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Earth System Dynamics Discussions

Interactive comment on "Tipping the ENSO into a permanent El Niño can trigger state transitions in global terrestrial ecosystems" *by* Mateo Duque-Villegas et al.

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Comment:

Recommendation: Accepted after major revisions

The authors present a thorough study in an intermediate complex global model (PlaSim) about the impact that a permanent ENSO state might have in the global energy and water balances and also in the global atmospheric circulation and terrestrial ecosystems. The results in the manuscript and in the supplementary material are generally very well presented. However, there are some main issues that must be revised.

Response:

We thank the reviewer for his/her comments. Specific answers to each comment are provided below. All support figures for our comments can be found as supplementary material to this comment, with prefix 'C' as part of the numbering

Comment:

1 - Despite the utility of this kind of simulations, there is no proof that a permanent ENSO could be a climatic equilibrium state, consistent with the present CO_2 concentrations. Both in CTL and PEN simulations, CO_2 is kept constant at 360 ppm, near the global mean value of 1995, whereas the present (2018-19) mean value is around 416 ppm. Authors agree that ENSO is becoming reinforced under a larger radiative (CO_2) forcing. Therefore, why have not the authors set the CO_2 concentrations to 2018 values. The fact that CO_2 is kept at the 1995 values introduces an inconsistency. Authors shall present the impact (at least in the water deficit) of changing simultaneously SST and CO_2 forcing. There is evidence that some Permanent El Niño-Like Conditions have occurred During the Pliocene Warm Period (Wara et al. 2005). Authors shall compare the forcing of PEN simulations with those of Pliocene.

Response:

Two things:

1.1 - You are right. We update all results using a CO_2 value of 415 ppm, which, as you pointed out, is closer to current estimates of this variable (Dlugokencky and Tans, 2019). This change directly affects the long-wave radiation and dynamic vegetation modules in the model. However, differences among simulations are modest enough (Fig. C1 and C2) that we only deem it necessary to present the results obtained with this new 415 ppm CO_2 value. In terms of the water deficit, the new results show many of the same patterns previously discussed and only some minor changes in the Northern Hemisphere can be seen (Fig. C3). We will extend our discussion to include these minor changes. For the manuscript, this means all figures except those that pertain the methodology (Fig. 1 and Fig. S1) will be updated. Experimental setup section will be updated accordingly.

1.2 - Wara et al. (2005) suggest the possibility that permanent El Niño-like conditions may have occurred during the warm early Pliocene period. Using environmental reconstructions from isotopes and bioindicators, they found that the zonal west-to-east gradient of sea surface temperature (SST) was very similar to the one observed during modern El Niño events. Although more recent studies suggest that their reconstruction may underestimate the Pacific warm pool temperature and its variability (Zhang et al., 2014), it is still interesting to compare PEN scenario's results with those of Pliocene simulations. In Fig. C4 we compare the SST boundary conditions of the PEN scenario with the paleoenvironmental reconstruction data set PRISM3 (Dowsett et al., 2009), which covers the mid-Pliocene warm period and has been used in many Pliocene modeling experiments (Haywood et al., 2016). PEN forcing was on average about 1°C warmer in the tropics, though the differences in this region are not all significant. PEN was cooler than PRISM3 elsewhere. The west-to-east zonal gradient was computed for both forcings, as well as that of the CTL simulation, at the sites shown in Fig. C4. For PEN the gradient was 1.5°C, whereas for PRISM3 it was 1.8°C. CTL simulation had a gradient of 3.1°C. Since this gradient is a good indicator of the strength of the Walker circulation (Wara et al., 2005), we can say that in the PEN scenario it was weaker than in the mid-Pliocene warm period, and much weaker than in the CTL scenario. Haywood and Valdes (2004) simulated the mid-Pliocene warm period (using a CO_2 concentration of 400 ppm) and found global surface temperature to rise. Near surface temperature also rose in PEN scenario with respect to its control scenario. Also in both studies warming was greater on land than on the oceans. Regarding precipitation rate, it also increases slightly in PEN and in the Pliocene simulation with respect to their control scenarios. Another resemblance is the fact that both in Haywood and Valdes (2004) and in PEN, annual mean precipitation decreases in Central and South America, whereas it increases in the Northern Hemisphere. Particularly for the Ama-

