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Earth System Dynamics Discussions

Interactive comment on "Late quaternary temperature variability described as abrupt transitions on a $1/f$ noise background" *by* M. Rypdal and K. Rypdal

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This is an instructive discussion of the variability observed in paleoclimatic time series. The premise for the discussion is that the so-called 1/f-noise is the "generic" model for the statistics and scaling of temperature over a very broad range of time scales. It is argued that abrupt changes such as Dansgaard-Oeschger events and the glacial cycles are abrupt changes, not related to the scaling. Thus when these are omitted from the analysis the 1/f model is a good description of the temperature fluctuations over time scales from months to hundred thousands of years.

I do not agree with the authors in all of their statements but I find this an interesting

paper contributing to the discussion of the nature of continuous part of the spectrum of natural variability. Thus I recommend publication. There are though a few points below that should be addressed to make a stronger case.

A central assumption is that there is a scaling relation for the temperature $T(t)$, such that the variance of the mean within a window of length Δt scales as

$$Var(T_{\Delta t}(t)) \sim \Delta t^{\beta-1}.$$

(Eq. (1) in the paper). It would be nice with a sentence or two with a more precise description and a reference. I can see that this is the case for a white noise with $\beta = 0$. But it is difficult for me to see how the variance of averages can grow with Δt. For the random walk or integral of the white noise (red noise), with $\beta = 2$, I get $Var(T_{\Delta t}(t)) \sim \Delta t^0 =$ const. and not $Var(T_{\Delta t}(t)) \sim \Delta t$ as I should according to Eq. (1). (See Fig 1, bottom panel). Perhaps I got the definition wrong?

Following their argument; for a white noise the temperature fluctuations decrease with (resolution-) time scale while they increase for the red noise. Exactly for $\beta = 1$ the variance is independent of the window size for averaging. It is thus argued that $\beta \sim 1$ is a natural a priori hypothesis for the temperature. I do not follow this argument, since it is not a priori given if the variance of averages should increase (rather; not decrease) or decrease with window size: It is an observation: It happens that the power spectrum scales (fairly) as a 1/f-spectrum.

In contrast to the authors, I find the red noise, or autoregressive model very useful. For that the variance of the averages will be constant up to a window size of the order of the correlation time and then decrease for longer window sizes. For the instrumental SST records this is a very good description (Frankignoul and Hasselmann, 1977). Thus I cannot see $\beta \approx 1$ being strongly motivated. Later in the paper it also seems as if the authors use the term 1/f-noise in the more loose sense to denote any scaling spectrum $S(f) \sim f^{-\beta}$, with $0 < \beta < 2$. This should be more explicit in the text.

Also related to the discussion on page 2325 about the spectral weight of different processes. The example mentioned is the El Nino, where it is stated that this is dominated by fluctuations at a few years time scales on top of the continuous 1/f spectrum. In Fig. 1 I have plotted Nino34 (top panel) (Downloaded from NOAA's web site). Middle panel shows the power spectrum where the black line is the power spectrum for an AR1 process with correlation time of 3 years. The red line is $f^{-\beta}$ with $\beta = 1.6$. The authors should argue better how to remove the spectral "hump" around 3 years such that the red line is a better fit than the black line. With regards to scaling of the spectra for stable isotope ice core records, we noticed a scale break around 150 years, with spectral slope of -1.6 for the part containing the DO events a long time ago (Ditlevsen et al. 1996). Though these are of millennial scale they to not show up above the continuous part of the spectrum. My take on this is the following: A spectral peak around 1470 years was noticed in the GISP2 ice core record (Grootes and Stuiver, 1997), this led to a long discussion of a periodic component in the DO dynamics. If that is the case this peak should be regarded as an addition on top of the continuous spectrum. In a statistical study we have shown that this peak is consistent with a by-chance occurrence in a purely stochastic process (Ditlevsen et al. 2007). As an aside it should also be mentioned that the peak is insignificant in the better-dated NGRIP ice core record. If the DO-events are triggered by stochastic internal fluctuations the simplest model would be a stochastic two state process, which could be seen modeled as a telegraph process with another fast timescale process added. The spectrum is thus the sum of two spectra of the Lorentzian type (AR1 processes), with different correlation times which in the intermediate interval pretty much looks like an $1/f$ spectrum. (Hausdorff and Peng, 1996). It would be useful with some discussions of this alternative view: It is stated on page 2331, bottom: There is strong evidence that the temperature fluctuations are better described by scaling models than by so-called red-noise models (or AR(1)-type models). This evidence should be mentioned or at least referenced.

