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Interactive comment on "Agnotology: learning from mistakes" *by* R. E. Benestad et al.

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At the surface of things, the conceptually simplest approach to detection of anthropogenic global warming should be the estimation of trends in global surface temperature throughout the instrumental observation era starting in the mid-nineteenth century. These kinds of estimates, however, are subject to deep controversy and confusion. The authors of Agnotology contribute to this confusion by their shallow statements about "circular reasoning." The only evidence offered is an R-script which shows that the autocorrelation function (ACF) develops an LTP-like tail if one adds a trend to a stationary, noisy, non-LTP signal. This is known to anyone who works seriously with LTP, and is a major reason why the ACF is never used to demonstrate LTP in short time records.

It is my view that there are several, equally valid, definitions of the notion of a trend. Which one that will prove most useful depends on the purpose of the analysis and the

availability and quality of observation data. At the core of the global change debate is how to distinguish anthropogenically forced warming from natural variability. As the authors of Agnotology point out, a complicating factor here is that natural variability has forced as well as internal components. Power spectra of climatic time series also suggest to separate internal dynamics into quasi-coherent oscillatory modes and a continuous and essentially scale-free spectral background. Over a vast range of time scales this background takes the form of a long-term persistent, fractional noise or motion [1]. Hence, the issue is threefold: (i) to distinguish the climate response to anthropogenic forcing from the response to natural forcing, (ii) to distinguish internal dynamics from forced responses, and (iii) to distinguish quasi-coherent, oscillatory modes from the persistent-noise background.

This conceptual structure is illustrated by the Venn diagram in panel (a) in the figure. Panel (b) in this figure illustrates three possible trend notions based on this picture. Fundamental for all is the separation of the observed climate record into a trend component (also termed the signal) and a climate noise component. The essential difference between these notions is how to make this separation.

The widest definition of the trend is to associate it with all forced variability and oscillatory modes as illustrated by the upper row in panel (b). With this notion the methodological challenge will be to develop a systematic approach to extract the persistent noise component from the observed record, and then to subtract this component to establish the trend. The physical relevance of this separation will depend on to what extent we can justify to interpret the extracted trend as a forced response with internally generated oscillatory modes superposed. If detailed information on the time evolution of the climate forcing is not used or is unavailable such a justification is quite difficult. In this case one could construct a parametrized model for the trend based on the appearance of the climate record at hand and physical insight about the forcing and the nature of the dynamics.

The next step could be to estimate the parameters of the trend model by conventional regression analysis utilizing the observed climate record. The justification of interpreting this trend as something forced and/or coherent different from background noise will be done through a test of the null hypothesis which states that the climate record can be modeled as a stochastic process with certain memory properties. Examples of such processes are persistent fractional Gaussian noises (fGns) or fractional Brownian motions (fBms). For comparison one can also test the null hypothesis against a conventional short-memory notion of climate noise, e.g., the first-order autoregressive process (AR(1)). Rejection of this null hypothesis will be taken as an acceptance of the hypothesis that the estimated trend is significant, and will strengthen our confidence that these trends represent identifiable dynamical features of the climate system.

The authors argue that the value of this kind of analysis of statistical significance is of little interest since the result depends on the choice of null model for the climate noise. One can, however, test the null models against the observation data, and here analysis seems to favor the fGn/fBm models over short-memory models. Bayesian iteration can be used in this process. This is not circular reasoning, but a systematic approach to hypothesis testing and establishment of knowledge.

If forcing data are available over the time span of the observed temperature record we can utilize this information in a parametrized, linear, dynamic-stochastic model for the climate response. The trend then corresponds to the deterministic solution to this model, i.e., the solution with the known (deterministic) component of the forcing. In this model the persistent-noise component of the temperature record is the response to a white-noise stochastic forcing. The method is described in a recent paper submitted to J. Climate where only exponential and scale-free long-range persistent responses are modeled, without allowing for quasi-coherent oscillations [2]. The approach in that paper adopts the trend definition described in the second row of panel (b) in the figure. Here the trend is the forced variability, while all unforced variability is relegated to the realm of climate noise. It is possible, however, to incorporate forced and natural oscillatory dynamics into such a response model. The simplest way could be to add the

response of a forced, damped harmonic oscillator to the scale-free response. These extra degrees of freedom would add an oscillatory response to the deterministic forcing (this would be a forced, oscillatory response), but also an oscillatory response to the stochastic forcing which would be interpreted as an internal oscillatory mode.

