Replies to Reviewer #1:

We sincerely appreciate the opportunity to further improve the manuscript. And we have revised the manuscript carefully based on your constructive suggestions. The following are our point-by-point replies.

General Comments:

"I thank the authors for the revisions. I have a couple of follow-up points to raise: In arguing that the Rocky Mountains are of lesser importance, the authors refer to their own previous study Jiang and Yang (2021), specifically the NoRocky experiment presented there. The problem with that argument is that the NoRocky experiment was initialized from an AMOC state, where PMOC was already suppressed by a build-up of freshwater in the North Pacific. The authors ran that experiment for only 400 years, which is too short to establish a new deep ocean equilibrium, and concluded that the NoRocky state could not sustain a PMOC.

Despite that, the authors did find in the "NoRocky" state that SSS was increasing in the North Pacific and decreasing the North Atlantic (Jiang and Yang 2021; Fig. 5e), after 400 years.

The authors did not test a scenario where "NoRocky" was initialized in a PMOC state. This is a key point. I think it is at least plausible that if the model were initiated in an established PMOC state with "NoRocky" topography, that it could sustain a PMOC more readily without the Rocky Mountains. I think this should be acknowledged in the discussion, since the authors haven't tested such a scenario.

At the least, the discussion section should acknowledge that these results appear to be model-dependent, since Maffre et al (2018) and Sinha et al (2012) made quite different conclusions about the importance of the Rocky Mountains to the AMOC-PMOC balance, with solid modelling evidence to support them."

Response: Thank you very much for your valuable comments.

We agree that deep ocean equilibrium needs a relative longer time to be established. The NoRocky vs. Real experiments were designed to be compared with the results of the OnlyRocky vs. Flat experiments. The patterns are identical, except for having opposite signs. Since the comparison between NoRocky and Real experiments includes the influence of other topographic features, greater attention is given to the results of the OnlyRocky and Flat experiments. In Jiang and Yang (2021), only the results from 400 years were analyzed. In fact, the OnlyRocky experiment ran from

801 to 2000 model years, during which the strength of the AMOC changed very little, leading to a slight weakening of the PMOC (Fig. R1). The presence of the Rocky Mountain contributes little to the AMOC but can slightly weaken the PMOC. However, its suppressive effect on the PMOC is less significant compared to that of the Tibetan Plateau (Fig. 2b in the revised manuscript). Since a longer NoRocky experiment is currently unavailable, we plan to conduct extended experiments and perform more detailed analyses in future work.

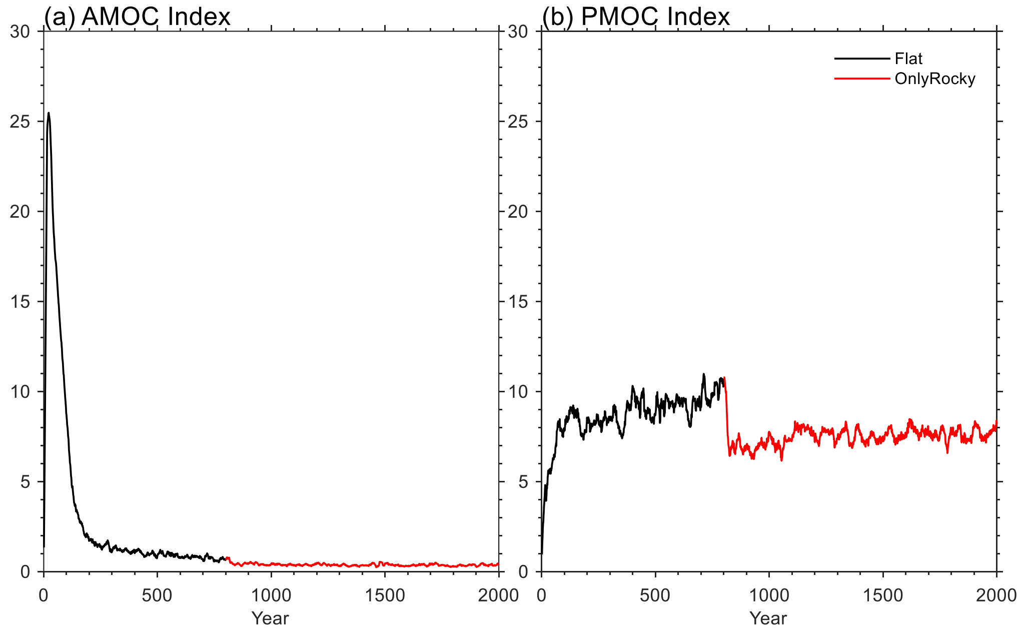

Fig. R1 AMOC and PMOC index in Flat and OnlyRocky experiments.

