Author response to referee comments for manuscript ESD-2018-84
TITLE: *Climate feedbacks in the Earth system and prospects for their evaluation*

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RESPONSE TO REVIEWER #1

!! ALL PAGE/LINE NUMBERS REFER TO THE DISCUSSION PAPER AS PUBLISHED ON THE ESD DISCUSSIONS WEBSITE !!

REVIEWER: General comments:
Heinze et al. provide a comprehensive review of various climate feedback processes in the Earth System Models (ESMs). Overall, this is a timely review paper, as we continue to add complexity to the ESMs which in turn make it difficult for us to understand feedback processes and quantification of uncertainty in climate projections by these models. I don't see any significant issues with the paper. At the same time, this paper discusses a broad spectrum of the feedback processes, and I don't have the expertise to evaluate some portions of the manuscript, especially those dealing with chemical and biogeochemical feedbacks. I have a couple of minor comments that the authors may consider in revising the paper. Otherwise, I recommend the paper be accepted.

OUR RESPONSE:
We would like to thank the reviewer #1 for the constructive comments.

REVIEWER Specific comment:
P19, section 3.2.3 Mid-latitude cloud amount feedback: This is a critical feedback process in the ESMs, and a more detailed discussion is desirable. The misrepresentation of the extratropical low-level clouds is a significant problem in most of the climate models in CMIP5. The biases in the simulation of these clouds cause increased absorption of shortwave radiation by the southern ocean which is attributed as the reason for the double ITCZ problem in those models (Hwang and Frierson, 2013).
Reference:
Hwang, Y-T and Frierson, D. M. W. (2013) Link between the double-Intertropical Convergence Zone problem and cloud biases over the Southern Ocean, PNAS, 110 (13), 4935-4940.

OUR RESPONSE:
(a) We will change the phrase (page 19, line 25): "These shifts of clouds to higher latitudes with weaker shortwave radiation induce a positive feedback of an uncertain amount…"
To:
"These shifts of optically thick storm clouds to higher latitudes with weaker incoming solar radiation makes them less efficient radiation reflectors and thus induces a positive feedback of an uncertain amount…". Further we will change the section heading "3.2.3 Mid-latitude cloud amount feedback" to "3.2.3 Mid-latitude cloud amount feedback" to "3.2.3 Mid-latitude cloud reflectance feedback". This change will also be made in Figure 6. In Figure 6, we will in addition change "polar cloud amount" to "mid-latitude cloud reflectance".
(b) We will add in section 3.2.4 (page 19, line 34):
"Extratropical low-level clouds are often misrepresented in Earth system models contributing to the double-intertropical convergence zone problem and to short-wave radiation biases (too much heating of the Southern Ocean) (Hwang and Frierson, 2013). A correction of this bias is likely to decrease the negative cloud water phase feedback (and introduces a positive low cloud feedback that is similar in mechanism to our Tropic low cloud feedback in section 3.2.2) (Frey and Kay, 2018). This misrepresentation of extratropical low-level clouds reduces the confidence in the magnitude of the feedback."
We will add the following references:

Frey, W. R., and Kay, J. E.: The influence of extratropical cloud phase and amount feedbacks on climate sensitivity, Climate Dynamics, 50, 3097-3116, 10.1007/s00382-017-3796-5, 2018.
Hwang, Y. T., and Frierson, D. M. W.: Link between the double-Intertropical Convergence Zone problem and cloud biases over the Southern Ocean, P Natl Acad Sci USA, 110, 4935-4940, 10.1073/pnas.1213302110, 2013.

REVIEWER Specific comment:
P23, section 3.4.2 Tropical circulation response to a warming climate. The discussion of Pacific Walker Circulation (PWC) response to global warming is incomplete, as the authors present one viewpoint about this widely debated problem. The argument by Vecchi et al. (2006) that the PWC weakens in a warming climate in response to a differential rate of increase in precipitation and atmospheric humidity was later contradicted (e.g., Tokinaga et al., 2012; Sandeep et al., 2014). Tokinaga et al. (2012) have shown that the PWC variability in the 20th century was related to the changes in the east-west gradient of equatorial Pacific sea surface temperature. Sandeep et al. (2014) have shown that the PWC can even strengthen while the global convective mass flux weakens, contradicting the arguments of Vecchi et al. (2006).
References:
Sandeep, S., Stordal, F., Sardeshmukh, P.D. et al. (2014) Pacific Walker Circulation variability in coupled and uncoupled climate models, Clim Dyn, 43, 103-117.
Tokinaga, H, Xie S-P, Deser, C, Kosaka Y, Okumura YM (2012) Slowdown of the Walker circulation driven by tropical Indo-Pacific warming. Nature, 491(7424), 439–443.

OUR RESPONSE:
We will include these additions to the debate of tropical climate feedbacks.
We will add the following text on page 23, line 23:
"Tokinaga et al. (2012), however, attribute the weakening of the Walker circulation with climate warming mainly to the ocean (SST changes)."
We will further add the following text on page 23, line 27:
"Sandeep et al. (2014) argued that SST changes during the 20th century warming even led to an overall strengthening of the Pacific Walker circulation (while this strengthening was to some degree compensated by variability induced by the El Niño Southern Oscillation climate variability mode)."
We will add the following references:
Sandeep, S., Stordal, F., Sardeshmukh, P. D., and Compo, G. P.: Pacific Walker Circulation variability in coupled and uncoupled climate models, Climate Dynamics, 43, 103-117, 10.1007/s00382-014-2135-3, 2014.
Tokinaga, H., Xie, S. P., Deser, C., Kosaka, Y., and Okumura, Y. M.: Slowdown of the Walker circulation driven by tropical Indo-Pacific warming, Nature, 491, 439-443, 10.1038/nature11576, 2012.