Anonymous Referee #2

We thank the anonymous reviewer for his/her helpful comments and suggestions. Please see our responses below.

This paper's focus is the local and large-scale effects of radiative forcing by greenhouse gasses and aerosol on precipitation in the Mediterranean region. A decrease trend was observed for precipitation in this region during the last few decades and this study aims to explore the main processes behind this trend. To do so they use the outputs of set of climate models participating in the Precipitation Driver and Response Model Intercomparison Project.

This work suggests that both GHG and aerosols contribute to this decrease trend, by local as well as large scale effects. In particular, the contribution of shortwave absorption by black carbon (BC) is highlighted. Clear sky radiative effects are treated in details while hardly no attention is given to the aerosol effect on clouds' processes and properties (defined here in general as the indirect effect, although some of the models do treat it). This work concludes that in addition to the local effects, BC absorption drives changes in large scale (global scale systems) such as enhanced positive North Atlantic Oscillation (NAO)/Arctic and it links it to a shift in the jet location (storm track) that implies drying of the Mediterranean and more rain over Europe. Let me start with the strength of the work. The insights on the link between the local BC absorption to the large-scale dynamics are interesting. Radiative effects on the local scale could be estimated by simpler radiation models but the derived effect on the dynamics could be resolved only by GCMs. Such dynamical results can be more important than the local effects and if all climate models show the same dynamical trend, it is important.
Response: thanks.

But even here, as in many (most) of the GCM studies, it is hard for someone who does not belong to the GCM community to evaluate this work. It is presented as model results and we have to believe it. One way to make such messages more approachable to all the climate researcher is to try to show the trend using as much as possible simpler models (toward an ideal GCM) such that the governing processes are demonstrated in a clearer way.
Response: the climate system is extremely complex and constitutes of many components. The PDRMIP models used in this study are the latest state-of-the-art GCMs, and they are the same or similar versions to those used in the latest IPCC report (Flato et al., 2013), representing the best global climate models in the community. Here we argue that models with finer resolutions and more components generally produce more realistic results than simple ideal models. We agree, however, that there is value in using simpler models such as those developed as companions alongside the new generation of the NCAR GCM. Such models, however, were not available for the versions used in PDRMIP and no groups using simpler models participated.

Apart from this, two main components are missing in this study:
(1) The most important aerosol type over the Mediterranean is dust. Mostly Saharan dust. There are many studies that have shown how important are radiative and microphysical effect of Saharan dust. In this study which is dedicated to aerosol effects the word "dust" does not appear. Even if the authors want to focus on other processes they should first discuss dust in the introduction and explain why dust is not considered in this work.

Response: dust aerosols are included in the model, but not in the experiments. We didn't include dust in the PDRMIP study, since we are only investigating the impacts of anthropogenic forcing. We added a comment on this in the revised manuscript.

(2) On a similar note, since this paper deals with aerosols, clouds and precipitation, much more attention should be given to cloud aerosol interactions. Even if the authors estimate that this effect is negligible compared to other effects, they should invest efforts in proving it. They write in the conclusions part that the indirect and semi-direct effects are estimated to be small. I fail to understand how they know it and why they are so sure about it. I expect clouds to be extremely sensitive both to changes in the aerosol loading internally and to changes in the temperature (and RH) profiles due to BC warming. Since rain is the sink of clouds it is not clear why such effects are less important.

Response: the energy budget analysis in the original manuscript (Fig. 3 and Fig. 6) shows that the local effects such as clouds, radiation (absorption and scattering) are overwhelmed by large-scale dynamical responses in the Mediterranean region. As a result, we place more emphasis on the dynamical responses instead of local responses. However, these large-scale changes are the result of remote forcings, the magnitudes of which may still depend on the inclusion of semi-direct and indirect effects. So even if local effects are not that important, it doesn't necessarily mean that indirect effects are not important in driving the responses. In fact, semidirect and indirect effects are included in most of the PDRMIP models, and thus the results in section 3. However, in the PDRMIP project, many of the models were run using climatological aerosols as a way to examine the similarity in model responses when driven with the same aerosol concentrations rather than including differences in both concentrations and responses. This leads to less realism in the physics, particularly of aerosol-cloud interactions, and hence the study focuses on aspects of the response that appear to be less sensitive to those interactions as they are relatively robust across the models despite some using interactive aerosols while others used climatological fields. This is now explicitly stated in the paper (section 2.1). In particular, in the present case in which we examine responses in the Mediterranean, the similarity between the models with detailed representation of aerosol-cloud interactions and those without give similar results (e.g. Figure 2 in the paper, panels b and c where there is no clear difference between climatological and interactive models), suggesting that such processes may not play a major role in this precipitation response. In addition, indirect effects are not complete in any of the models. For example, ice particles and internal cloud absorption are not included. For BC, these effects contribute to an overall small forcing with a very large uncertainty, so these are discussed but cannot be explicitly included for BC. For SO_4, the forcing could be as much as doubled when accounting for aerosol-cloud interactions, and thus the impact on precipitation could also be doubled if including them, but this would still be a small impact, as noted in the discussion section.

References

Flato, G., J. Marotzke, B. Abiodun, P. Braconnot, S.C. Chou, W. Collins, P. Cox, F. Driouech, S. Emori, V. Eyring, C. Forest, P. Gleckler, E. Guilyardi, C. Jakob, V. Kattsov, C. Reason and M. Rummukainen, 2013: Evaluation of Climate Models. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.