As for Fig. 5e in Jiang and Yang (2021), the increase in SSS in the North Pacific occurs only along the western coast of North America. This is accompanied by warming in the upper North Atlantic, where the contributions of temperature and salinity to density changes tend to compensate for each other, resulting in a slight decrease in density (Fig. R2d, e, f). The impact on the mixed layer depth is also minimal (Fig. R3), which is insufficient to cause a significant change of PMOC.

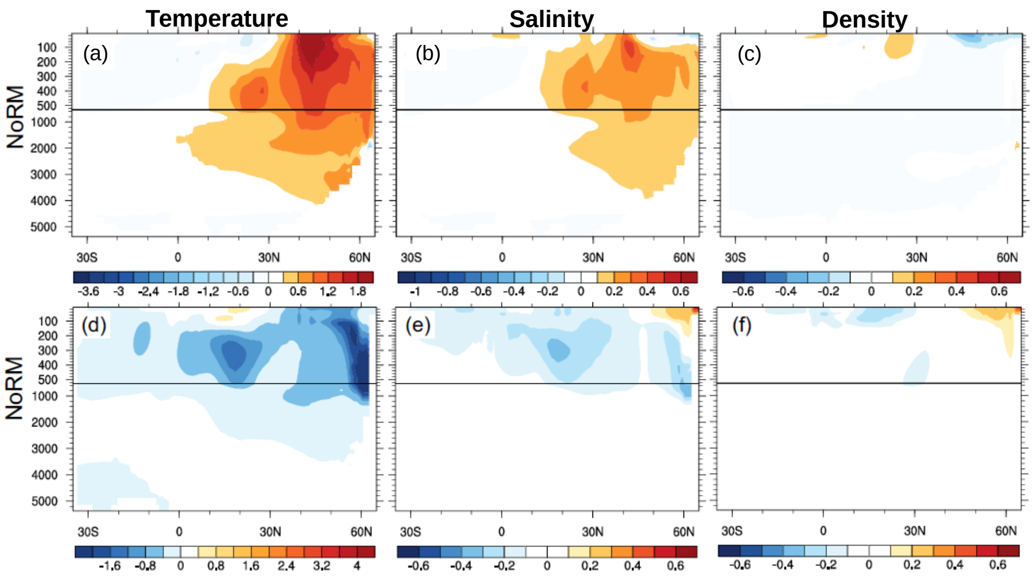

Fig. R2 Sea surface buoyancy changes between NoRocky (NoRM) and Real experiments. The upper row shows changes of sea surface salinity, temperature, and density in the Atlantic, while the lower row represents those in the Pacific. This figure is adapted from Jiang. 2023. PhD thesis.

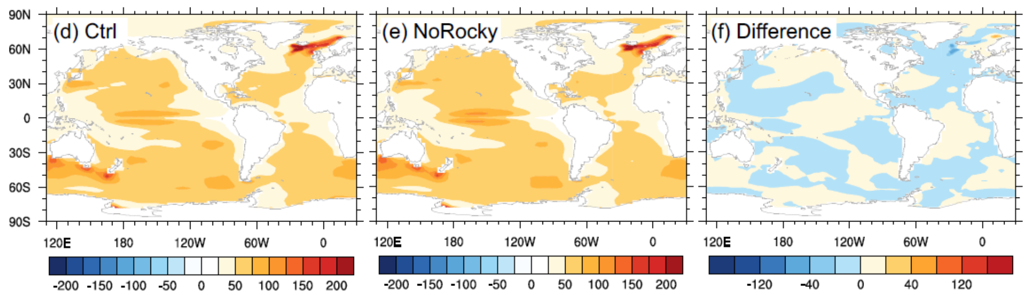

Fig. R3 Mixed layer depth in Real (d) and NoRocky (e) experiments. The differences are shown in Figure (f). This figure is Fig. 9 in Jiang and Yang. (2021).

We admit that the Rocky Mountain's role in establishing AMOC conducted by CESM1.0.4 is model-dependent. Additional discussion has been included in the revised manuscript (Lines 435~438). Maroon (2016) utilized Geophysical Fluid Dynamics Laboratory (GFDL) model to investigate the impacts of Rocky Mountain topography on ocean circulation. They found removing the Rocky Mountain resulted in a 7 Sv weakening of the AMOC and PMOC was established with a strength of approximately 24 Sv. However, they also found similar results when removing the global topography. They speculate the AMOC in GFDL is not as sensitive to topography as other models.

