Anonymous Referee #1

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

This study intercompares model predictions of precipitation resulting from changes in black carbon, sulfate, and greenhouse gas forcings. While the issue is interesting, the problem with this study is that the paper virtually ignores any discussion of the intricate aerosol-cloud interactions that affect precipitation. Not only does the paper not even describe the aerosol-cloud interactions or the relevance of the mixing state and hygroscopicity of aerosols or of cloud microphysics, it is not clear to what extent any or all the models treat these processes. As such, it is impossible to determine whether the conclusions reached by the authors are reasonable because they don't even discuss if their models are appropriate for studying the issue.
Response: the energy budget analyses in our study show that large-scale dynamical responses rather than local responses (aerosol-cloud interactions) appear to dominate the precipitation change in the Mediterranean region. As a result, and due to the large spread in how the available models treat aerosol-cloud interactions, we did not emphasize aerosol-cloud interactions in our current study. However, how the GCMs treat the aerosols will be included in a table in the revised manuscript. The PDRMIP models used in the study are essentially the same as or similar to those used in the Coupled Model Inter-comparison Project Phase 5 (CMIP5) archive from the 5th report of Inter-governmental Panel on Climate Change. In the PDRMIP project, most 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). Undoubtedly, analyses with the setup used in PDRMIP are not perfect, but still useful and these have now been widely accepted as such by the peer-review process. In the present case, the similarity between the results of models with detailed representation of aerosol-cloud interactions and those without such processes suggests that those may not play a major role in the precipitation response that we focus on in this work, though we agree that this topic is worth additional future study.

Additional comments are given below.
Abstract. "The results from this study suggest that future BC emissions may significantly affect regional water resources, agricultural practices…" Whereas, this statement may or may not be correct, I don't agree that it is a conclusion of the present study because this study does not specify that it even considers the impacts of cloud activation of BC versus sulfate aerosol. The word activation is not even used in the paper.
Response: this conclusion is based on the results in section 3 (Fig. 1), which indicates a higher sensitivity of precipitation response in the Mediterranean region to BC forcing. As a result, changes in BC concentrations could greatly impact precipitation and thus, water resources in this region. Aerosol-cloud interactions including cloud activation that takes into account differences between BC and SO_4 are included in most of the PDRMIP models in this study, and thus, in the results for section 3, although these are not represented in as much detail as in the most

sophisticated models (which are too expensive to be used in CMIP-type analyses). As noted above, the similarity in the results of models with relatively detailed representation of aerosol-cloud interactions and those without such processes suggests that those may not play a major role in the precipitation response that we focus on in this work.

Introduction. The authors are missing a major effect of dark aerosols, namely cloud absorption effects, which is the burning off of clouds due to absorption by black and brown carbon particles either within cloud drops or between them (Jacobson, 2012). The authors should mention this effect and discuss how it might affect results of the study if it were included, since it is one of the reasons clouds are thinner and precipitation is lower in highly polluted regions.
Response: Admittedly, these effects are not included in the PDRMIP models nor any other current CMIP-class GCMs, which may impact the results. As noted in the discussion section, those effects generally have a small overall forcing with a large uncertainty range. This limitation, including the reference, has been included in the discussion section in the revised version.

Introduction. "In addition to their influence on temperatures and precipitation, aerosols may also affect large-scale atmospheric circulation." The fundamental effect of aerosols on circulation starts with their reduction in near-surface wind speeds (Jacobson and Kaufmann, 2006).
Response: thanks for the reference. It is included in the revised manuscript.

Models. The impacts of aerosol particles on precipitation involve intricate and detailed physical processes, yet the paper treats such processes as a black-box subject. The information about the models provided in Table 1 is not sufficient to evaluate the models' ability to simulate the impacts of aerosol particles on precipitation. The information needed include the following parameters (ideally presented in a table), and it is not helpful to refer readers to other papers to dig out this information, particularly paper by paper.

1) How many aerosol modes or size bins?
Please see the table below.

2) How many aerosol components per mode or size bin, and what are the components?
Please see the table below.

3) Are aerosol particles treated as fully externally mixed, fully internally mixed, or evolving from externally to internally mixed. If they evolve, do they evolve based on an empirical time constant or based on physical processes.
Please see the table below.

4) Which physical processes affect the aerosol size distribution? Homogeneous nuclear, coagulation, condensation, dissolution, reversible internal chemical reaction, dry deposition, sedimentation?
Response: all these processes affect the aerosol size distribution, which varies model by model in terms of which aerosols are represented as a function of size (see the table).

