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Interactive comment on "The Flux-Anomaly-Forced Model Intercomparison Project (FAFMIP) contribution to CMIP6: Investigation of sea-level and ocean climate change in response to CO_2 forcing" *by* Jonathan M. Gregory et al.

Anonymous Referee #1

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This manuscript documents the protocol of the Flux-Anomaly-Forced Model Intercomparison Project (FAFMIP) and presents the results obtained so far. As a component of the forthcoming CMIP6, the goal of FAFMIP is to investigate the spread of the fully coupled AOGCMs in simulating sea level rise and ocean climate change under CO2 forcing, especially the roles of momentum, heat and water fluxes at the ocean surface. It is found that CO2-induced heat flux anomalies are the dominant factor in causing the weakening of the Atlantic meridional overturning circulation (AMOC) and the dipole

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Discussion paper

pattern of dynamic sea level changes in the North Atlantic. In the Southern Ocean, both momentum and heat fluxes contribute to the increased dynamic sea level gradient across the Antarctic Circumpolar Current. Different processes responsible for the ocean heat content change, such as added and redistributed heat, are also investigated and compared.

This is an important manuscript that represents a community effort. This type of manuscript systematically describes the design of coordinated projects, provides guidance for follow-up studies, and usually gets frequent citations. For the climate modeling community, a better understanding of model spread is as important as the identification of common simulation features across models. In particular, momentum, heat and water fluxes at the ocean surface are tightly coupled. It is not easy to separate their individual contributions to ocean climate change and sea level rise pattern. By reading the manuscript, I found the design of FAFMIP is clever, reasonable, and quite effective at revealing the role of different air-sea fluxes. Although compared with previous studies, no significant new conclusion has been drawn so far with FAFMIP, the project tackles critical issues in a more systematic and complete way, and provides the community with valuable data for further analyses. For example, the proposed new ocean diagnostics would facilitate attribution studies. The outcome would benefit the climate modeling community.

The manuscript is well written. So I recommend publication of the manuscript in Geoscientific Model Development. My comments below are minor and mainly for clarification purpose.

(1) Line 35: Please define “YJ” as some readers may not be familiar with this unit.

(2) Lines 199-200: Is the purpose of the faf-all experiments to compare with the original coupled simulations? The motivation for faf-all needs further discussion.

(3) Section 2.4: In this section, three methods for treating the surface heat fluxes are discussed. To help the understanding, I suggest adding a schematic illustration for

better demonstration and comparison of the three methods.

(4) Figure 3: In Panel b, the global mean surface air temperature is relatively stable in Method B compared with Method A. In Panel d, by contrast, the ocean volume-mean temperature increases faster for Method B than Method A. Looking into the text, the reason is such that SST is determined by TR without the influence of the heat flux perturbation - F. By contrast, temperatures in the ocean interior are affected by F. This difference can be reiterated in the caption of Fig. 3 as readers may first look at figures before digging into the text.

(5) Lines 247-248: The weakening of the AMOC causes a cooling in the northern North Atlantic and an increase in heat flux into the ocean. Does that actually mean a decrease in oceanic heat loss in this region? The effect on temperature would be the same but physically different.

(6) Line 334: Please define DECK.

(7) Line 400: Heat flux perturbations -> Heat flux anomalies. The former implies external while the latter can be internal.

(8) Lines 430-435: This paragraph discusses $\sigma\zeta$ which contains both spatial and temporal variability of ζ. From the bottom row of Fig. 4, any information can be inferred about the "signal-to-noise" ratio or the time of emergence of the externally forced signals?

(9) Line 445: The Pacific Decadal Oscillation plays an important role in causing the largest regional sea level trends in the Pacific since the 1990s. Without ocean initialization, models are unlikely to capture these trends on decadal/interdecadal time scales. These comments could be added regarding model performance.

(10) Lines 551-555: The positive feedback between the AMOC-induced cooling and the increase in downward heat flux into the ocean is interesting. As I know, the temperature feedback associated with AMOC can also operate in another way. The

AMOC-induced ocean cooling causes increase in surface water density, which in turn enhances oceanic deep convection and strengthens AMOC. I'd like to see some discussion about how to reconcile these feedback processes.

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