Irreproducible Results in

"Abrupt Tropical Climate Change: Past and Present,"

by Thompson *et al*. (*PNAS* 2006)

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Abstract

In a prestigious and influential article in the *Proceedings of the National Academy of Sciences* (*PNAS*), Thompson *et al.* [1] put forward a Tropical Composite Z-score series (*TCZ*), purportedly computed from ice core δ^{18}O ratios, as evidence of tropical warming over the past 2000 years. This note demonstrates that it bears no replicable linear relationship to the seven series on which they claim it is based, as archived by the authors themselves on the *PNAS* website. Although *TCZ* does equal the average of the two Himalayan and Andean component series (*HCZ* and *AC*Z) to within rounding error, *HCZ* cannot be constructed linearly from the four Himalayan isotope ratio series with an error less than 100 times the expected rounding error, and *ACZ* cannot be constructed from the three Andean isotope ratio series with an error less than 30 times the expected rounding error.

The authors should provide *PNAS* with corrected and internally consistent data sets and figures for these series.

Introduction

In a prestigious and influential article in the *Proceedings of the National Academy of Sciences* (*PNAS*), Thompson *et al.* [1] report a Tropical Composite ice core $\delta^{18}O$ Z-score index (herein *TCZ*), which they say

> clearly reveal[s] that a large and unusual warming (^{18}O enrichment) is underway at high elevations in the tropics. Although the factors driving the current ^{18}O enrichment (warming) may be debated, the tropical ice core $\delta^{18}O$ composite (Fig. 6A) confirms that it is unusual from a 2,000-yr perspective. (p. 10540).

In their Figure 6D, they invite visual comparison of this series to Northern Hemisphere meteorological observations back to 1860 AD, and to a controversial multiproxy temperature reconstruction back to c. 200 AD. Aside from the units of measurement (Z-scores vs. degrees Celsius), there is indeed a remarkable similarity between the two graphs.

Thompson *et al*. claim that their *TCZ* is constructed from seven individual ice core $\delta^{18}O$ isotope ratio series, partial data for which they provide on the *PNAS* website. The present note attempts, unsuccessfully, to verify this claim.

The present author attempted to clear up this apparent discrepancy by e-mailing Lonnie Thompson and most of his co-authors on Jan. 23, Jan. 26, and Feb. 6, 2008, but received no reply. An abstract of this note, with details in an online Supplementary Information, was then submitted as a letter to *PNAS*, but was rejected on the grounds that *PNAS* does not publish corrections to articles more than three months old. *Energy and Environment* has kindly agreed to publish this comment instead.

Data

Decadal data for *TCZ* in Fig. 6A of Thompson *et al.* [1] was published as supporting information on the *PNAS* website as Data Set 3, and is plotted in the accompanying Figure 1. Note that the last decade, that of 1990-1999, is conspicuously higher and therefore presumably “warmer” than any previous decade.

Figures 6B and 6C in that article plot two regional subindices, a Himalayan Composite δ^{18}O Z-score index (herein *HCZ*) and an Andean Composite δ^{18}O Z-score index (herein *ACZ*), decadally back to 0 AD. The authors also provide the data for these two graphs in their Data Set 3. Details of these series are plotted in the accompanying Figure 2 together with *TCZ* from 1600 – 1999. Although both end much “warmer” than the 1970s, only HCZ is at an all-time high, and so must be source of the record-high terminal value of TCZ.

Data from the seven ice core series in question were plotted as 5-yr averages in their Figure 5A, but only for 1600 to 1999. The data for this restricted period was published on the *PNAS* website as Data Set 2. The accompanying Figure 3 shows decadal averages constructed from this Data Set for the four Himalayan series: Guliya (hereafter *G*), Puruogangri (*P*), Dunde (*Du*), and Dasuopu (*Da*). Figure 4 shows similar decadal averages for the three Andean series: Quelccaya (*Q*), Huascarán (H), and Sajama (*S*). Although a few decades have some missing data, all 7 series are available for the 37 decades 1610-1979. Data for Figures 2-4 are provided in the accompanying Supplementary Data File, available online at <http://www.econ.ohio-state.edu/jhm/AGW/Thompson>.