Maroon (2016) conducted another experiment, in which only the river flow directions were altered to reflect the river runoff changes after removing the Rocky Mountain. It is noted that Rocky Mountain is retained in this experiment. Under this special scenario, increased runoff to the North Atlantic weakened the AMOC, while wind stress changes from the mountains had little effect (Fig. R4). Thus, they concluded that the Rocky Mountains influence the MOC through freshwater forcing, not wind stress, and are not essential for maintaining North Atlantic deep-water formation.

In CESM1 simulations, river runoff doesn't change as significant as that in GFDL. Thus, the final conclusions between Jiang and Yang (2021) and Maroon (2016) are kind of different. Previous studies, including Maffre et al. (2018) and Sinha et al. (2012), highlighted the Rocky Mountains' contribution to AMOC. However, their conclusions were primarily based on comparisons between Flat and Real experiments, which may lead to less definitive assertions about the role of the Rocky Mountains in establishing AMOC, as the evidence provided is not entirely conclusive.

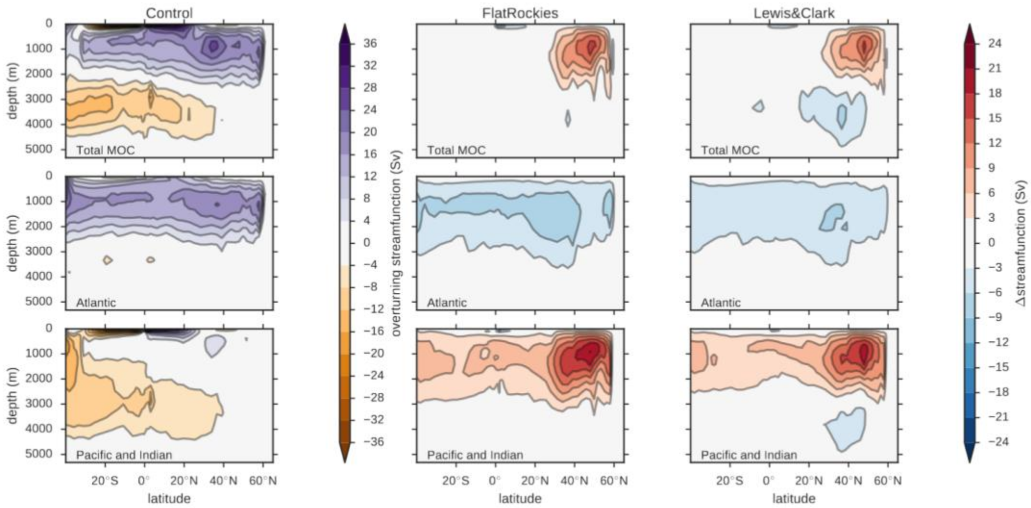

Fig. R4 MOC pattern difference in Control, FlatRockies, and Lewis& Clark experiments from Maroon (2016). Control is a 700-year long simulation. FlatRockies simulation is identical to the Control simulation, but the Rocky Mountain are flattened. "Lewis & Clark" simulation represents all of the runoff drained into the Pacific was re-routed to the St. Lawrence Seaway.

Minor points:

(Line numbers refer to the Track changes document that was submitted):

1. L90: "giant" should be changed to "large" (what does "giant" mean?)

Response: Thanks for point out this. "Giant" is too informal for a research paper. Revised.

L91: "Both of their work" should be changed to "Both of these studies" (grammar) Revised.

2. *L93: "think" should be changed to "argued"* Revised.
3. *L95: "think" should be changed to "argued"* Revised.
4. *L99: "an individual mountain" is misleading text here. The discussion is about "all of the mountains in North America", which have been shown to have a large impact on the AMOC and PMOC in previous climate modelling studies.*

Response: Thank you for your suggestion. We have revised this sentence to avoid the misleading. And more discussions about Rocky Mountain's role is added in the revised manuscript (Lines 99~103, 105~106).

Data Availability:

5. *The topography data in Figure 1 is not available in the Data supplement. It should be included. The model topography used in the experiments is not freely available to download, nor are the perturbations to that topography that the authors have made. A contour plot such as Figure 1 hides a lot of details of what went into the topography, and the point of a data supplement is to make such details transparent and reproducible.*

Response: Thank you for pointing out this problem. We have added the topography data in the zipped file. All of the data can be obtained from https://corp.fudan.edu.cn/Data4Paper.htm.

References

Maroon, E. A., 2016: The roles of land and orography on precipitation and ocean circulation in global climate models. Ph.D. thesis, University of Washington, 155 pp.

Replies to Reviewer #2:

To me, the authors have addressed my comments thoroughly. I would like to recommend this manuscript to be accepted for publication.

Response: Thank you very much. We appreciate your recommendation for the manuscript's acceptance.