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Climate of the Past Discussions

Interactive comment on "Insights into the early Eocene hydrological cycle from an ensemble of atmosphere–ocean GCM simulations" *by* M. J. Carmichael et al.

Anonymous Referee #2

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General comments: This paper compiles the results of several general circulation models run under "Eocene" conditions (although these conditions differ between models, in some cases substantially) and compares the patterns of precipitation and evaporation between models and against proxy estimates for precipitation from geologic records in the Eocene. The study concludes that qualitatively, all of the models (as well as the proxy data) confirm the expectation that high pCO2 (and more importantly, the resulting warmer climate) of the Eocene results in a more intensified global hydrologic cycle, that is, higher global rates of precipitation and evaporation. However, quantitatively the models differ in the sensitivity of global precipitation rates to warmer climates, quite significantly when specific regions are examined. Model-data comparison reveals

that all of these models seem to underestimate high-latitude precipitation (and hence meridional latent heat transport), which seems to be related to the underestimation of high-latitude temperature. This is a useful "state-of-the-art" contribution which presents objectively what GCMs have to say about the hydrologic cycle in warmer climates, and even backs that up with model-data comparisons which are unfortunately too rare in model-based papers on Paleoclimate.

Specific comments: The paper's largest issue is one that the authors acknowledge openly: the different models are run under different conditions (paleogeography, and most importantly, pCO2). This certainly complicates exact model-model comparisons: when one model produces less high-latitude precipitation than another, it makes it unclear if that is due to the different behavior of the models, or to the different boundary conditions. Short of re-running all of these models under the same conditions, however, there is not much to be done about this.

However, a second shortcoming which deserves to be addressed is the comparison of model results to different proxy estimates which come from vastly different ages and hence must record different climates. As the paper is currently laid out, the proxy data are treated together as an estimate of what Eocene precipitation was like, however in reality each proxy estimate provides an independent estimate of what precipitation was like at one point in space and time. The estimates listed in table S3 span from "Paleocene" to 44Ma, a time interval which includes a range of deep-ocean temperatures greater than 7 degrees C (larger if the PETM is included) which is a larger spread than many of the model-model differences. The authors make a good and explicit point out of the fact that looking at model-model differences is not exactly comparing apples to apples, and they should extend that caveat to the treatment of proxy data.

My opinion is that there could be a more complete introduction detailing the climate dynamics that create our expectation of hydrologic intensification in warmer climates. Many aspects of this are introduced one at a time as those aspects are discussed later in the context of model-model and model-data differences, but an introduction

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to the physics involved would be helpful. The existing introduction to previous work and geologic evidence for higher precipitation in the Eocene is excellent. Technical comments:

P 3299 Line 12: Should the partition of runoff and groundwater not also depend on how vegetation is parameterized in the various models?

Line 17: "the wet become wetter and the dry become drier" seems like useful background for what's generally expected in warmer climates, so perhaps belongs in the introduction

P3300: The discussion of the differing response of meridional heat transport would benefit from more explanation of the role of such transport in the global heat budget. If one model produces more latitudinal heat transport (by latent heat of water vapor) than another, does that mean that it must necessarily feature less meridional heat transport via sensible atmospheric and ocean heat? Or, do the differing effects of pCO2 on the surface radiative heat budget at different latitudes mean that different models are allowed to have different total meridional heat transport for given levels of pCO2?

P3301 Line 10: "They" should be "these" or "the"

Table 3: Clarify what "MA" means here.

Figure 9: It would be nice to see the modern real-world P-E and inferred heat transport to compare to the model control cases.

Figure 10: Give age ranges for each of the sources of proxy data. This is certainly a complicating factor in model-data comparison: many of these data come from different time periods with different climates. Do any of them come from within the PETM or other hyperthermals? This would be especially troublesome.

Interactive comment on Clim. Past Discuss., 11, 3277, 2015.