According to the approach described in that submitted paper we have to classify all deterministic forced responses as trends, implying that a trend defined this way is not necessarily slow. For instance, the irregular sequence of volcanic eruptions provides a shot-noise like forcing signal. After having estimated the parameters of the forced response model using the full forcing data and the observed temperature record, the residual can be analyzed to assess the validity of different noise models. The responses to fast components in the forcing (like volcanic spikes) will be shifted to the forced response, rather than being incorrectly represented as parts of the internal noise. The test of different noise models via analysis of the residual will therefore give more correct results in the forced-response model than the trend-fit approach.

The lower row in panel (b) depicts the trend notion of foremost societal relevance; the forced response to anthropogenic forcing. Once one has estimated the parameters of the forced-response model, one can also compute the deterministic response to the anthropogenic forcing separately. One of the greatest advantages of the forced-response methodology is that it allows estimation of this anthropogenic trend/response and prediction of future trends under given forcing scenarios, subject to rigorous estimates of uncertainty.

A systematic approach to estimating the significance of the linearly rising trend in global land and ocean temperatures, and the of the 60 yr oscillation observed in these records, throughout the instrumental can be found in a manuscript that we are about to submit [3]. I feel provoked by to have this work dismissed in advance by the authors of Agnotology as "cultural production of ignorance."

[1] Lovejoy, S., and D. Schertzer (2013), The Weather and Climate: Emergent Laws

and Multifractal Cascades, Cambridge University Press. Markonis, Y., and D. Koutsoyiannis, Climatic Variability Over Time Scales Spanning Nine Orders of Magnitude: Connecting Milankovitch Cycles with Hurst-Kolmogorov Dynamics (2013), Surv. Geophys., 34, 181-207

[2] M. Rypdal and K. Rypdal, Long-memory effects in linear-response models of Earth's temperature and implications for future global warming, submitted to J. Climate, http://arxiv.org/pdf/ 1305.5080v1.pdf

[3] https://dl.dropboxusercontent.com/u/12007133/Landocean-Kris-II%20copy.pdf

Interactive comment on Earth Syst. Dynam. Discuss., 4, 451, 2013.

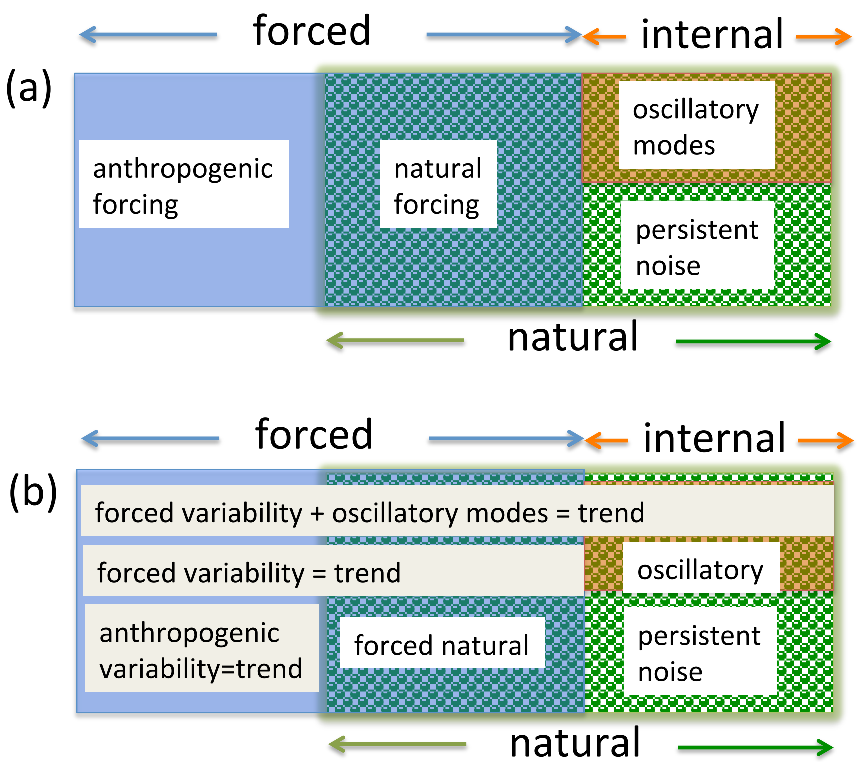

Fig. 1. Venn diagrams illustrating the interplay between forced, internal, and natural variability and various definitions of trend.