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Climate of the Past Discussions

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Interactive comment on "The effect of mountain uplift on eastern boundary currents and upwelling systems" *by* Gerlinde Jung and Matthias Prange

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Response to Reviewer #2 for the Manuscript: "The effect of mountain uplift on eastern boundary currents and upwelling systems" by Gerlinde Jung, Matthias Prange

We are grateful for the referee's additional comments which helped us to further improve the quality of the manuscript.

Anonymous Referee #2 Received and published: 26 June 2019

This manuscript explores the impact of different mountain uplifts on eastern boundary upwelling systems, through a set of sensitivity experiments to topography run with CCSM3 model. It echoes a previous publication by the authors, but this particular ms appears as a generalization assessment of the previous results that were obtained

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Discussion paper

for Africa and the Benguela upwelling system. This contribution is particularly interesting as the authors attempt to decipher amongst several mechanisms that can lead to sea-surface temperature changes in the EBUs regions, namely changes in Ekman pumping, changes in surface turbulent fluxes, changes in radiative forcing and horizontal heat advection. Authors show that different mechanism are at play depending if California, South America, or Benguela EBU is considered. The MS will fit well in Climate of the Past, still I suggest some clarifications / improvements that are somewhere between minor and major.

First, the “uplift history” part could be improved. Despite uncertainties, numerous papers have been published in the last decade that help constraining the elevation history of the different mountain ranges considered. For example: For the Andes, (Garzione et al., 2008, 2014; Leier et al., 2013) . For Africa see (Moucha and Forte, 2011; Wichura et al., 2010, 2015).

=> We extended the literature review of the uplift histories according to the reviewers' advice.

Having a more complete review of the literature on these paleoel- evations could in turn fuel a discussion on the relevance of sensitivity experiments to assess the EBU evolution: If topography was already partly uplifted during the Miocene, would the later phases of uplift involve changes in elevation strong enough to trigger the atmospheric and oceanic dynamics mechanisms invoke in the paper ?

=> The atmospheric and oceanic changes described in the manuscript refer to elevation changes from 50% to 100%. Hence our sensitivity experiments already showed the changes from an already partly uplifted situation. Other literature indeed showed also effects of an uplift from a completely flat earth (e.g. Feng and Poulsen, 2014) or continent (e.g. Sepulchre et al, 2009 for Southern America). There is definitely a much larger effect in these cases (e.g. completely different air flow over Southern America with flat terrain and already significant blocking of the Westerlies with 50% altitude of the Andes.

Second, I acknowledge the effort to validate the model, but this part (5.1) is the weakest of the manuscript in its present form. The authors use their control experiment, which they acknowledge have different boundary conditions than present-day (orbital parameters and lad surface conditions, specifically), to compare to data or higher resolution modelling. Moreover they do not provide actual figure of differences of Ekman pumping between their simulation and data/validated model. I would suggest to rewrite this part, use a "true" preindustrial simulation, and compare and show the anomalies with available upwelling climatologies.

=> We changed figures 2-3 (->Fig 3-4) and added a similar figure for the Benguela upwelling region (Fig 2) where we now use the data from a true preindustrial control run and compare this run qualitatively with the data available and described in paragraph 5.1. We have to make the reviewer aware of the fact that this comparison is also hampered by the fact that the respective observational/model data is mostly present-day and not preindustrial.

See for example Yi et al. (Yi et al., 2018) for such climatologies.

=> We could unfortunately not find any upwelling climatologies in the named reference, but we considered some of the cited literature of regional model simulations and added those to the evaluation our model results. Moreover, we post-processed and plotted vertical velocities from the Carton-Giese SODA 2.2.4 reanalysis data for additional comparison in the Supplement.

Lastly, figures show strong Ekman pumping on oceans western boundaries. It would be relevant to explain these signals.

=> We added some information on other upwelling systems (like the Southern Caribbean upwelling) to paragraph 5.1, but did not go into detail, since our publication is concentrating on the Eastern Boundary upwelling systems.

I think that at some point, either in part 5.1 or in the discussion, the authors need to discuss the need (or not) of high spatial resolution to correctly represent upwellings in GCMs.

=> We added some information on higher resolution runs and the benefits of higher resolutions to paragraph 5.1.

By the way, fig. 4 to fig 6. It would be easier to follow the text if the figures depicted NOTOPO and CTL-NOTOPO, rather than CTL and CTL-NOTOPO.

=> We thank the reviewer for making us aware of this inconsistency. We now changed all figures to the scheme CTL and CTL-NOTOPO (hence now all figures are consistant in that). We therefore did not change figures 4-6 (now Fig. 5-7), but added the illustrations for CTRL to figures 10-13.

The results are well-presented, but could be improved by a deeper analysis of the links between uplift and atmospheric physics/dynamics. Some diagnoses (maybe different geopotential heights, slp and air-temperature) could help the reader understand how surface winds and cloud covers are affected by the topography.

=> A deeper analysis of the mechanisms is beyond the scope of this manuscript and might in future publication be discussed for the different upwelling areas. We added some additional information from literature on publications that focused on similar effects to the discussion section.

I was also wondering if removing the topography would alter subgrid-scale parameterizations of moutain drags, and in turn alter the atmospheric dynamics. The ms would be more complete if authors could elaborate a bit on that.

=> Since we do not remove the topography entirely, but only reduce the altitude to 50% of the present-day topography and we leave the sub-grid scale orographic standard deviation untouched (also no paramterizations e.g. gravity-wave drag scheme are switched off), there is no direct effect on sub-grid scale parameterization, but only the effect through interaction with the changed large-scale flow.

The cloud radiative forcing (CRF) change between experiments with and without uplifted mountain ranges is well-described and seducing. I think the discussion could still be improved by (1) giving a bit more information about the main characteristics of cloud parameterizations in CCSM3 and

=> we added information on the cloud parameterization in CAM3 to the model description

(2) mapping the CRF changes both in LW and SW, to confirm the invoked mechanisms.

=> We added some figures that show the changes in cloud coverage at different levels and the changes in shortwave, as well as long-wave cloud forcing to the Supplement and discussed that issue in paragraph 5.2.4 for the different upwelling regions.

At some point a discussion on CCSM3 ability to represent correctly cloud cover along mountain ranges will be necessary.

=> We added some information on the ability of CCSM3 to simulate low clouds in the discussion.

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