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Long-range memory in millenium-long ESM and AOGCM experiments

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Summary

Consider the Earth's global mean surface temperature time series (GMST) as a realization of a stochastic process. Based on a number of studies, a long-range memory (LRM) stochastic process seems to describe the GMST better than a short-range memory model, such as the AR(1)-process. We want to study the persistence in climate model simulations, to find out if simulated temperature data exhibit the same LRM-properties as instrumental and paleo data. To infer whether the LRM originates from variations in external forcing or from internal variations in the climate system, both forced model runs and control runs are studied.

LRM is characterized by an autocorrelation function decaying as a power law:

- $\lim_{t\to\infty} C(t) \propto t^{\beta-1}$, where β is a scaling exponent describing the degree of persistence.
- For a stationary LRM process: $0 < \beta < 1$.
- In this particular study, the persistence in Northern Hemisphere (NH) mean ST time series is determined by estimating β by the DFA2 method.
- We investigate the LRM in NH mean ST time series from millenium-long climate simulations and paleo data.

Data

Northern Hemisphere mean surface temperature time series from:

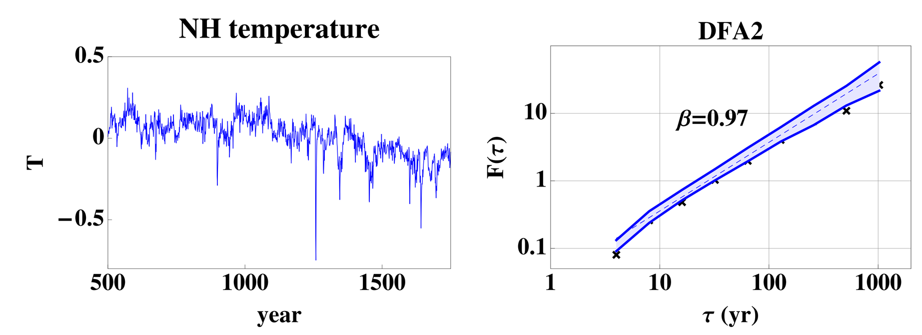
- One forced run from the LOVECLIM model, Goosse et al. (2012)[1]
- One forced and one control run from the COSMOS model, Jungclaus et al. (2010)[2]
- One forced and one control run from the ECHO-G model, Zorita et al. (2003)[3], von Storch et al. (2004)[4]
- One temperature reconstruction, Moberg et al. (2005)[5]

The Second Order Detrended Fluctuation Analysis method

- Removes linear trends from the data
- The resulting fluctuation function for segments of equal length τ is associated with β in the following manner: $F(\tau) \propto \tau^{(\beta+1)/2}$.