zon region, both studies show that temperatures rise and precipitation decreases. Fedorov et al. (2011) report that in the mid-Pliocene warm period there might have been strengthening of the meridional circulation leading to aridification of Africa, Australia and North America, which is very similar to what we observe in PEN results. In spite of the similarities between PEN and the mid-Pliocene warm period, a biomes reconstruction of the Late Pliocene period (Salzmann et al., 2011) seems to disagree with our results, specially for Africa and Australia, since it shows more vegetated regions than we would expect with the water deficit changes observed in PEN. We believe PEN to be a more arid equilibrium partly because land cover in this scenario (which is similar to current global land cover) has a smaller extent of vegetation than that of the Pliocene. This will be included as a Pliocene-related subsection in the discussion section.

Comment:

2 - The model bias given by the difference CTL minus observations is of the same order of that of some GCMs. However, the mean difference between PEN and CTL simulations is much lower in amplitude for certain fields (e.g. land surface temperature and precipitation) and locations, thus raising duties about the significance of the ENSO impact. Conclusions are only valid under the hypothesis that model bias is the same, both in climatological SST conditions and ENSO conditions. The confidence in the impact results is only valid by assessing the model bias under ENSO conditions. It is quite simple to do so through the difference PEN minus composite mean observations under ENSO (by choosing the set of larger ENSO events).

Response:

2 - Since our original results changed slightly, due to setting atmospheric CO_2 to 415 ppm, we first checked that CTL biases were still in the same order of that of other general circulation models. The new CTL biases were very similar to those shown in Fig. 3 of the unrevised manuscript. Then we followed your recommendation and plotted Fig. C5, in which we compare PEN simulation versus observational databases

during strong El Niño events. MODIS is an exception since data only covers period 2000 - 2015, so it does not include any strong El Niño events, but only moderate ones. We again find similarities between PEN and observations in the broad scale patterns of these variables. Bias panels for PEN in Fig. C5 are very similar to those of CTL in Fig. 3 in the unrevised manuscript. For ease of comparison we have plotted Fig. C6 in which all these bias panels are shown, as well as their absolutes difference. Overall, we see that model bias is similar for climatological and El Niño conditions. Only for MODIS we see relatively large bias differences, most likely because the database does not include any strong El Niño events. Hence we are confident that differences between scenarios are a realistic representation of the effects caused by the strong El Niño SST forcing. This will be included in the results section.

Comment:

3 - Authors refer the sensitivity of model climatology to initial conditions by considering perturbed initial condition fields. However, the results of that sensitivity and the t-Student tests are not explicitly presented.

Response:

3 - Although the model does not seem to display great sensitivity to initial conditions, we believe that it is an important part of atmospheric modeling experiments to test for chaos and this is why we have ensemble mean results rather than single simulation results. As shown in Fig. C7 for the CTL simulation mean values, differences among ensemble members are nonetheless very small. Notice that in Fig. C7 we have used a significance level of 0.1 to be able to at least show that they are in fact different simulations. When we used 0.05 instead, most maps showed up empty. This will be clarified in the experimental setup section.

Comment:

4 - Quantitative diagnostics of the Walker circulation (bias and impact) shall be in-

cluded.

Response:

4 - Walker circulation in the equatorial Pacific is now shown in Fig. C8 for both CTL and PEN simulations. In both PlaSim simulations we see that the pattern is not as coherent as displayed in ERA-Interim, however the same broad scale structures are observed. In CTL, air rises in the west Pacific near longitude 150°E, flows eastward and sinks around longitude 120°W. This the expected behaviour during normal conditions (Collins et al., 2010) and is also observed in ERA-Interim climatology. It seems like PlaSim underestimates both upward and downward motions as compared to the reanalysis. In PEN simulation we see convection is displaced into the central Pacific while subsidence in the east is decreased. This is very similar to what happens in ERA-Interim for strong El Niño years (mean of 1997-98 and 2015-16), although in the reanalysis subsidence in the east Pacific ceases almost completely. In this case we also see PlaSim underestimating vertical motions. Overall, PlaSim is able to adequately show the weakening of the Walker circulation during El Niño-like conditions. This will be included in the results section.

References

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Please also note the supplement to this comment:
https://www.earth-syst-dynam-discuss.net/esd-2019-14/esd-2019-14-AC3-supplement.pdf

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