

acp-2016-340: Changes in the Width of the Tropical Belt due to Simple Radiative Forcing Changes in the GeoMIP Simulations

Response to RC2

The authors thank Reviewer #2 for their time and their suggested revisions. Regarding major changes, we have updated figures so that they are color-blind-friendly and have added additional discussions of relevant previous work. We have also expanded the discussion of the seasonality of the width changes.

This paper documents the response of the width of the zonal mean tropical Hadley circulation to suddenly applied CO₂ and solar forcings. The work is timely, the writing understandable, the methods appropriate, and the figures mostly clear. Some results worth highlighting include the following.

1. Reducing the solar constant to counteract greenhouse gas induced warming may maintain a steady Hadley circulation in spite of a cooling stratosphere.
2. Model dynamical sensitivity is distinct from climate sensitivity (see Grise & Polvani, 2016).
3. Well-mixed GHGs produces a seasonally varying shift.

My main criticism of the article is the same as RC1: the authors state that previous climate model studies have not "...examined how comprehensive climate models respond to simplified climate forcings." While this study is certainly useful, there is already other, similar work out there that ought to be discussed.

Thank you for this suggestion.

We agree this statement concerning idealized experiments in comprehensive models is too strong. The neglect of these papers was unintentional, and we have included the references suggested by RC1. We have added a discussion of these papers so that our work is better situated in the context of previous work (see lines 108-117).

Line 102 - I don't believe the studies cited in this paragraph justify the statement that an increase in the height of the tropopause - independent from stratospheric cooling or tropospheric warming - drives a poleward shift in the circulation. I think this is an over-generalization.

This is a fair point – tropopause height changes are indicative of other thermodynamic changes in the climate system, so they should not be discussed as independent factors. We have now made it clear that Lorenz and DeWeaver raised the tropopause height *and* cooled the stratosphere, and have removed mention of tropopause height as an independent mechanism for expansion (now line 104).

Line 146 - What were some typical effective degrees of freedom calculated in this way?

We have added the approximate degrees of freedom for the G1 (~400, shortest) and piControl (~4000, longest) experiments to line 157.

Line 266 - "temperature structures" should probably be "zonal mean temperature structures"

Thank you, we agree it is important to note that this study only focuses on the zonal-mean (now line 279).

Line 289 - I think that "successfully used to study tropical expansion" suggest more closure than the theory provides. It's proven useful but insufficient.

We agree that "successful" may give the impression that these scaling theories are in some way "proven". We have removed "successful". In the discussion on lines 399-404 we have also clarified that Hadley cell expansion appears to scale with the increase in static stability (and many other thermodynamic indices), but that actual mechanisms for expansion were not investigated here and are far from certain. Please also see the response to RC1 concerning the timescale of the adjustment to the radiative forcing, and the relationship between equilibrium climate and dynamical sensitivity.

Lines 324-326 - Some clarification is needed here. I find the combination of "more linear", "more scattered," and "Despite the nonlinearity" all refer to the same result

We have clarified the text in this section – now lines 335-337 and lines 343-345.

In the references There are missing DOIs (line 413), and several DOIs that point to the wrong paper (e.g. the DOI for the Allen & Sherwood reference about aerosols on lines 414-415 points instead to an Allen & Zender paper on Siberian snow cover).

Thank you, we have checked all DOIs and fixed any in error.

The figures are nicely rendered, but some are carelessly produced. Figures 1, 4, 5, and 7-10 all use color as the only/primary way of conveying model information. "Do not use text color alone to convey information." I have attached a rasterized revision of Figure 1 which is much clearer, and a version of Figure 4 with a colorblind filter applied (roughly 1 in 10 men will perceive the figures this way.) Use symbols, or just annotate points with model names where it matters.

We thank the reviewer for these suggestions and the example figures. We have changed Figure 1 to black and white and rotated it, as per the reviewer's suggestion, so that the differences between mean model edge latitudes are easier to discern. For Figures 4 and 5 we have changed the model identifiers to symbols (it is difficult to discern numbers on these plots), and for 7-10 we have changed the model identifiers to numbers (the symbols are difficult to discern in this case). In Figures 7-10, a black and gray scheme is used to

distinguish the different experiments and minimize any problems for readers with color-blindness. We appreciate these suggestions and will keep color-blind-friendly schemes in mind for future work.