

Analysis of additivity in the NorESM model

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Lovejoy and Varotsos (L&V) analyse in their paper the additivity of the response to solar and volcanic in the Zebiak-Cane (ZC) model. There were at least three drawbacks with these data. The ZC model is not representative for the global temperature response, the data analyzed had been averaged over 100 realisations, and there were no control runs available to assess the magnitude of internal variability. They also analysed data from the NASA GISS-E2-R model, but here they lacked the full suite of simulations with solar-only, volcanic only, and solar+volcanic forcing, and hence the could not perform the test of the additivity of responses on a full-blown GCM.

We showed in our comment that L&V's analysis on the additivity on the ZC-model is flawed. Now we have been able to acquire a full suite of millennium-long simulations for the NorESM Earth System Model, which is part of the CMIP5 ensemble. More specifically, we have analysed solar-only, volcanic only, solar+volcanic+anthropogenic, and control runs for the 900 yr period 935-1834 CE. We have omitted the period after 1835 CE to minimize the anthropogenic forcing in the full forcing simulation, and treat this as a solar+volcanic simulation.

The global temperature responses and their corresponding Haar fluctuation functions are given in Figure 1. It is remarkable that all Haar fluctuation curves are almost flat, corresponding to $H \approx 0$ or $\beta \approx 1$, i.e., to a so called $1/f$ -noise.

In Figure 2 we have plotted in the same panel the Haar fluctuations for the solar+volcanic (total) forcing (red), for the summed responses to solar and volcanic forcing (blue), and for the control run (magenta). Observe that the responses to solar and volcanic forcing add up to the response of the combined forcing. *The subadditivity claimed by L&V is completely absent.* We also observe that the internal variability represented by the control run is quite strong. The standard deviation of the internal variability is $2/3$ of the variability of the signal with solar+volcanic forcing. Moreover, the internal fluctuations are almost equally strong on long-time scales as on short time scales, contrary to what has been claimed by L&V.

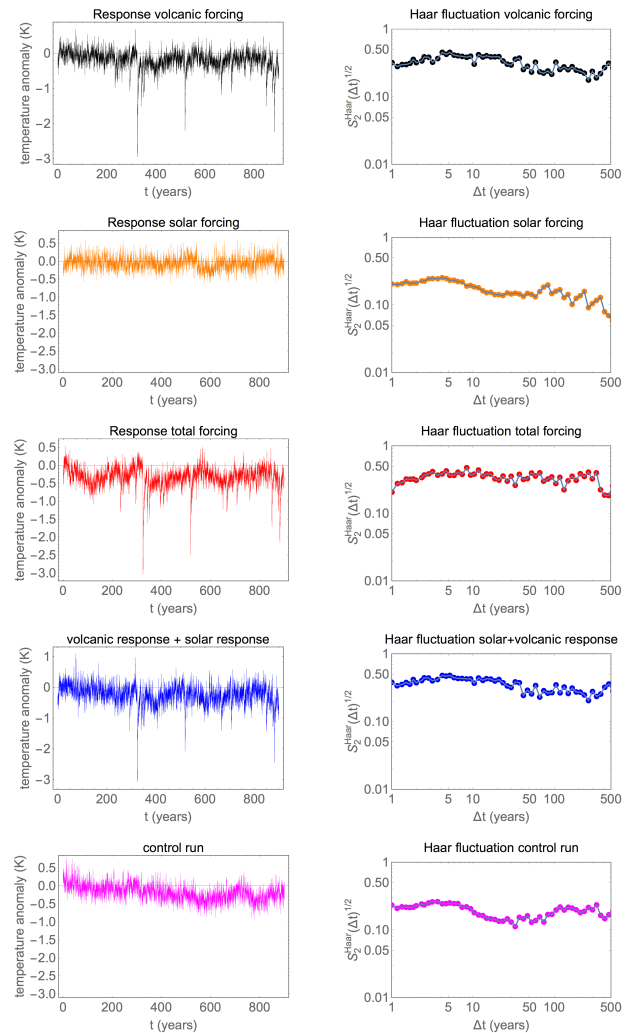


Figure 1. Left column: the response signals in the NorESM model. Right column: the corresponding Haar fluctuation functions.

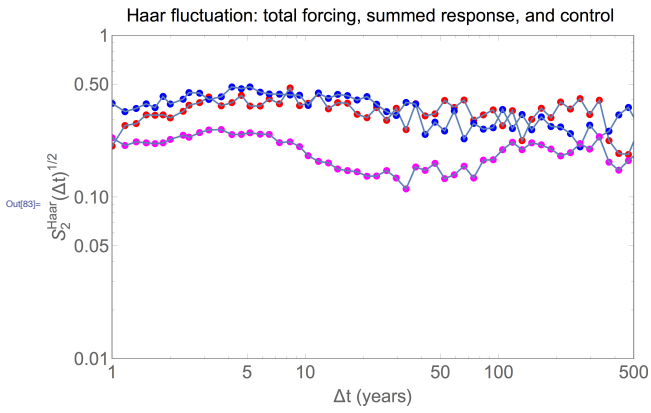


Figure 2. Red curve: Haar fluctuation of the response to solar + volcanic forcing. Blue curve: the Haar fluctuation of the summed solar and volcanic response. Magenta curve: Haar fluctuation of the control run.

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