We would like to thank all three reviewers for their valuable comments and suggestions. We have responded to each referee's comment and revised the manuscript based on the suggestions. We also attached the modified figure at the end of this response for reference.

Referee #2

Since the 1980s, the anthropogenic aerosols (AA) in the western hemisphere are reduced whereas those in the eastern hemisphere continue to increase. The study is to contrast the effect of regional AA from the western and eastern hemispheres in driving the Pacific climate change in the past four decades, using large ensemble regional AA forcing simulations. The analysis is straightforward and the manuscript is clearly written. I only have some minor comments.

Response

Thanks for the inspiring review and good assessment of our manuscript. Please check our responses below.

1. Wang et al. (2024) show that the AA in China has been decreasing between 2007 and 2020. Is this also reflected in your experiment setup? Or is it assumed to have continuously been increasing? Uncertainties in the AA forcing make me question the validity of comparing regional AA simulations with observations. Caveats regarding the uncertainties in the AA forcing should be discussed.

Response

Thanks for the comments. Yes, the experiments use the CMIP5 historical emission up to 2005 and then the RCP8.5 emission scenario thereafter (2005–2020). We followed this scenario setup to ensure our regional model experiments were comparable to the CESM1 single forcing large ensemble experiments.

Based on the observational studies (e.g., Wang et al., 2021; Xiang et al., 2023), aerosol emission in East Asia reached a peak and started to decrease slightly Since the early 2010s, while South Asia emissions continued to increase. Generally speaking, the RCP8.5 scenario overestimates the aerosol forcing in the EastFF domain from 2010 to 2020, which definitely introduces bias to the attribution in Fig. 3, as mentioned by the reviewer. Nevertheless, we want to mention that we only performed a *qualitative* comparison between the aerosol-driven multi-decadal responses and the observed variation. Also, although the aerosol forcing is overestimated in the simulations, the EastFF emission level remains at high levels from 2010 to 2020. Therefore, we believe that our comparison between model results and the observed variations still indicates possible relationships between aerosol forcings and the observed results.

Following the reviewer's concern, we add caveat statements about the emission scenario issue at the end of Sect. 3.2 and also in the last paragraph of the conclusion section.

We add the following statement in Sect. 3.2:

"One caveat to be noted is that the aerosol forcing scenario (RCP8.5) used in the Fix_EastFF1920 experiments has been proven to overestimate the aerosol emission level in East Asia since the early 2010s although it remains at a high level (Wang et al., 2021; Xiang et al., 2023). This leads to the overestimation of the EastFF forcing in the experiments. Therefore, the comparison above can only be treated as a qualitative comparison but not a quantitative attribution. In addition, the South Asia emission largely follows the emission scenario, which leads to a dipole of aerosol forcings changes within the EH. The forcing dipole might introduce complex circulation responses and new simulations with accurate emission forcings are necessary to further explore more realistic climate responses."

We modified the last paragraph in the conclusion section:

"In this study, we focus on the period of 1980–2020, when aerosol emissions over Asia show an overall increasing trend. However, studies have shown that the emission from East Asia reached a peak around the 2010s and have started to decline recently while South Asia emissions continue to increase (Samset et al., 2019; Ramachandran et al., 2020; Wang et al., 2021). The discrepancy between observed forcing and the forcing scenarios applied in the experiments in East Asia introduces additional biases to the results in EastFF, and new simulations with more accurate forcing scenarios are necessary to further test the climate response to regional aerosol forcings. In fact, the sensitivity of aerosol forcing's latitudinal placement within Asia is also highlighted by recent studies on dipole patterns emerging in Asia (Wang et al., 2022; Xiang et al., 2023). Moreover, the current offsetting effects between EastFF and

WestFF can flip to a joint effect over specific regions of the North Pacific in the coming few decades. Such declines and/or redistribution of aerosol emissions can lead to distinctly complex climate responses locally and remotely, which demands further continuous investigation in the future."

2. Indicate the significance of the responses in the figures.

Response

Thanks for the constructive comments, we now added significance tests in Fig. 2, Fig. 4, Fig. 5, and Fig. 6. All our conclusions stay the same. Based on the significance test, we updated the statements about the nonlinearity issues (see previous response). Also, we added the statistical significance statements here and there in the manuscript. Please check the modified figures by the end of the document.

3. Section 3.2: I presume the EOF is applied to the ensemble-mean. What about applying the EOF to each ensemble, and then taking the mean? It is more comparable to contrast the ERA5 with each ensemble rather than with ensemble-mean. It'll also be useful to see the spread of indices in Fig. 3e,f.