Note that only one of the individual Himalayan series in Figure 3 is complete through the 1990s, and it actually turns down in that decade. It is therefore difficult to see how *HCZ,* and hence *TCZ*, reach unprecedented highs in their last decade.

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Analysis

Although Thompson *et al.* present *TC*Z as an indicator of "large and unusual warming," they make no attempt to calibrate it to either the instrumental or multiproxy temperature series they compare it to. In order to perform such a calibration and to construct valid confidence intervals, it would be necessary to know if *TCZ* was computed from the component δ^{18}O series using fixed weights, *e.g.* equal weights (before or perhaps after constructing Z-scores), or if weights were chosen that maximized the fit of *TC*Z to one or both of the temperature series.

Thompson *et al.* do not indicate how their weights were chosen, or even what they were. However, if any fixed weights were used, it should be straightforward to back these out of even the incomplete data they archived, to within rounding error, and thereby at least to determine how *TCZ* was constructed.

First, if *TCZ* is any fixed affine function (constant plus linear combination) of *HCZ* and *ACZ,* the three coefficients should be recoverable from any three or more observations on all three series, to within the precision implied by the rounding error of up to 0.005 permitted by the two decimal places to which the series were reported in their Data Set 3. If *TCZ* is regressed on a constant, *HCZ,* and *ACZ,* for all 40 decades shown in Figure 2, the fit should be nearly exact, and the effect of any rounding error on the coefficients should be minimal. The standard deviation of the residuals, *s*, should be close to $0.01/\sqrt{12} = 0.0029$, the standard deviation of a U(-.005, .005) distribution.

The results of this Ordinary Least Squares (OLS) regression, with standard errors in parentheses and *t*-statistics (for a 0 coefficient) in square brackets, are indeed as close to an exact fit as could be hoped for:

$$\begin{array}{llll} TCZ = & 0.00219 & + 0.49781\,HCZ & + 0.50159\,ACZ \\ & (0.00065) & (0.00088) & (0.00062) \\ & [3.36] & [567.49] & [805.64] \end{array} \qquad (1)$$

R^2 0.999985

s 0.0028

The fact that the intercept is within rounding error of zero and the coefficients are both very near 1/2 strongly suggests that *TCZ* was simply computed as (*HCZ* + *ACZ*)/2. Indeed this is always true to within the 0.005 permissible rounding error, so we may safely conclude that this is in fact the formula that was used. It is not clear why one would ever want to average Z-scores in this manner, but still it is a well-defined and replicable calculation. The statistically significant yet very small positive intercept may simply be due to an inconsequential bias in the rounding algorithm that was used, and this may have slightly perturbed the two slope coefficients.

Similarly, if *HCZ* is any fixed affine function of the 4 Himalayan δ^{18}O series, the five coefficients should be recoverable from any five or more observations for which all series are available. If *HCZ* is regressed on a constant and the four contributing series over the 37 decades for which data is complete on all four series, R^2 and the *t*-statistics on any included series should be comparably large to those in Equation (1) above, and *s* should be comparably small. The results of this regression are as follows:

$$HCZ = 11.83 + 0.020\,G + 0.217\,P + 0.114\,Du + 0.344\,Da \qquad (2)$$

(1.48)	(0.050)	(0.066)	(0.100)	(0.050)
[8.02]	[0.41]	[3.29]	[1.14]	[6.90]

R^2 0.7673

s 0.2897

Although two of the slope coefficients, for Puruogangri (*P*) and Dasuopu (*Da*), are significantly different from zero, their *t*-statistics are vastly smaller than those for the precisely-defined slopes in Equation (1). The R^2 is much smaller, and *s* is 100-fold larger than it could be if just due to rounding error.

The regression indicates that Guliya (*G*) and Dunde (*Du*) were not used at all in constructing *HCZ*, and therefore *TCZ*. This might have been the legitimate outcome of a calibration of *HCZ* and therefore *TCZ* to a hemispheric or global temperature series, but no explanation for omitting these particular sites was given in the text.

