the Canaries[7].

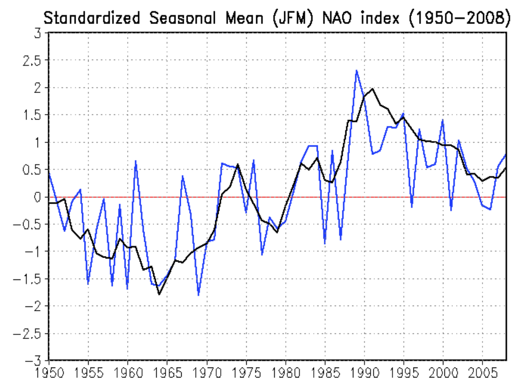

Figure 4: *North Atlantic Oscillation Index –NAO–, reached a strong maximum in 1989.* (http://www.cpc.noaa.gov/products/precip/CWlink/pna/JFM_season_nao_index.shtml)

To numerically evaluate the importance of one point, we have replaced 1989

[5]http://www.wmo.int

[6]See, for example, the description made in the Canadian Weather Office: http://www.climate.weatheroffice.ec.gc.ca/climate_normals/climate_info_e.html

[7]See, e.g., http://www1.secam.ex.ac.uk/nao-images.dhtml?#naoindex for an explanation

with the average of 1988 and 1990 and we have repeated the analyses (see Figs. 5 y 6). The ten–years–gradients fall more than 25% after this replacement, and the gradients curve clearly goes smoothed. In spite, the probabilities of well fitting the hypothesis stay with very low values. These results also stress the importance of compiling a enough number of years to try to conclude a significative trend value.

7 Conclusions

- We have replicated the result presented by Lombardi et al. **??** with a decadal warming trend for ORM of (∼1.0±0.3) °C/10yr. We have employed the same data series and, after a detailed filtering, we have obtained of (∼0.94±0.4) °C/10yr, that means a **42**% of error.

- We have noted that Lombardi et al. did not take into account the data statistical fluctuations when making the fits. Under these conditions, the ten–years–gradient becomes (∼0.77±1.7) °C/10yr, that carries an error of **220**%.

- We have tested the statistical significance of the results. We have assumed the hypothesis of no significant variations are expected in the ten–years–gradient evolution if moving ahead the series start point. After a χ^2 goodness–of–fit test, the probability of a well fitting to the hypothesis is very low ($\lesssim$ 1 e−11 assuming a 20% of error). Therefore, the stated ten–years–gradients have a **null statistical significance** (the result is likely due to chance).

- We have noted the importance of a long enough series of data to establish temperature trends. We have noted that our data series are **10 years sorter** than the WMO criteria for normals, and that only **8 of the 20 years** achieve the continuity requirements. In the case of climatological trends, where many tens of years or hundreds, if possible, are desired, our data is even more **insufficient**.

- We have evaluated the importance of understand the data context in a shortage of data scenario, where the weight of each point becomes highly significative. After replace the 1989 value with the average of 1988 and 1990, the ten–years–gradients fell more than 25%, although statistical significance stays very low.

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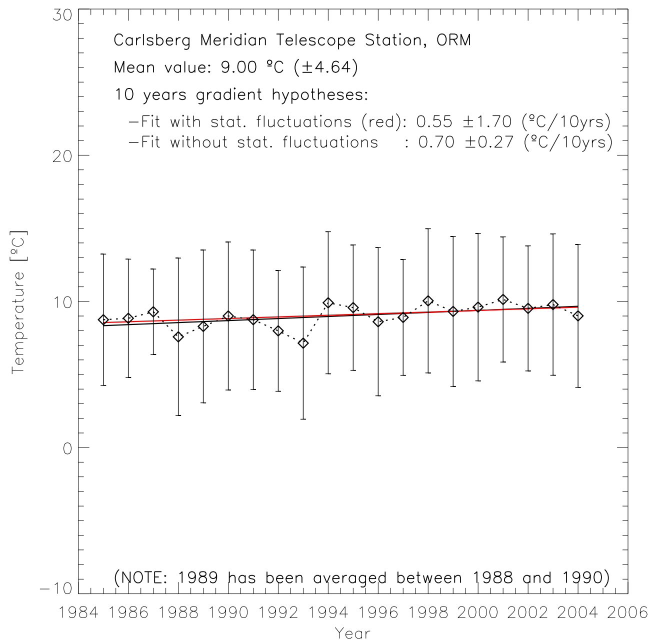

Figure 5: *Temperature series recorded at CAMC station and ten–years–gradients trends with and without taking the statistical fluctuations into account. Year 1989 value have been replaced with the average of 1988 and 1990. The ten–years–gradients fall more than 25% after this replacement*

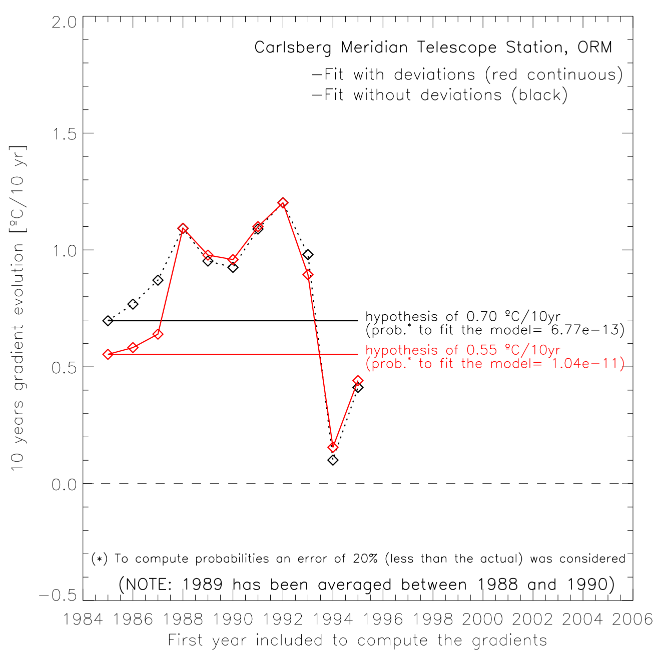

Figure 6: *Ten–years–gradients evolution if moving ahead the temperature series start point. Year 1989 value have been replaced with the average of 1988 and 1990 in the temperature series. The hypothesis that the first value was accurate was subjected to a* χ^2 *goodness–of–fit test. In spite of the curve goes smoothed, the probabilities of well fitting the hypothesis stay with very low values.*

References

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