The discussion on subtracting or not of a trend when estimating the scaling exponent β is interesting. I am, however, a little confused: The 1/f noise assumption by nature

does require there to be a trend over the whole series as a part of the process, so how to distinguish if there should be an additional (unrelated) trend on top of the 1/f process? My last comment is just a note on Figure 2, where it is shown that different scaling is obtained for different parts of the NGRIP record, depending on if there are DO events or not: The scaling for 22 kyr + 8.5 kyr (black curve) seems poor. Below (Fig 2) I have added a much better second order polynomial fit (red curve). There seems to me to be a scale-break from a flat scaling to a scaling comparable to the part with the DO events from around a few kyrs. Please comment.

Minor points:

P2324, L21: $\beta > 0$ should be $\beta > 1$

P2331, L8: the almost the -> almost the.

References:

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Frankignoul, C. and Hasselmann, K., Stochastic climate models, Part II Application to sea-surface temperature anomalies and thermocline variability, Tellus, 29, 4, 289–305, 1977

Grootes, P. M. and Stuiver, M.: "Oxygen 18/16 variability in Green- land snow and ice with 10−3- to 105-year time resolution", J. Geo- phys. Res., 102, 26 455–26 470, 1997.

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Interactive comment on Earth Syst. Dynam. Discuss., 6, 2323, 2015.

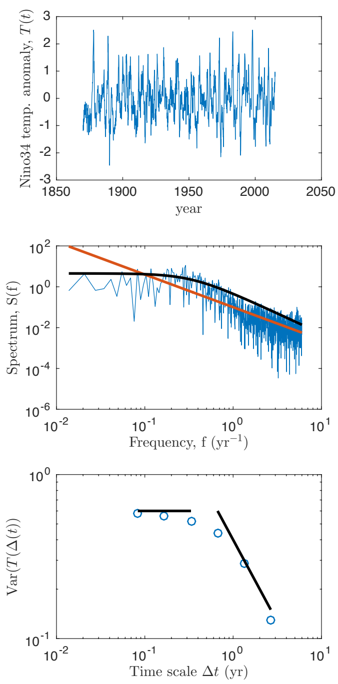

Fig. 1. Top panel: Nino 3.4 Temperature anomaly. Middle panel: Power spectrum, black line is spectrum for AR1 process with correlation time of 3 yrs, red line is $f^{-1.6}$. Bottom panel: Variance of means of

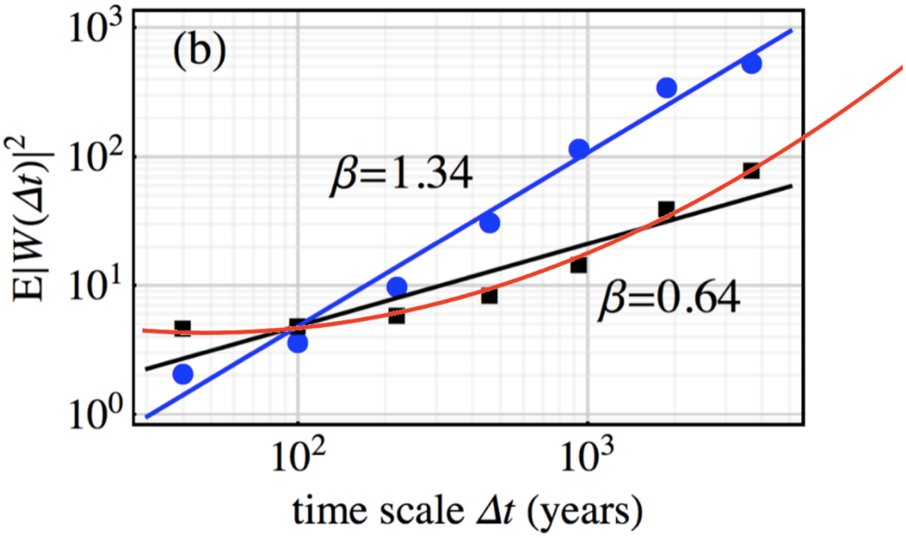

Fig. 2. Insert from Manuscript Figure 2. Red curve is a second order polynomial fit.