In order to investigate the possibility of time-changing coefficients, the full sample of 37 decades was divided into four subperiods of size 10, 9, 9, and 9. It was found that even Puruogangri was not significantly significant at any level worth mentioning ($|t| < 1$), except in the last subperiod (1890-1979; $t = 3.17$). In the third subperiod (1800-1879), not a single one of the four slope coefficients had a *t*-statistic greater than 1 in absolute value. In this subperiod, the hypothesis that all four coefficients were zero, including even Dasuopu, could not be rejected at any test size worthy of mention (F(4, 4) = 1.313; $p = 0.399$).

The results for the Andean composite *ACZ* were less incoherent, but still unacceptable. Using the same 37 decades as were employed in (2),

$$ACZ = 22.43 + 0.483\,Q + 0.541\,H + 0.232\,S \qquad (3)$$

$$\begin{array}{cccc} (0.48) & (0.028) & (0.018) & (0.015) \\ [46.32] & [17.44] & [29.47] & [15.92] \end{array}$$

R^2 0.9871

s 0.1032

Here, the R^2 and t-statistics are substantially larger than in (2), and a clear pattern emerges that Quelccaya (Q) and Huascarán (H) received approximately equal weights, while Sajama (S) received about half their common value. However, s is still more than 30 times larger than could have been caused by rounding error alone.

When the Andean data is divided into the same four subperiods, the standard errors are larger, as is to be expected. However, the general pattern of the coefficients is the same for all four subperiods, so that there is no evidence of time-changing coefficients. Unlike the Himalayan case, there is at least a clear, if imperfect, pattern to the weights, although again, no explanation was given in the text for how these particular weights were chosen. Even if an equal-weighted average of z-scores was taken, the weights should precisely reflect the inverted standard deviations of the four series.

It should be noted that although none of the four Himalayan sites is south of latitude 28ºN, Thompson *et al.* identify their seven-core composite series as "tropical" in both their text and Figure 6A. "Low latitude" (as used in their Figure 5E) would be more accurate, but to avoid confusion this comment simply follows the terminology used in their text.

Conclusion

The Thompson *et al.* [1] tropical composite δ^{18}O Z-score series *TCZ* bears no replicable linear relationship to the seven ice core isotope ratio series on which they claim it is based. Although *TCZ* does equal the average of the two Himalayan and Andean component series *HCZ* and *ACZ* to within rounding error, *HCZ* cannot be constructed linearly from the four Himalayan isotope ratio series with an error less than 100 times the expected rounding error, and *ACZ* cannot be constructed from the three Andean isotope ratio series with an error less than 30 times the expected rounding error. Two of the isotope ratio series were, without explanation, not used at all, and during 1800-1879, *HCZ* bears no significant relationship to any of its four underlying series.

It is conceivable that *TCZ* in their Data Set 3 was constructed from an already obsolete or less reliable version of the ice core data in their Data Set 2. If so, the authors should provide *PNAS* a corrected version of Data Set 3 and Figures 6A-C that is actually based on the updated or more reliable values in Data Set 2. Or, if Data Set 2 itself was already obsolete or considered less reliable when *TCZ* was constructed, they should instead provide a corrected version of it as well as Figure 5A, so that the relationship of *TCZ* to its actual component series can be confirmed. In either case, Data Set 2 should be extended back to include all the data that was used in constructing *TCZ*, in order to permit replication of the pre-1600 portion of this now-questionable series, as well as its calibration to instrumental global temperature.

Reference

1. Thompson, Lonnie G., Ellen Mosley-Thompson, Henry Brecher, Mary Davis, Blanca León, Don Les, Ping-Nan Lin, Tracy Mashiotta, and Keith Mountain (2006). Abrupt tropical climate change: Past and present. *Proceedings of the National Academy of Sciences, USA* (*PNAS*) 103 (July 11): 10536-10543. Data Sets online via <http://www.pnas.org/cgi/content/full/0603900103/DC1> (accessed Nov. 25, 2007)

Note: Supplementary Data file online at <http://www.econ.ohio-state.edu/jhm/AGW/Thompson>

