Is temperature or the temperature record rising?

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Abstract

In this paper, we demonstrate a logical circularity that undermines the validity of a commonly used method of homogenizing surface temperature networks. This study provides an explanation for the exaggeration of surface warming found in official temperature networks.

1 Introduction

Homogenization consists of adjusting the baseline of sections of the temperature record up or down in an attempt to mitigate the effects of changes in location or instrumentation. Recent audits of the surface temperature networks have found that homogenized temperature networks show more warming that the raw temperature data: in Australia +0.9C vs +0.7C per century [1], in New Zealand +0.9C vs +0.3C per century [2], and globally +0.7C vs +0.4C [3] respectively. A recent study by the Australian Bureau of Meteorology (BoM) also reported a similar difference of +1.09C vs +0.69C between the homogenized ACORN and the non-homogenized WNAWAP networks respectively [4, 5].

These differences between the trends of homogenized and unadjusted data are quite large. Homogenization seems to be favored in official meteorological networks, ostensively because of a capacity to correct micro-site shifts and temporal inhomogeneities due to changes in observing practices, instrumentation, or reporting. The BoM acknowledges, however, that "clear evidence in favour of this hypothesis is yet to be obtained" [5].

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There are potentially valid reasons to adjust raw data, particularly where artificial discontinuities and spurious changes can be proven and quantified. There are also potentially legitimate reasons for a non-climatic warm bias in early records, justifying adjustments to maintain consistency. Demonstrable improvements in the quality of shelter, instrumentation and software [6], or a consistent pattern of micro-site shifts to cooler, higher altitude sites away from creeping urbanization are two such non-climatic factors.

There are also compelling reasons not to adjust. Adjustments destroy the ascendency of record temperatures. Adjustments may add more errors than they remove. Adjustments that amplify warming, simply to increase the consistency with an overall trend, are clearly not legitimate.

Here we show that homogenization by comparison of a target site with a reference climatology can introduce a bias into a temperature network. Such biases have been found to contaminate other findings of alarming warming [7, 8, 9, 10].

2 Analysis

One approach to homogenization is the Standard Normal Homogenization Test (SNHT) where the individual target series are examined for sudden jumps indicative of station moves or other problems. The SNHT commonly optimizes information metrics such as the AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) in conjunction with break-tests based on F statistics using a Chow and supF test [11]. Informed by these tests the target series is adjusted up or down.

A more recent approach is to compare the target series S with an estimate of regional climatology Rp, either constructed from some weighted mean of neighbors [12] or a more complex pairwise comparison [13]. This amounts to applying SNHT to the difference series $D = S - Rp$. The S is then adjusted according to the breaks identified in the difference data.

While there is a known problem of aliasing whereby different signals tend to become indistinguishable [13] the consequences for inferences about observed temperature change is not generally appreciated.

The aliasing of the reference homogenization method is obvious from the mathematical expression for the homogenized target series $H(S)$. The target series is replaced by the reference series.

$H(S) = S - D = S - (S - Rp) = Rp$

If the breaks in D are spurious, the trend of S will be coerced towards the trend of the regional climatology Rp. Even if the breaks are real, aliasing leads to a biased estimate of the magnitude of the jump.

To demonstrate aliasing on real data, we selected a surface station whose trend deviates from the continental average temperature trend, but does not exhibit any obvious inhomogeneity. Deniliquin is not chosen to be representative. Many stations will exhibit the average warming trend. Deniliquin is chosen to show that *any* station that deviates from the average global warming trend will be coerced into the warming trend by homogenization, irrespective of its trend or quality.

Figure 1 illustrates the steps in the homogenization process on the raw minimum temperature for Deniliquin Post Office site number 074128 (series offset for clarity). After subtracting the raw data ("Raw") from the Australian temperature average, an iterative Chow test finds a significant break in 1975. Adjustment to the cooling "Raw" series produces a series with a warming trend identical to the version of Deniliquin in the Bureau of Meteorology (BoM) High Quality dataset "BoM HQ".

The metadata records for Deniliquin describe an adjustment to the minimum in 1971 by -0.8C in concert with a station move of 1km to the north west. However, the metadata does not indicate whether the move changed the stations average temperature. The neighboring stations of Eucha and Hay are cooling or flat (-0.14C and 0.08C per decade respectively) and do not appear to have any marked discrepancies with Deniliquin to justify the 1971 adjustment. Moreover, there does not appear to be anything unusual about the diurnal range around 1971. The Deniliquin adjustments do not appear to be justified on any basis other than divergence from the general warming trend.

Breaks can potentially be justified using a robust statistical test for structural change on autocorrelated series, like the empirical fluctuation process (EFP), in particular the recursive CUSUM tests [14]. Figure 2 shows the EFP (dashed lines) on raw and difference series for Deniliquin where crossing the red line indicates a significant change in level. The cooling raw temperatures at Deniliquin are not yet significant, but the difference series is significant.

