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Interactive comment on "Changes in theWidth of the Tropical Belt due to Simple Radiative Forcing Changes in the GeoMIP Simulations" *by* Nicholas Davis et al.

Anonymous Referee #1

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This study examines the response of the width of the tropical belt to an abruptly applied 4xCO2 forcing and an abruptly applied 4xCO2 forcing that is balanced by a decrease in the solar constant ("G1 experiment") in 9 CMIP5 models. The authors find that the tropical width responds unevenly to identical forcing across seasons and hemispheres. The response of the tropical width is correlated strongly with the response in global-mean surface temperature and the attendant increases in subtropical static stability, tropical upper tropospheric temperature, and Arctic surface temperature.

Overall, this paper is very well done. The text is written very clearly, and the figures are straightforward to interpret. What is particularly novel about this study is the usage of the GeoMIP experiments to demonstrate a linkage between tropical belt expansion and

global-mean surface temperature. My main criticism of this paper is that the authors fail to compare their results to a number of recent studies that have already examined simplified climate forcings in comprehensive global climate models, including the exact same abrupt 4xCO2 CMIP5 experiments that were examined here. The authors' assertions that "[no previous studies] have examined how comprehensive climate models respond to simplified climate forcings" (lines 8-9) and that "what is lacking is a study that applies simple climate forcings in clearly designed experiments to fully-coupled models" (lines 106-108) are too strong in my opinion. In many aspects, this paper is written more clearly and goes farther than previous studies, but I think it's important to put the new findings in much better context of previous work on the subject. Suggested revisions are detailed below.

Minor Revisions

GENERAL: As stated above, a greater cross-comparison of results with previous studies that used simplified climate forcings is warranted. A handful of these studies have already addressed the tropical expansion issue in some detail:

a) Polvani et al. (2011) force CAM3 with a (2000-1960) greenhouse gas forcing only and find a similar seasonality to the Southern Hemisphere Hadley cell edge response documented here (see their Fig. 13e).

b) McLandress et al. (2011) force CMAM with greenhouse gas forcing only and find no seasonality to the Southern Hemisphere Hadley cell edge response (see their Fig. 8).

c) Grise and Polvani (2014) use the abrupt 4xCO2 experiments from 23 CMIP5 models and find a strong correlation between the magnitude of Southern Hemisphere Hadley cell edge expansion and the global-mean surface temperature response during all seasons (similar to what is found here). A recent paper by the same authors addresses the influence of global-mean surface temperature warming on Northern Hemisphere Hadley cell edge expansion (Grise and Polvani 2016).

d) Vallis et al. (2015) use the 1%/year CO2 increase runs from 35 CMIP5 models and find little correlation between global-mean surface temperature warming and the magnitude of Hadley cell expansion (see their Fig. 21).

Line 39: You might want to clarify here that the strength of the Hadley cell is actually projected to weaken in a warming atmosphere. (Vecchi and Soden 2007)

Line 137: I'm surprised that the circulation metrics adjust to the abrupt forcing in only two years. The point of this paper is that the Hadley cell edge responds to global-mean surface temperature warming, but the global-mean surface temperature warming continues throughout the duration of the 140-year run (as the ocean temperatures slowly warm). More could be said about this apparent contradiction.

Line 147: "are" is repeated twice.

Line 175: "Models with more equatorward edge latitudes in one hemisphere have more equatorward edge latitudes in the other hemisphere." It might be useful to provide the correlation value here.

Line 197: Could the non-uniform stratospheric cooling be due to variations in the strength of the Brewer-Dobson circulation, for example?

Lines 199-201: This is consistent with IPSL-CM5A-LR having one of the higher climate sensitivities of the nine models examined, and CCSM4 have one of the lowest. It might be useful to note somewhere on Figure 2 the climate sensitivities of the models.

Line 262-263: The lack of robustness in the Northern Hemisphere tropical expansion could reflect the compensating effects of two large robust responses, the effect of warming land on the tropical circulation and the effect of warming ocean on the tropical circulation (see Shaw and Voigt 2015).

Line 274: The upper stratospheric cooling appears to be similar in the two subsets of models. It's just the lower stratospheric cooling that varies.

Line 326: "The change in" is repeated.

Lines 389-402: Another potential mechanism to mention here is the upper tropospheric-lower stratospheric meridional temperature gradient. Certainly, increased subtropical static stability and increased tropical upper tropospheric temperatures go hand in hand. But, cooling in the polar lower stratosphere can shift the circulation poleward (e.g., Butler et al. 2010), and this has nothing to do with tropical heating or static stability. Both factors though change the meridional temperature gradient near the tropopause.

Table 1: Why are the radiative forcings listed in Table 1 different than those documented in Table 1 of Forster et al. (2013) for CMIP5 models (4xCO2)?

Figures 2 and 3: I believe that IPSL-CM5A-LR is mislabeled as IPSL-CM5A-MR.

Figure 6: Are these figures composited about the total width of the tropics (NH + SH)? If so, have you tried compositing about the NH and SH tropical edges separately? Are the results similar? Would you get the same composites if you subset the models by their global-mean surface temperature increase (instead of their Hadley cell widening)?

Figures 7-10: How do these relationships vary seasonally? Are the correlations uniform year-round, or do they have a distinct seasonality?

References:

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