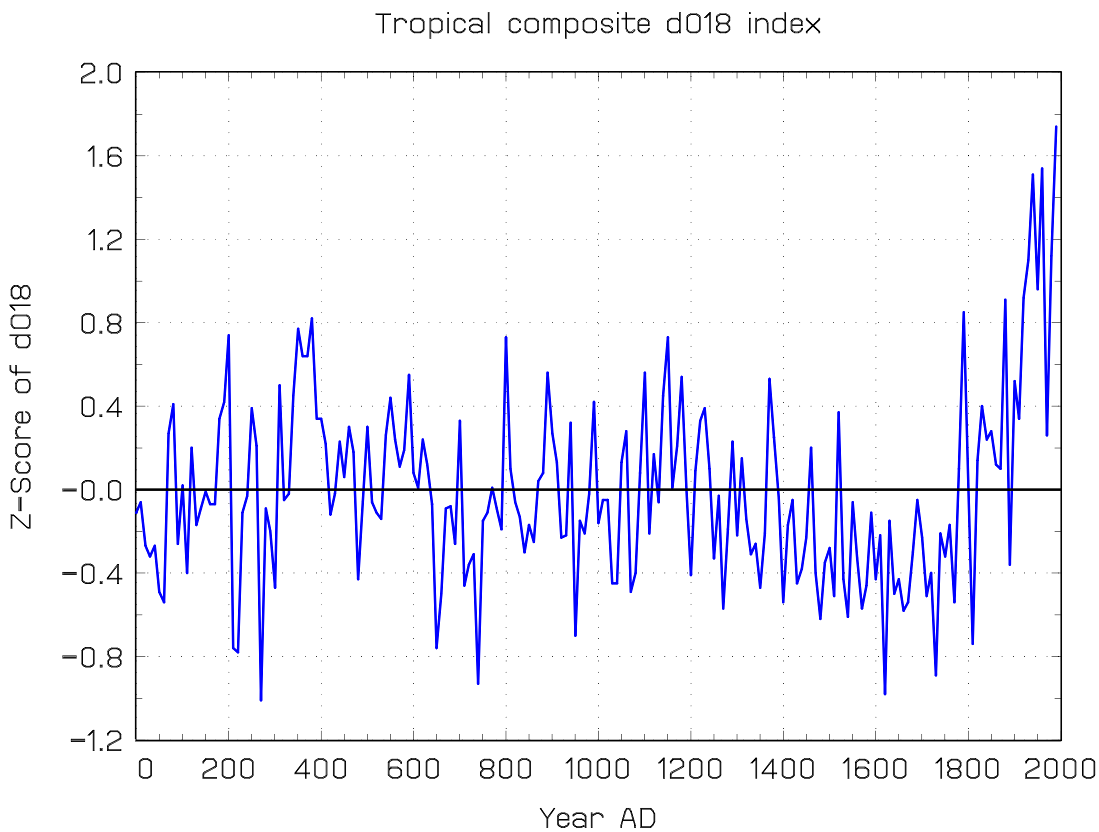

Fig. 1.

Composite $\delta^{18}O$ Z-score for 7 Tibetan and Andean ice cores, decadal averages, from Thompson *et al*. [1], Data Set 3. Years indicate beginning of decade in question.

