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Bias correction in Global Mean Temperature comparisons between Global Climate Models and implications for the deterministic and stochastic dynamics

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Global mean temperature (GMT) provides a simple means of benchmarking a broad ensemble of global climate models (GCMs) against past observed GMT which in turn provide headline assessments of the consequences of possible future forcing scenarios. The slow variations of past changes in GMT seen in different GCMs track each other [1] and the observed GMT reasonably closely. However, the different GCMs tend to generate GMT time-series which have absolute values that are offset with respect to each other [2]. Subtracting these offsets is an integral part of comparisons between ensembles of GCMs and observed past GMT. We will discuss how this constrains how the GCMs are related to each other. The GMT of a given GCM is a macroscopic reduced variable that tracks a subset of the full information contained in the time evolving solution of that GCM. If the GMT slow timescale dynamics of different GCMs is to a good approximation the same, subject to a linear translation, then the phenomenology captured by this dynamics is essentially linear; any feedback is to leading order linear in GMT. It then follows that a linear energy balance evolution equation for GMT is sufficient to reproduce the slow timescale GMT dynamics, provided that the appropriate effective heat capacity and feedback parameters are known. As a consequence, the GCM's GMT timeseries may underestimate the impact of, and uncertainty in, the outcomes of future forcing scenarios. The offset subtraction procedure identifies a slow time-scale dynamics in model generated GMT. Fluctuations on much faster timescales do not typically track each other from one GCM to another, with the exception of major forcing events such as volcanic eruptions. This suggests that the GMT time-series can be decomposed into a slow and fast timescale which naturally leads to stochastic reduced energy balance models for GMT.

[1] IPCC Chapter 9 P743 and fig 9.8,IPCC TS.1
[2] see e.g. [Mauritsen et al., Tuning the Climate of a Global Model, Journal of Advances in Modelling Earth Systems, 2012] 4, IPCC SPM.6