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Interactive comment on "Evolution and forcing mechanisms of ENSO over the last 300,000 years in CCSM3" *by* Zhengyao Lu et al.

Anonymous Referee #1

Received and published: 3 March 2017

Recommendation: *Publish with major revisions*

Summary: *The article studies the evolution of ENSO under orbital and prescribed greenhouse gas and ice sheet boundary conditions using a low-performance coupled GCM over the past 300,000 years. Attempts are made are explaining the physical underpinnings of the model behavior (via the BJ index), but the model's lack of realism, and the extremely problematic acceleration technique, both undermine the extent to which the results can be generalized outside of the CCSM3 world. The paper may be suitable for publication after major revisions, but the abstract and title need to more accurately reflect hat is substantiated by the analysis.*

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Discussion paper

1 Scientific Comments

- Objection#1: A poor model
  No model is ever perfect, and the authors do acknowledge that. However, I am concerned that the excessive semi-annual cycle, the absence of a combination tone, and the very strong link to the annual cycle (see Objection 2 below) really limit the generalizability and usefulness of these simulations.

- Objection#2: Frequency entrainment

  The authors also seem to believe in the frequency entrainment mechanism as an explanation for virtually everything. Although it does seem to explain the orbital response of most PMIP3 models, it does not apply to all GCMs, especially a more realistic one [An, SI. & Choi, J. Clim Dyn (2013) 40: 663. doi:10.1007/s00382-012-1403-3]. More importantly, it was recently shown to be incompatible with observations over the Holocene [Emile-Geay et al., (2015), doi:10.1038/ngeo2608]. The authors cite the latter paper but seem to completely discount its critical conclusion, and how this conclusion undermines most of their reasoning.

  Let me, therefore, rephrase it: in a model where the annual cycle runs the show, one will infer relations to forcings that are overly centered on the annual cycle. This would be actively misleading, perhaps worse than no model at all. I urge the authors to seriously consider the implications of frequency entrainment being an unphysical aspect of CCSM3, perhaps by targeted experiments with other community models like GFDL's CM2.1, which does not exhibit this behavior (and presumably reacts differently to orbital forcing).

  It is no longer good enough to assume that frequency entrainment explains everything.

- Objection#3: Problematic acceleration

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Discussion paper

Central to the long time span claimed in the title (300,000 years) is the hundred-fold acceleration technique used by the authors. Just because it's been done 15 years ago, doesn't mean it's a good thing to do today. To their credit, the authors do a good job of using the TRACE simulation to evaluate the consequences of the acceleration. However, they fail to adequately emphasize in their conclusions how seriously this alters the model's response compared to the non-accelerated case, which in my view completely undermines the rest of their conclusions. To wit: the response to orbital variations takes place during 200 years, not 20,000. This is barely sufficient for ventilation to takes place in the lower thermocline, and seriously compromises any claim made about the quantitative importance of the thermocline feedback, to take one example. The authors partly concede this, but in my opinion this needs to be the main topic of the paper: acceleration is a bad idea, and completely distorts the physics of the response. There is still value in the results presented in this article, but only from the strict perspective of paleo modeling techniques.

The applicability of CCSM3 results to the real world is questionable, but still of interest. The applicability of accelerated CCSM3 results to the real world is non-existent.

In summary, major revisions are needed to bring the title and abstract of this work in line with what can be reliably concluded from these simulations.

2 Editorial Comments

- The English is remarkably poor. To give but one example from page 17 (ca line 5):

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> *We have also demonstrated that there is possibly precession-induced variation of stochastic forcing outside the EEP that 5 influences ENSO variability through remote mechanisms. ENSO can be driven by the exterior driver of weather noises either from TWP by exciting oceanic Kelvin waves or from North Pacific via the PMM activity. At present, it is difficult to identify which process plays a quantitatively more important role*.

which should read (corrections in caps): "We have also demonstrated that there is A possibly OF precession-induced variation of stochastic forcing outside the EEP that influences ENSO variability through remote mechanisms. ENSO can be driven by the exterNAL driver of weather noise (no s) either from THE TWP by exciting oceanic Kelvin waves or from THE North Pacific via the PMM activity. At present, it is difficult to identify which process plays a quantitatively more important role"

There is no point in addressing this as long as the science is not on a firmer footing, but I highly recommend that the authors ask a native English speaker to check their revised manuscript. Some do this for a fee; it's worth the price.

- The Thomas et al 2006 reference lists the paper as 'in review'... 10 years ago. What is the current status of this article?

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