Earth Syst. Dynam. Discuss.,
doi:10.5194/esd-2015-88-AC1, 2016

Earth System Dynamics
Discussions

Interactive comment on "Vegetation-climate feedbacks modulate rainfall patterns in Africa under future climate change" *by* M. Wu et al.

M. Wu et al.

minchao.wu@nateko.lu.se

Received and published: 21 April 2016

Comments from reviewer #1:

This paper presents analysis of simulations with a regional climate model constrained by an earth system model (ESM) and coupled with a dynamic vegetation model (DVM). In the 21st c. simulation forced with the RCP8.5 scenario, including vegetation feedback led to drying in central Africa.

(1) A clarification on the model setup is needed. The authors mention (lines 478-481) that "SSTs were prescribed from CanESM2, therefore the land-ocean thermal contrast ... originated solely from the changes ... induced by vegetation dynamics". As far as I can see, this is the last mention of the prescribed SSTs in the paper, but exactly what are these prescribed SSTs? Climatology? For what period? Given the known

Printer-friendly version

Discussion paper

sensitive of the West and central African climate to SSTs, this needs to be explained carefully and the SSTs prescribed need to be evaluated. A coupled model such as the CanESM2 is not necessarily producing correct SSTs for the observational period. Of particular concern for the region of the analysis is the seasonal formation of the Atlantic cold tongue which, I believe, generally fails to form in coupled GCMs.

Response: The SSTs (section 2.2) are from the CanESM2 simulations and they are applied in the same manner as other boundary conditions, i.e., from the time-evolving GCM simulation. They are not a climatology (abbreviation "SST" will be added in line 167). Both the FB and the NFB simulation use the same set of SST forcing. The evaluation of CanESM2 SSTs in the oceans around Africa has been done in previous studies. Rowell (2013) indicated an acceptable agreement of CanESM2 SSTs with observations for their African teleconnection study; Xu et al. (2014) suggested relatively small SSTs biases from CanESM2 among CMIP5 models over the southeastern tropical Atlantic; LaRow et al. (2014) showed that SSTs of CanESM2 over the tropical oceans agree well with the reconstructed SSTs (derived from surface marine observational records). We will summarize the findings from these studies in the section 3.1 of the manuscript and will add references to these as "The SST forcing is also important for the African climate, and the CanESM2 SSTs have been validated and shown to be accurate in previous studies (e.g. Rowell, 2013;Xu et al., 2014;LaRow et al., 2014)"

(2)The biases in the regional model are significant (Fig. 1). The dry bias in the Congo Basin in the regional model (Fig. 1. b2), while common in models, seems extreme but it is similar to the dry bias in the ESM (Fig. 1.b3). It is important to consider how these biases influence the results, especially since one of the big results is additional drying in central Africa.

Response: The figure title "Model (CanESM2)" in the original version of Figure 1, referred to by the reviewer, refers to the NFB simulation with the RCM forced by CanESM2 boundary conditions, and not to the global CanESM2 model. We will clarified this by changing the title and figure text in Fig. 1. The dry bias is similar to other

RCMs (Kim et al., 2014;Nikulin et al., 2012), and very likely can be traced back to the convective scheme, rather than the circulation simulated by the physical sub-model. Following the reviewer's suggestion, we have also evaluated the low-level circulation and humidity in the CanESM-forced RCM simulation (the new figure Fig. A1), and we found that the dry bias over central Africa and wet bias over Sahelian savannah are not primarily related to the bias in circulation. In contrast, the model has done a relatively good job in reproducing the overall circulation patterns, including the southern and northern trade wind over the Atlantic ocean (the new figure Fig. A1) and the Walker circulation (Fig. 6), which is important for this study. We will give further explanations of this issue in section 3.1 & 4.3, and will add reference to the studies mentioned above.

(3)The wet bias in the Sahel in the regional model is unusual – many models fail to bring rainfall into the Sahel, as is the case for the ESM that is providing boundary conditions for the regional simulation (Fig. 1.b3). Is it relevant to the results that the regional model over-produces rainfall primarily in the spring?

Response: Yes, as shown by Fig.1b3, this could relate to the early onset of the rainy season. The issue is not unique to RCA and is common among RCMs (Kim et al., 2014). This can relate to the bias of the simulated West Africa Monsoon (WAM) dynamics, one possible explanation can be the biased interaction between deep convection and the Africa Easterly Waves (AEW). The propagation of AEW, which brings moisture to the Sahel regions, is dependent on the strength of deep convection: a strong deep convection can usually spread moisture at higher vertical atmospheric level, and cause rainfall over a wider latitudinal band along the ITCZ, whereas a weaker deep convection can result in a narrower but more concentrated precipitation band (Sylla et al., 2011). RCMs' sensitivity to the intensity of WAM can explain their different precipitation pattern over Sahel (Gbobaniyi et al., 2014). For the precipitation over central Africa, however, precipitation is primarily driven by orographic uplifting and low-level convergence, and it is maintained by low-level mass convergence over the ITCZ (Sylla et al., 2011) and the Walker circulation (Nicholson and Grist, 2003;Cook and Vizy, 2015). Therefore, the influences from such bias on the dynamics in our study should be limited. We will give further explanations of this issue to section 3.1 as: “The simulated daily precipitation for central Africa tends to be underestimated during the late afternoon and night (Nikulin et al., 2012), resulting in dry bias. The wet bias over the northern savannah is mainly caused by a too early onset of the rainy season (b1, Fig. 2) which is possibly caused by the interactions between the simulated deep convection and the Africa Easterly Waves (Sylla et al., 2011)”.