Is the change in level at Deniliquin significant? It could be argued that comparison with a reference increases the power of the test, so that breaks

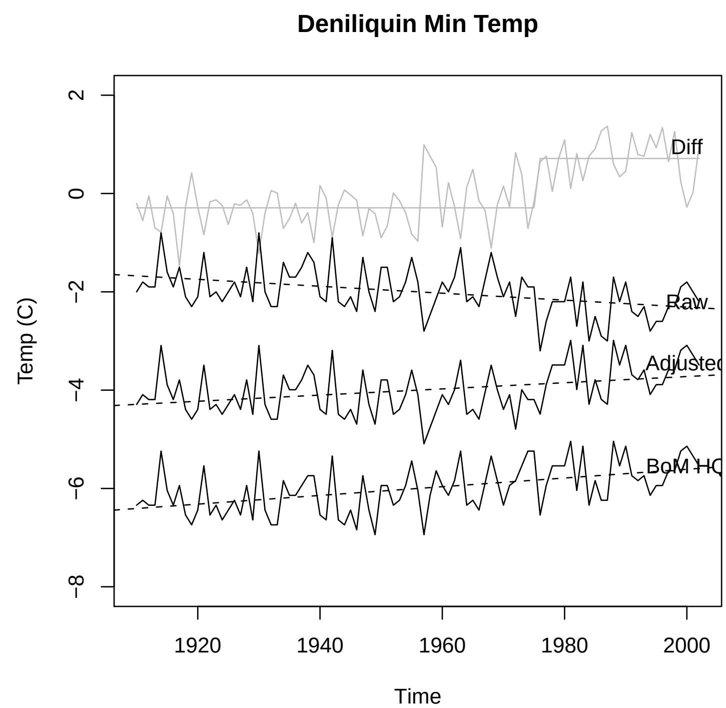

Figure 1: Homogenization of the temperature record at Deniliquin, Australia between 1910 and 2007 ("Raw") (series offset for clarity). "Diff" in gray, is the subtraction of "Raw" from the reference series, the average annual Australian temperature. A break in the level of the difference series, shown by a segmented gray line, was generated from an iterative Chow test in the package strucchange in R [14]. The segmented line was then added to "Raw" to produce the "Adjusted" Deniliquin series. The trend of the adjusted series matches the trend on the official Bureau of Meteorology High Quality series ("BoM HQ") for Deniliquin.

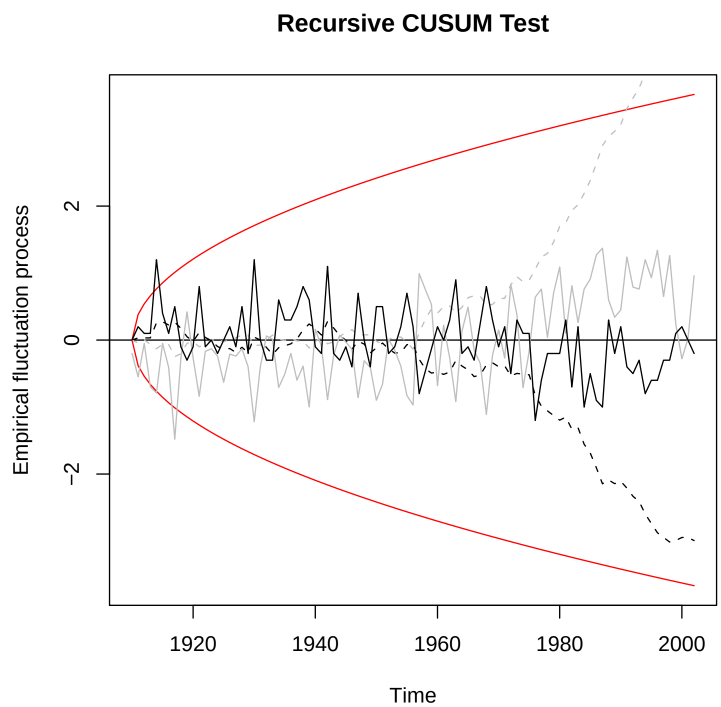

Figure 2: Robust test of a change in level of the raw temperature in Deniliquin (black) and its difference series (gray) using an empirical fluctuation process (dashed lines). The EFP of the difference series exceeds the 99% significance level (red) but the EFP of the raw data does not.

of marginal significance become significant. But as we have shown above, and demonstrate in the following figures, the homogenization methodology would find breaks in any trend that deviates sufficiently from the regional average. Such breaks are not real breaks; they are false positives or type I errors.

In Figure 3 an artificial warming trend of 0.5C degrees per decade was added to the raw Deniliquin series prior to homogenization. As previously, subtracting the raw data from the Australian temperature average yielded a significant break, and the strongly warming trend of ”Raw” was adjusted down to match the Australian temperature reference series ”BoM HQ”. Figure 4 demonstrates that even stronger coercion of trends occurs when a segmented line is fit to the difference series. An exact match to the reference series is obtained if both breaks and trends in the difference series are used to adjust the raw series.