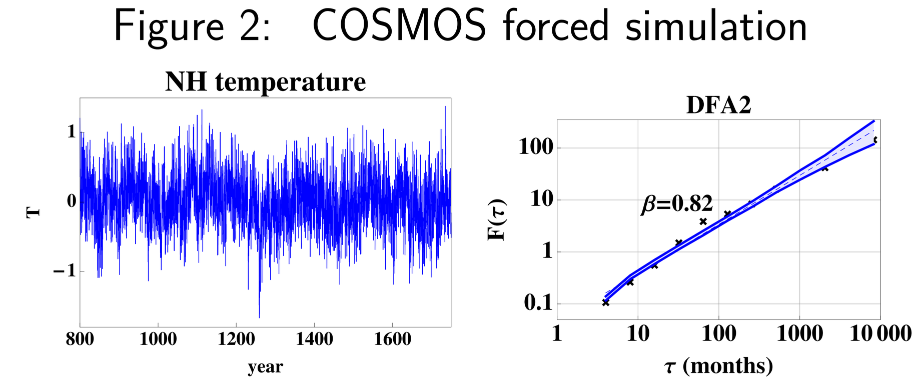
Results

Figure 1: LOVECLIM forced run



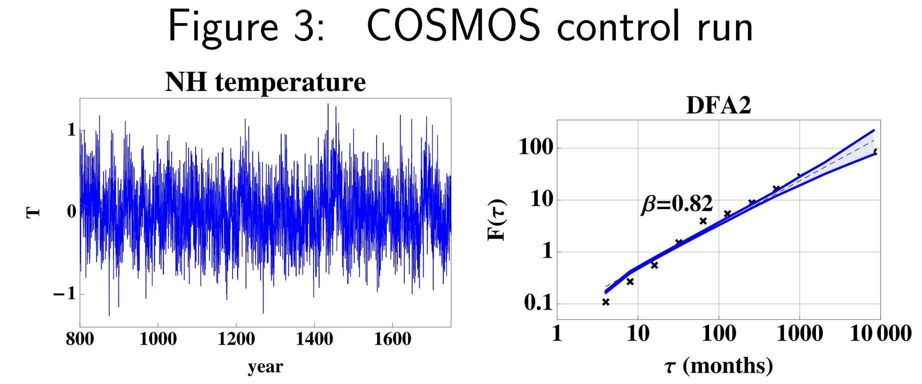
(a) 500-1750 AD (b) β =0.97 by DFA2

Figure 2: COSMOS forced simulation



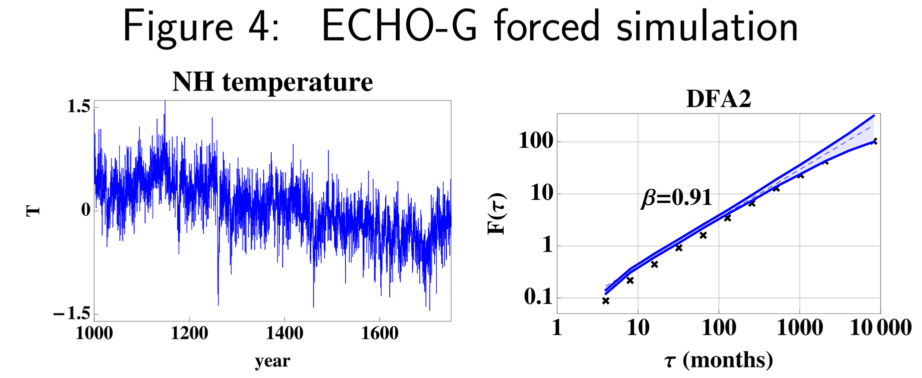
(a) 800-1750 AD (b) β=0.82 by DFA2

Figure 3: COSMOS control run



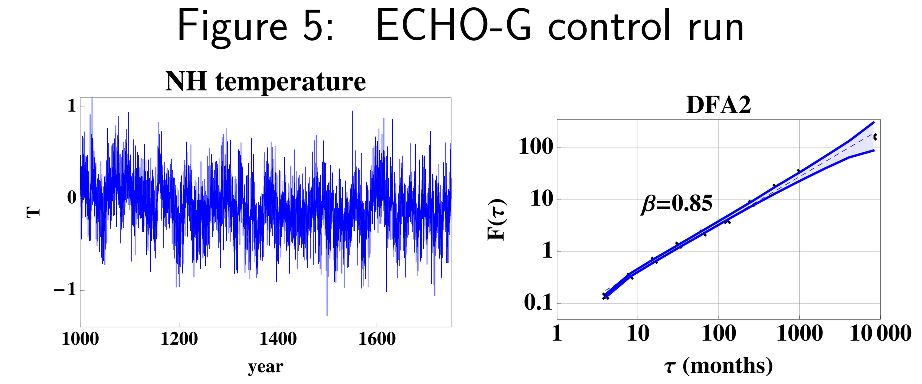
(a) 800-1750 AD (b) β=0.82 by DFA2

Figure 4: ECHO-G forced simulation



(a) 1000-1750 AD (b) β=0.91 by DFA2

Figure 5: ECHO-G control run

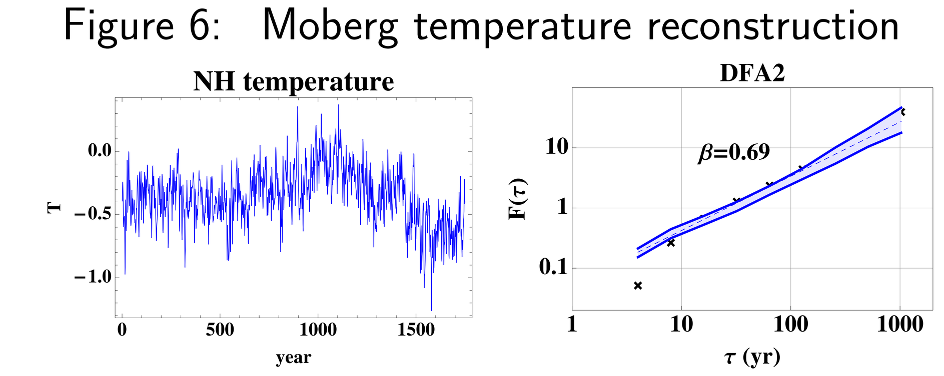


(a) 1000-1750 AD (b) β=0.85 by DFA2

The figures on the left-hand side display the Northern Hemisphere mean temperature time series. To the right, β is estimated from the fluctuation function. The blue area denotes a 95% confidence area, computed from Monte Carlo ensembles of synthetic fractional Gaussian noise.

Comparison with the Moberg et al. 2005 NH temperature reconstruction:

Figure 6: Moberg temperature reconstruction



(a) 0-1750 AD (b) β=0.69 by DFA2

Conclusions

- High degree of persistence for all model simulations and the temperature reconstruction.
- There is not systematically less persistence in the control runs than in the forced runs. This indicates that the observed LRM is generated by internal variability, and not primarily by external forcing

References

[1]Goosse et al. (2012), "The role of forcing and internal dynamics in explaining the "Medieval Climate Anomaly", *Clim. Dyn.*, 39, 2847-2866.

[2]Jungclaus et al. (2010), "Climate and carbon-cycle variability over the last millenium", *Climate of the Past*, 6, 723-737.

[3] Zorita et al. (2003), "Testing the Mann et al. (1998) Approach to Paleoclimate Reconstructions in the Context of a 1000-Yr Control Simulation with the ECHO-G Coupled Climate model", *J. Climate*, 16, 1378-1390.

[4] von Storch et al. (2004), "Reconstructing Past Climate fromm Noisy Data", *Science*, 306, 679-682.

[5]Moberg et al. (2005), "Highly variable Northern Hemisphere temperatures reconstructed from low and high-resolution proxy data", *Nature*, 433, 613-617.