Response to referee #1

Referee #1: *The paper is very interesting, novel and merits immediate publication. The approach is that of a 'proof of concept', but the idea behind the research is extremely interesting and worth of attention by the community.*

Reply: Thank you very much. We really appreciate your comments and suggestions.

Referee #1:
However, I believe the authors must touch upon several topics in order to improve the paper. Specifically:
Last part of section 3.1 needs further explanation. Please expand the section and provide more information about potential applications. I think that is an important part of the paper (probably the most important part), and it is a pity that the authors give just such a swift account of the topic.

Reply: Thanks indeed. This is an important point that we didn't explain in full in the first version of the manuscript**.** We added two paragraphs now explaining the potential applications.

The text now reads:

> *Potential applications of POPEM include not only sensitivity analyses of local CO_2 emissions policies, but also the added feature of performing tests for 'what-if' scenarios. One interesting example would be the climate response under the hypothesis that China and India –the most populated countries in the world- reach US CO_2 per capita emissions rates. Another 'what-if' scenario would be the climate response of an increasingly urbanized world. In both cases, POPEM provides a flexible framework for testing the alternative hypotheses.*
>
> *The realism of the ESM will be enhanced with a fully-coupled system. Such a fully-fledged ESM will include bidirectional feedback between POPEM and CESM to evaluate the effects of climate change on population dynamics and emissions.*

Referee #1: *-Given the large number of papers using CESM I think more attention should be devoted to previous work using this model. Please add several references to show how CESM has been used, including merits, shortcomings and the like.*

Reply: We added two paragraphs in section 2.1. They include references from different topics.

The new paragraphs read:

> *CESM –formerly the Community Climate System Model (CCSM)- was conceived as a coupled atmospheric-oceanic circulation model (Boville and Gent, 1998; Collins et al., 2006; Gent et al., 2011; Hurrell et al., 2013; Williamson, 1983). Since the release of the first version, CESM has evolved into a complex Earth System Model now used in different fields. This includes research into atmospheric (Bacmeister et al., 2014; Liu et al., 2012; Yuan et al., 2013), biogeochemical (Lehner et al., 2015; Nevison et al., 2016; Val Martin et al., 2014), and human-induced processes (Huang and Ullrich, 2016; Levis et al., 2012; Oleson et al., 2011), as well as others. The core code of CESM has also been utilized by various research centers for developing their own models (norESM, Bentsen, 2013; CMCC–CESM–NEMO, Fogli and Iovino, 2014; MIT IGSM-CAM, Monier et al., 2013). CESM has been used in many hundreds of peer-reviewed studies to better understand climate variability and climate change (Hurrell et al., 2013; Kay et al., 2015; Sanderson et al., 2017). Simulations performed with CESM have made a significant contribution to international assessments of climate, including those of the Intergovernmental Panel on Climate Change (IPCC) and the CMIP5/6 project (Coupled Model Intercomparison Project Phase 5/6) (Eyring et al., 2016; IPCC, 2014b; Taylor et al., 2012).*
>
> *A major advantage of CESM over other ESMs is its availability. Some climate models are developed by scientific groups and access to the source code is limited. The CESM source code is free and available to download from the NCAR website. This approach helps improve the model by setting up a framework for collaborative research and makes the model fully auditable. CESM is a good example of a 'full confidence level' model, after Tapiador et al. (2017), where many 'avatars' of the code are routinely run in several independent research centers, and there is an entire community improving the model and reporting on issues and results. However, the model is not immune to bias. One important shortcoming is the poor representation of precipitation in terms of spatial structure, intensity, duration, and frequency (Dai, 2006; Tapiador et al., 2018; Trenberth et al., 2017, Trenberth et al., 2015). Another major bias is the anomalous warm surface temperature in coastal upwelling regions (Davey et al., 2001; Justin Small, 2015; Richter, 2015).*

Referee #1: *-The double ITCZ issue needs referencing. Who did first mention that? Without such reference it seems that that feature is a novel observation from the authors, which I think it is not.*

Reply: Sorry about that. We have added a citation.

The paragraph now reads:

> *The first step in evaluating the new parameterization is to compare the outputs with a control simulation to make sure the new addition does not negatively*

interact with the dynamical core or spoil the contributions of rest of the parameterizations. Figure 4 shows that this is not case with the POPEM parameterization, which does not negatively affect the outputs of precipitation and temperature. Rather, both variables are now closer to the observed data than they were in the control run, especially in terms of reducing the double ITCZ (Intertropical Convergence Zone), which artificially features in global models (Mechoso et al., 1995; for a recent analysis of double ITCZ in CMIP5 models see Oueslati and Bellon, 2015).

Referee #1: *-The following sentence is confusing to me.˘The improvements of POPEM for the El Niño-4 area show that detailed, dynamical modeling of GHG emissions is important for more precisely quantifying precipitation in dry areas, which validates the main hypothesis of the paper. Please explain what do you mean by that.*

Reply: What we meant was that precipitation in dry areas is extremely important, since human activities and biota are highly dependent of it. Improving the representation of precipitation in models is thus crucial. The main hypothesis of the paper, namely that point-wise emissions can improve the modeling, is validated for the El Niño-4 area where we show that our model improves the representation of precipitation in the left tail of the distribution (cf. Figure 8). We have reworded the paragraph:

"The results for the El Niño-4 area show that detailed, grid-point emissions of GHG improves the quantification of precipitation in dry areas, in agreement with our hypothesis about the benefits of locally-distributed versus global mean forcings."

Referee #1: *- Please, check the references to the figures in the text (Figs. 4 and 5)*

Reply: Amended now, thanks.

Referee #1: *- Please, check the place where you put the definition of some acronyms (e. g. ITCZ -you use it on page 7 and is defined in page 10-, SST -similar-).*

Reply: Sorry about that. Amended now.

References

Mechoso, C. R., Robertson, A. W., Barth, N., Davey, M. K., Delecluse, P., Gent, P. R., Ineson, S., Kirtman, B., Latif, M., Treut, H. Le, Nagai, T., Neelin, J. D., Philander, S. G. H., Polcher, J., Schopf, P. S., Stockdale, T., Suarez, M. J., Terray, L., Thual, O. and Tribbia, J. J.: The Seasonal Cycle over the Tropical Pacific in Coupled Ocean–Atmosphere General Circulation Models, Mon. Weather Rev., 123(9), 2825–2838, doi:10.1175/1520-0493(1995)123<2825:TSCOTT>2.0.CO;2, 1995.

Meehl, G. A. and Arblaster, J. M.: The Asian-Australian monsoon and El Nino-Southern Oscillation in the NCAR climate system model, J. Clim., 11(6), 1356–1385, doi:10.1175/1520-0442(1998)011<1356:TAAMAE>2.0.CO;2, 1998.

Oueslati, B. and Bellon, G.: The double ITCZ bias in CMIP5 models: interaction between SST, large-scale circulation and precipitation, Clim. Dyn., 44(3–4), 585–607, doi:10.1007/s00382-015-2468-6, 2015.

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