Keenan's Giant Natural Fluctuation model unveiled

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Introduction

In [*Lovejoy et al.*, 2016] (hereafter L2016) we analyzed 1000 realizations of a stochastic model fit to the annually and globally averaged temperature series from 1880-2014. These realizations were the data provided by D. Keenan's for his $100,000 "climate contest". The contest aim was to bring into question the Intergovernmental Panel on Climate Change (IPCC) statistical uncertainty assumptions and hence to undermine the empirical basis of the anthropogenic warming theory. Specifically, the IPCC assumed that the residuals after trend removal had only short range (exponential) correlations whereas in reality (e.g. [*Lovejoy*, 2014], hereafter L2014) - and in Keenan's contest - the residuals had on the contrary long range (power law) correlations.

Keenan actually had two models: the basic (on average) trendless model ($T_{init}(t)$), and another one which consisted of randomly adding to this a trend of plus or minus 1^{o}C/century ($T(t)$). The aim of the contest was to identify which of the basic models had trends added: 900 correct out of 1000 were needed to win.

The key conclusions of the analysis in L2016 were:

a) Trends are not needed to test the hypothesis that the warming since 1880 was due to a Giant Natural Fluctuation (GNF); the contest therefore proves nothing about anthropogenic warming. For example, L2014 showed that the GNF hypothesis could be rejected with 99.9% certainty by using probability distributions of temperature changes (estimated from pre-industrial paleo data).

b) After removing trends, Keenan's model had long range (power law) residuals. Taking these strong dependencies into account, allowed for tighter (less dispersed, less uncertain) trend estimates. Ironically, Keenan's model illustrates that by making the short range dependency assumption, that the IPCC *overestimated* the uncertainties in its trends.

c) Over the period 1880 - 2014, the variability of Keenan's model was quite realistic. Indeed, if the only information that existed about temperature variations were these 135 numbers, then his model could not be rejected. However when the model was compared to pre-industrial temperature data, its variability was clearly far too large. For example, both of his models predicted ice ages every one thousand years or so (rather than every 100,000 years, see the figure below). His model could thus be easily *scientifically* rejected.

Keenan's model

As promised, on November 30th 2016, Keenan announced that none of the 33 contest submissions were winners and he unveiled the computer code that generated the 1000 series. His computer model was actually quite bizarre, it consisted in a random shuffling of each of 4 rather different submodels, one of which was actually an IPCC numerical model output! Two of the other three submodels were basically standard stochastic models with long range dependencies: an integrated ARMA model that gives standard Brownian motion at long time scales, and a fractional Brownian motion (fBm) model. The third submodel was a complicated homemade concoction but it also gives standard Brownian motion at long time scales. As predicted, all the submodels (and hence the overall model) had strong (power law) statistical dependencies.

Things were actually even more complicated than this since Keenan spiced things up in a manner that is very difficult to theoretically analyze. In actual fact, he made 365 realizations of each submodel and for each (using a nontrivial "excision" procedure), the 32 realizations with the largest variability were thrown away. The resulting 3X333 "clipped" series were then added to the fourth submodel (the unique GCM output) to make the total up to 1000. The trends of the clipped submodels had a nonstandard - and nontrivial to analyze probability distribution. In the L2016 supplement, the trends were (appropriately) estimated by assuming that the residuals had long range dependencies but when the series were classified into trended or nontrended, their statistical distribution was assumed to be Gaussian. This lead to the prediction that 893±9 could be correctly classified. It seems that the clipping invalidated the Gaussian assumption and reduced this to only 860 correct.

In L2016, a model that gave quite similar statistics to Keenan's was proposed based on fractional Brownian motion (with virtually identical parameters to one of the submodels used by Keenan); the fBm was combined with an additional random trend. This model notably gave a distributions of trends very similar to Keenan's, and was used to extrapolate Keenan's model to longer time scales, see figure 1 below (updated from fig. 2 of in L2016). The key point of L2016 being that the model variability was so strong that ice ages would occur much too frequently.

The updated figure 1 was obtained by running Keenan's (now) published code but for 10,000 simulated years rather than 135. It confirms that the root mean square (RMS) temperature fluctuation of the model with added trends ($T(t)$) was accurately predicted, (top dashed red line), and that the model implies ice ages every thousand years or so (compared to every 100,000 from the paleodata). Extending this model to ice age periods, it predicts a whopping ±200°C variation (a difference of 400°C between glacial and interglacial conditions, this is off-graph). In contrast, the basic model without the added trends ($T_{init}(t)$, solid red line) was somewhat less extreme than predicted: figure 1 shows that it predicts ice ages with half period 5,000 - 10,000 years, i.e. about 5 times too frequently. The glacial-interglacial temperature variation (at 30,000 -50,000 years for a half-period) was typically about 14°C (±7°C) which is about three times too high to be realistic.

In the classical style of British aristocracy, after L2016 was published, Keenan threatened libel action against the paper's editors at the Geophysical Research Letters (GRL) and against GRL's parent organization (the American Geophysical Union, AGU), a threat that may have quashed a story planned for AGU's popular *EOS* magazine.