3 Discussion

Unlike the policy arena where the type II error (false negative) is often a concern, type I error should be the main concern in scientific studies, and is typically reduced below 5% or ideally less than 1%.

The false alarm rate (or FAR) in a typical temperature network (Case 4, two random change points in all series, Table 4 in [13]) for the pairwise comparison and reference methods was 8.5% and 46.0% respectively. If series have two breaks on average, this entails a type I error rate of 12% and 70% respectively. Such high error rates exceed the generally acceptable scientific error rates and should severely limit the use of adjusted series in studies of observed temperature change. Methods should be rejected as ’not-fit-for-purpose’ if the FAR exceeds conventionally acceptable levels of error.

High type I error is symptomatic of circular reasoning and ’data peeking’. Here, peeking at the regional average to obtain a more powerful test may seem harmless, but is actually highly inappropriate. The only valid sources of information for adjusting a series are completely independent of the regional average: the site metadata, significant breaks in the series itself (SNHT), or comparison with a small number of near neighbors that are not included in the final network. Selection of reference stations by high correlation (even though they are 1000’s of kilometers from the target series) is also a form of circularity [8].

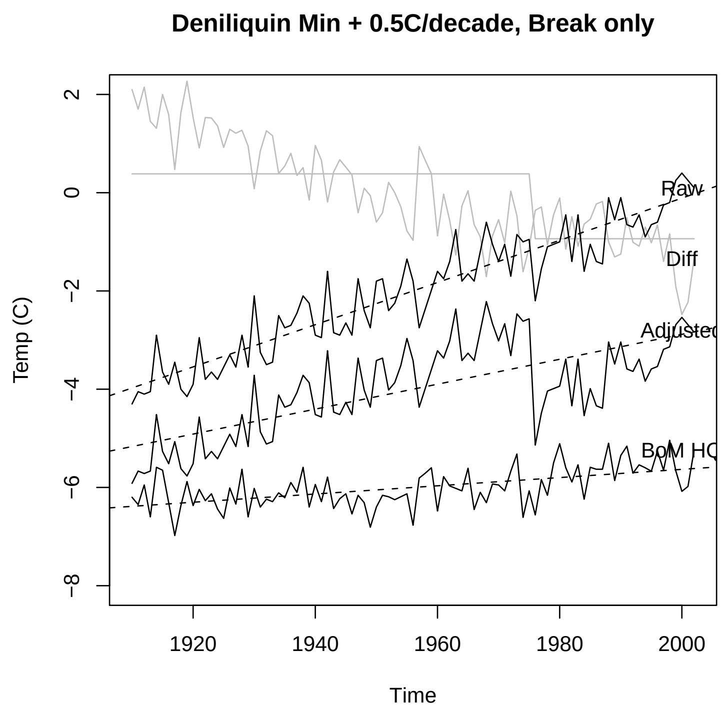

Figure 3: Homogenization of Deniliquin with an artificial warming trend of 0.5C per decade. The break down in the level of the difference series coerces the "Adjusted" Deniliquin series towards the trend of the Australian average temperature used as the reference series ("Bom HQ").

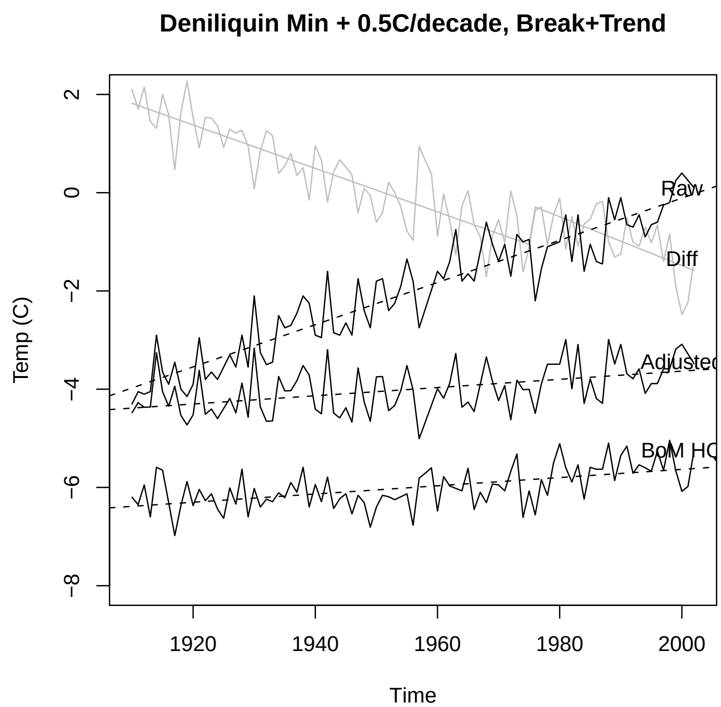

Figure 4: Homogenization of Deniliquin with an artificial warming trend of 0.5C per decade with the difference series fit to a segmented line. The adjusted Deniliquin series is coerced to the trend of the reference series ("Bom HQ") exactly.

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