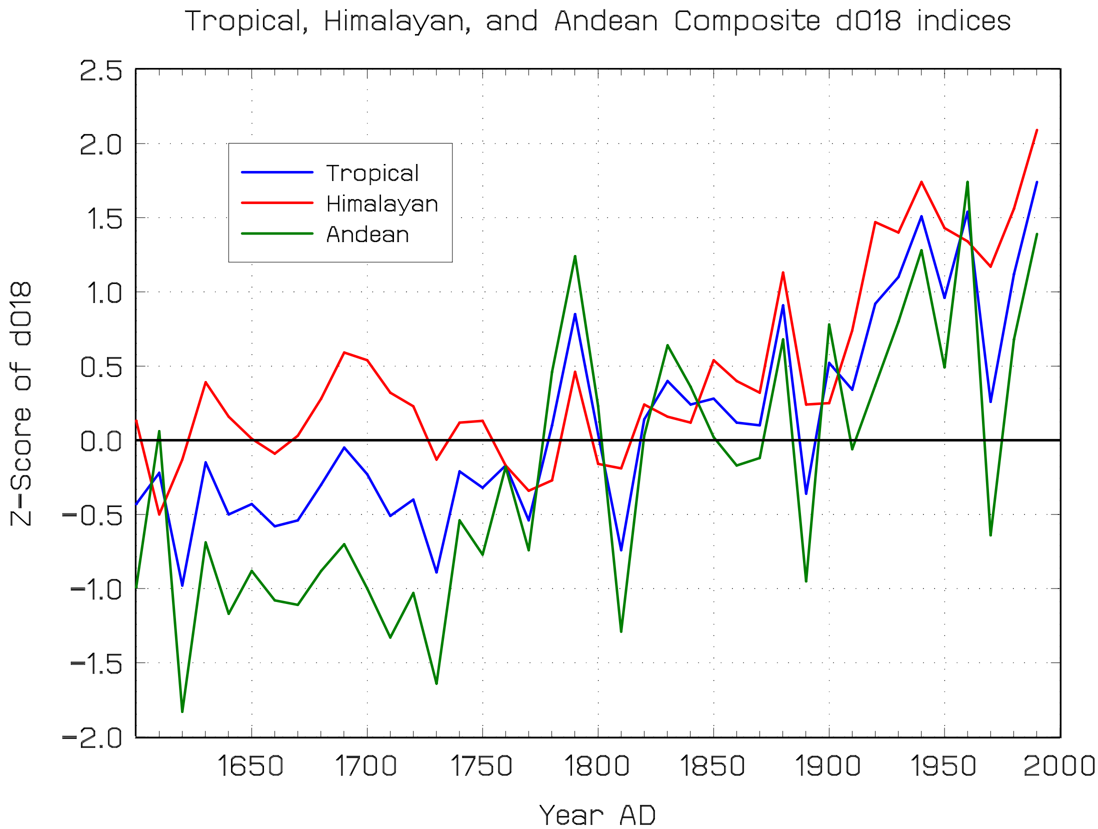

Fig. 2

Composite $\delta^{18}O$ Z-score index for 7 Himalayan and Andean ice cores, together with regional subindices, from Thompson *et al*. [1], Data Set 3, decadal averages. Years indicate beginning of decade in question.