5) Do cloud drops physically activate on aerosol particles or is there an empirical relationship between the number of activated cloud drops and aerosol particles?
Please see the table below.

6) What is the assumed mixing state of black carbon for cloud activation purposes? Is it hygroscopic or hydrophobic? Are different sources of black carbon treated differently in terms of composition?
Please see the table below.

Model	Size bin/aerosol mode	Aerosol per size bin	Mixing state	Evolve Empirically or physically	Aerosol size distribution	Cloud drop activate physically or empirically	interactive vs climatological aerosols
CanESM	S, N, BC, dust, SS, OC	N/A	Internal	N/A	Log-normal	N/A	Interactive
GISS	S (1), N (1), OC (1), BC (1), SS (2), dust (4)	N/A	Internal & external	N/A	Log-normal	Empirically	Climatological
HadGEM2	S: 3 modes (Aitken, accumulation, dissolved) BC, OC, BB: 3 modes (fresh, aged, dissolved/in-cloud) SS: 2 modes (jet, film) Dust: 6 size bins	N/A	External	Physically	Log-normal	Empirically	Interactive
HadGEM3	S: 3 modes (Aitken, accumulation, dissolved) BC, OC, BB: 3 modes (fresh, aged, dissolved/in-cloud) SS: 2 modes (jet, film) Dust: 6 size	N/A	External	N/A	Prescribed log-normal distribution for radiation	Empirically	Climatological

	bins						
MIROC	S (1), BC (1), OC (1), dust (6), SS (4)	N/A	Internal & external	N/A	Prescribed log-normal for radiation and diagnosing number concentration	Based on the Köhler theory (Abdul-Razzak and Ghan 2000)	Interactive
CAM4	S, SS (4 size bins), dust (4 size bins), BC (2 modes), POM (2 modes), SOA	Fixed sizes	External	N/A	Log-normal	N/A	Climatological
CAM5	S, POM, SOA, SS, BC, dust (3 modes)	Aitken: S, SOM, SS Accumulation: S, POM, SOM, BC, dust, SS Coarse: dust, SS, S	Internal	Physically	Log-normal	Physically	Interactive
NorESM	13modes, 44 size bins, S, OM, BC, SS, dust		Internal & external	Physically	Log-normal	Physically	Interactive
IPSL	S, BC, OC, dust, SS	N/A	External	N/A	Prescribed log-normal for radiation	Empirically	Climatological

S = sulfate, N = nitrate; SS= sea salt, OC = organic carbon, BC = black carbon, OM = organic mass, BB = biomass burning, SOA = secondary organic aerosol, POM = primary organic matter

7) Are clouds treated as bulk parameters or are they treated with size modes or with size bins?
Response: clouds are generally bulk parameterized in GCMs.

8) What physical processes affect cloud drop growth to precipitation particles?
Response: condensation, evaporation and coalescence.

9) Are clouds treated as subgrid phenomena in the GCM? How are they treated? How many clouds are allowed in each model grid column?
Response: clouds are treated as subgrid in GCMs. Cloud amount (fraction) is generally parameterized on the basis of meteorological conditions, such as relative humidity, atmospheric stability and convections. Cloud amount in each grid varies by model.

Once such information is provided, the authors should evaluate which models, if any, are most likely to provide reasonable results regarding the impacts of aerosol particles on precipitation.
Response: the emission-driven models are potentially more realistic in this regard. However, the results are similar across the models and no significant differences are observed between the models using interactive and those using climatological aerosols. Thus, all models are included, and indeed this underlies our conclusion that the results are generally associated with large-scale dynamics are less sensitive to details of local aerosol-cloud interactions.

Results. The authors provide end results of temperature change for a given emission or concentration but should discuss whether and how aerosol-cloud or cloud-cloud microphysical processes are treated and are affecting the results.
Response: the temperature change is out of the scope of this paper. We didn't include any results for temperature change. For aerosol-cloud processes, we have added related information (table) and discussion in the revised manuscript.

References Jacobson, M.Z., and Y.J. Kaufmann, Wind reduction by aerosol particles, Geophys. Res. Lett., 33, L24814, 2006

Jacobson, Investigating cloud absorption effects: Global absorption properties of black carbon, tar balls, and soil dust in clouds and aerosols, J. Geophys. Res., 117, D06205, 2012