We would like to take this opportunity to thank Keenan for fleshing out the Giant Natural Fluctuation (GNF) hypothesis with a trendless stochastic model with statistics very close to those of the anthropocene temperatures. His model clearly demonstrates that pre-industrial temperature information is needed to reject the GNF hypothesis and that anthropogenic warming is a *scientific*, not a statistical problem.

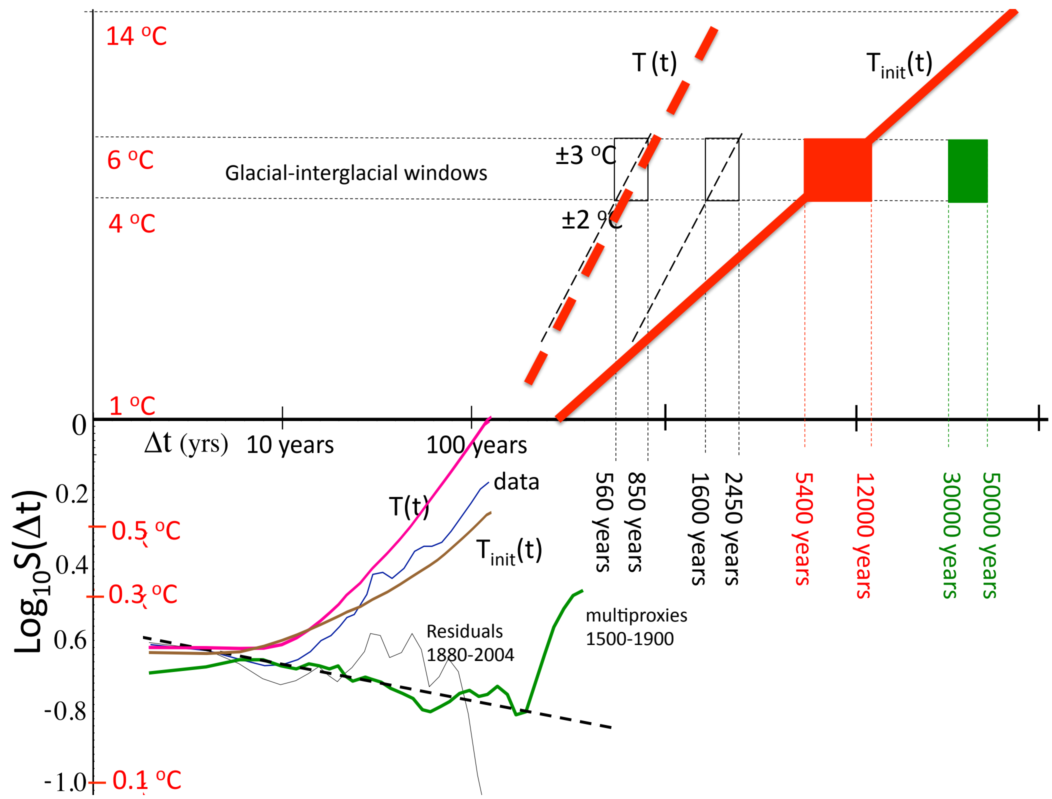

Figure 1: This is an update on the original figure 2 in L2016 (the details of the original figure are given in italics, below). The new results are the red lines (dashed: T(t), solid: $T_{init}(t)$) indicating the actual RMS temperature fluctuations (S(Δ*t*); in the increasing part of the graph, these are typical temperature differences over the period of time Δ*t*). The behavior predicted in L2016 is shown by the dashed black lines. The boxes show the typical glacial-interglacial temperature variability over the typical half cycle length, the red one for $T_{init}(t)$) and the green one from paleo data (from [*Lovejoy and Schertzer*, 1986]).

The original figure caption fro of figure 2 in L2016:

The RMS Haar structure functions of Keenan's model (top; magenta and brown for T and Tinit, respectively) and of the average of three global surface data sets (the second from the top; blue, taken from L2014). Also shown for reference are S(Δt) of the average of the three preindustrial temperature multiproxies analyzed in L2014 (green) along with the residuals with respect to a linear regression of the three 1880–2004 temperatures against $logCO_2$ *(thin black line). The fluctuations decrease roughly with* *exponent -0.1 (dashed line) corresponding to a (statistically stationary) fractional Gaussian noise (fGn) process, not a (nonstationary) fBm process as assumed by Keenan. All results were multiplied by a "canonical" factor of 2 for "calibration." This means that over the part of the curve that is increasing with Δt, the result is very close to the usual difference fluctuation. For example from the graph we see that typical (i.e., RMS) temperature differences at century scales are ≈1°C and 0.5°C (T and T_{init}) at the extreme large Δt. Also shown (top right) is the extrapolation of Keenan's models to longer time scales (see the supporting information). The model predicts typical temperature fluctuations of ±2°C at 560 and 1600 years and ±3°C at 850 and 2450 years (rectangles for T and T_{init}, respectively). Since going in and out of an ice age is a change of roughly this order, this is the models' prediction for the glacial-interglacial window. The time scales estimated from paleodata are roughly 50–100 times longer [Lovejoy and Schertzer, 1986].*

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