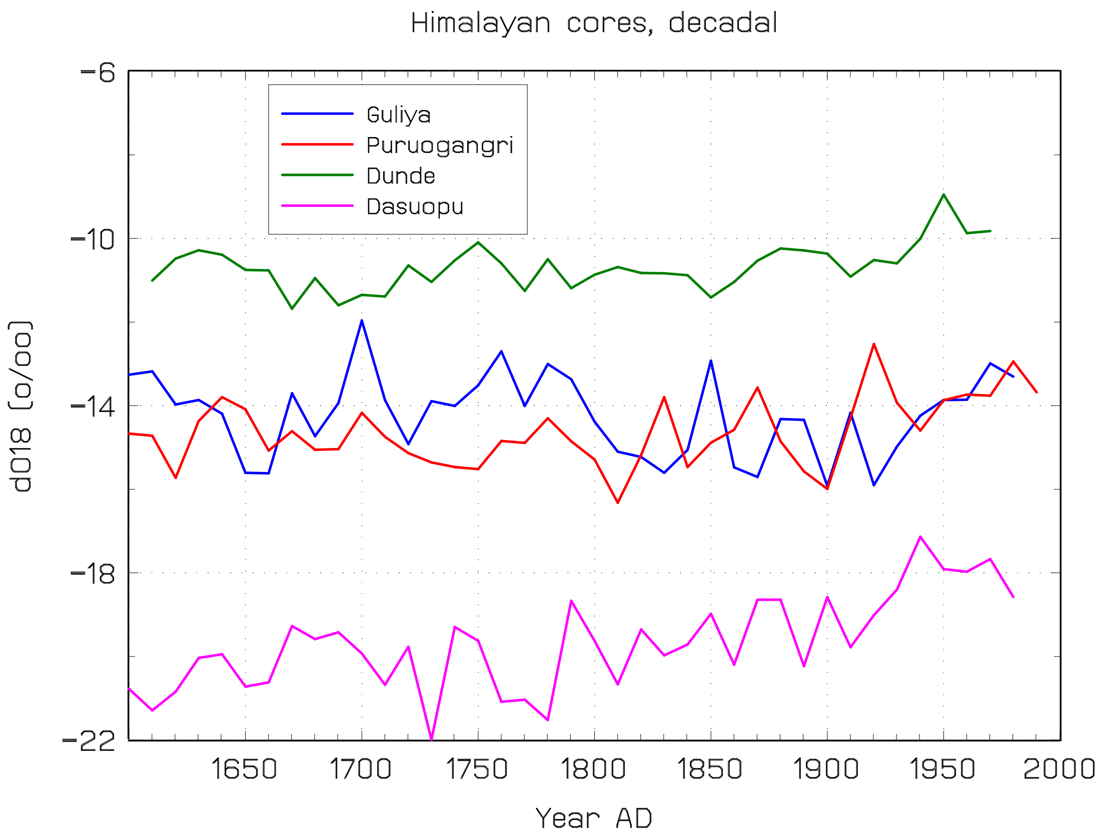

Fig. 3

Himalayan $\delta^{18}O$ isotope ratio series, decadal averages constructed from 5-year averages in Thompson *et al*. [1] Data Set 2. Years indicate beginning of decade in question.

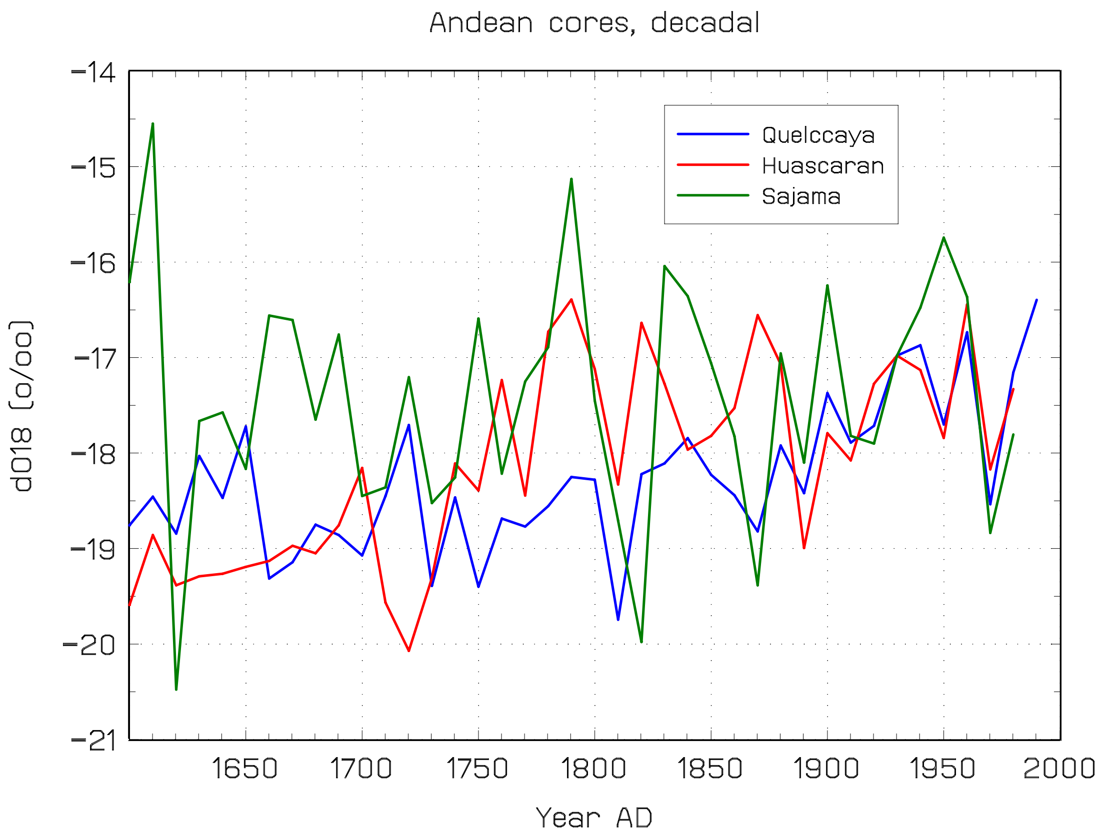

Fig. 4

Andean $\delta^{18}O$ isotope ratio series, decadal averages constructed from 5-year averages in Thompson *et al*. [1] Data Set 2. Years indicate beginning of decade in question.