(4) I am puzzled by the large differences between the GPCP and CRU precipitation observations shown in the Sahel (“northern savanna”) Fig. 2.b1. I think this is more related to the choice of averaging region than to a disparity in the observations, given the difference in the resolution of these 2 data sets. Please check this.

Response: We have investigated the possible errors of the interpolation from a coarser to a finer resolution. In our study we followed the approach in Nikulin et al. (2012) with bilinear interpolation for the GPCP (1 degree) and CRU datasets (0.5 degree) to regrid respective data to 0.44 degree. We have performed some technical checks on our analysis, including a check for mass conservation, and found mass differences due to the regridding negligible, difference is less than 0.01%. The disparities between the observation-based precipitation datasets are not unique. The CRU dataset is particularly challenged by the small amount of observing stations in Africa, and there of course are other well-recognised issues with other datasets, including satellite-based, which cause differences. Examples of studies that have commented on this are Nikulin et al. (2012) and Kim et al. (2014). They find considerable disparities among observation-based precipitation products, including TRMM and UDEL, also found for the Sahel region. We will give further information to section 3.1.

(5)References to the Charney (1975) and related studies are problematic since the idea that vegetation changes (i.e., “over-grazing”) caused the precipitation decline in West Africa during the 1960’s and 70’s has been thoroughly refuted in the mode modern literature. It’s SSTs forcing, of course.

Response: We agree that the role of SSTs is central, but also want to acknowledge Charney's paper which was seminal in hypothesising the potential impacts of vegetation changes on the monsoon circulation, which has formed the basis for many other vegetation change-related studies, not least those related to long-term vegetation changes in this region. Our study investigates how vegetation changes can lead to feedback in the region. This will be rephrased to "Hypothesised mechanisms of vegetation-atmosphere coupling include modulations of the surface albedo (Charney, 1975), changes in the North-African monsoon system (Claussen, 1997) and internal climate variability (Zeng et al., 1999)." in the revised manuscript.

(6)The authors note (lines 240-242) that "The simulated patterns and magnitude of precipitation for this area are similar to a previous study using an earlier version of RCA, RCA3.5, without dynamic vegetation". So doesn't that mean that dynamic vegetation is not influential, in contrast to the findings of this paper?

Response: The comparison to RCA3.5 in previous study refers to the simulated present-day climate. For the present-day period, influences from vegetation dynamics are limited as the present-day land cover types in terms of forest cover and open land are able to reproduce (Fig. 4a) though given the bias in LAI, and large-scale vegetation changes rarely happen over the short period of comparison. However, for the century-long transition period under climate change considered in this paper, changes in climate and CO2 forcing are strong enough, and lag effects of vegetation response short enough, to induce large-scale and long-term vegetation change and its feedback effect on climate is found to be much stronger than that seen during the present-day period. This will be further explained in section 4.3 as "Despite biases in the initial precipitation and vegetation state (LAI) for some regions, our model was able to reproduce the present-day land cover type in terms of forest cover and open land (Fig. 4a), and the simulated present-date climate is close to previous study (Nikulin et al., 2012) using the same physical sub-model with observed land cover type. Under future climate change, vegetation-induced changes in circulation, thus a substantial change in moisture transport and precipitation, are mainly triggered by changes in land cover type (Fig. 4A), therefore, we argue that the influences from biases in initial conditions on such mechanism found in this study should be limited."

(7)I would appreciate seeing an evaluation (e.g., a comparison with the ERAI reanalysis) of the circulation and specific humidity at 850 hPa wind and specific humidity from the present day, NFB simulation since the authors are pointing to changes in the circulation/moisture advection as relevant. This seems more crucial than evaluating LAI, for example.

Response: Thank you for this suggestion. A new figure will be added (as Fig. A1) in the Appendix and new text will be added in the section 3.1. and Fig. A1 can be found in the attached Supplement file in the comment system.

(8)There's not a lot of literature on the dynamics of the Walker circulation in this region and its sensitivity to SSTs (and/or land/sea contrast), but these recent papers will help: Pokam WM, Djiotang LAT, Mkankam FK, 2012: Atmospheric water vapor transport and recycling in equatorial central Africa through NCEP/NCAR reanalysis data. Climate Dyn. 38, 1715-1729. Pokam MW, Bain CL, Chadwick RS, Graham R, Sonwa DJ, Kamga FM, 2014: Identification of processes driving low-level westerlies in West Equatorial Africa. J. Climate 27, 4245-4262. Cook, K. H., and E. K. Vizy, 2015: The Congo Basin Walker Circulation: Dynamics and Connections to Precipitation, Climate Dynamics, DOI 10,1007/s00382-015-2864-y.

Response: Thank you for pointing us to these studies, new references will be added to the section 3.3 and 3.4.

(9)A couple of minor points: Please note that "Savannah" is the city in Georgia, U.S., while "savanna" is the grassland.

Response: The Oxford English Dictionary gives "savannah" as the preferred spelling.

(10)Figure A1 caption needs to be improved to provide more detail about what is plotted.

Response: Agreed. The revised caption will appears as “Fig. A2. Simulated seasonal surface temperature for present day (a-d), for changes in future in the NFB experiment (e-h, future minus present day), and for changes from vegetation feedback in future (i-l, FB minus NFB for future). Definitions for calculation period, climate change signal and vegetation feedbacks are given in Sect. 2.2.”

Please also note the supplement to this comment:
http://www.earth-syst-dynam-discuss.net/esd-2015-88/esd-2015-88-AC1-supplement.pdf

---

Interactive comment on Earth Syst. Dynam. Discuss., doi:10.5194/esd-2015-88, 2016.