Response

Thanks for the suggestion. However, with respect, we do not think the mean of EOF for each ensemble makes sense here. First, the 1st and 2nd EOF patterns of each ensemble member should represent the global warming and randomly modeled internal variability, because these two have much larger signals in single realizations compared to aerosol forcings. This is why we performed large ensemble simulations to separate the aerosol forcings from the internal variability. Therefore, direct comparisons between ERA5 and single ensemble members cannot clearly show the climate responses to aerosol forcings from our understanding. Second, our forced response is calculated by subtracting "fixed regional aerosol ensemble mean" from "all forcing ensemble mean", if we want to generate EOF for each ensemble member, we have to randomly pick one realization from the two experiments and calculate the difference, which introduces subtraction between two random generated internal variability. Hence, we would like to keep our figures to EOF to ensemble-mean.

4. The authors explain the upper-level low anomaly over the extratropial North Pacific in EastFF as a result of a Rossby wave train excited from the enhanced convection over the central equatorial Pacific (Fig. 5a,c,e).

Response

Thanks for the good assessment of our paper.

The precipitation response in the tropical Pacific exhibits a comparable order of magnitude between EastFF and WestFF (Fig. 4c,d). In particular, both simulations show precipitation increase in the western tropical Pacific. I'd expect a similar Rossby wave pattern driven by the enhanced diabatic heating over the warm pool. However, the response of upper-level wave activity is much weaker in WestFF. The fact that the tropical precipitation response is similar between EastFF and WestFF makes me think that strong circulation responses in the extratropical Pacific in EastFF are due to local AA radiative forcing via modulating storm tracks. That said, I don't follow the discussion in Section 3.4.

Response

Thanks for the comments. Based on our results, the precipitation responses in EastFF and WestFF show different mechanisms: The EastFF, which has forcings at low latitudes near the warm pool region, excites the typical El Niño-like SST and precipitation patterns in the tropical Pacific, which serves as the wave source for tropical-extratropical teleconnection. Meanwhile, the WestFF, which has forcings at mid-to-high latitudes, excites the teleconnection from mid-latitudes to the tropics and remotely impacts the tropical regions. Therefore, the tropical rainfall in WestFF is the climate response but not the wave source. The storm track analyses in an interesting idea to further explore the extratropical precipitation response. However, given the small extratropical precipitation responses and the weak local aerosol forcings, we think it is beyond the scope of the current study and decided not to include this analysis in this manuscript.

Modified Figures

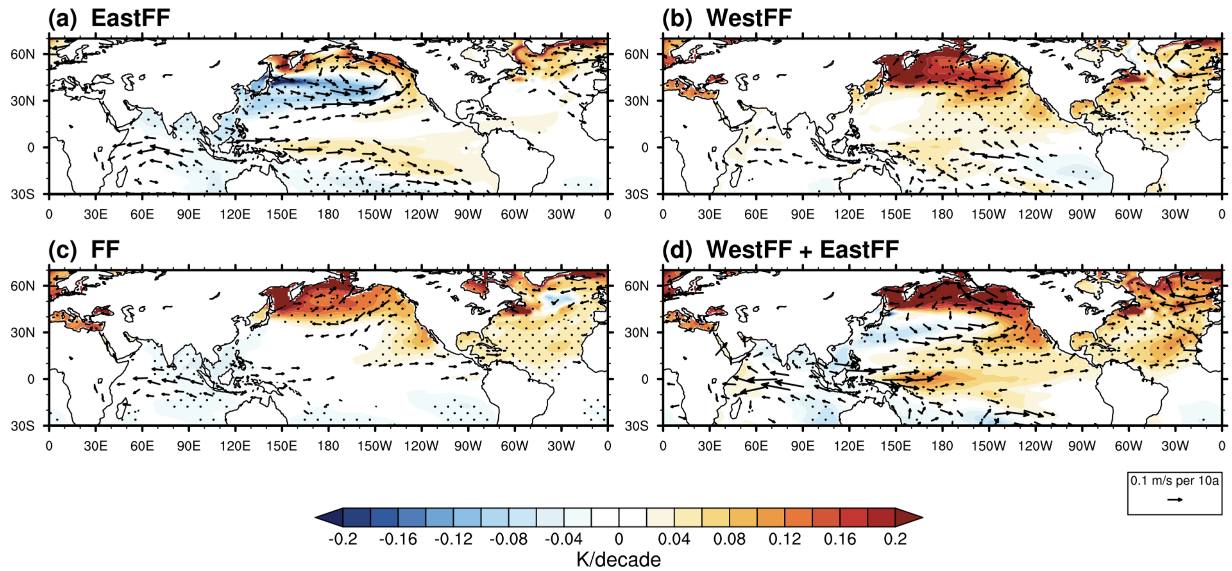

Figure 2

(a) Decadal changes in sea surface temperature (shading; K per decade) and 850 hPa horizontal wind (vectors; m s^{-1} per decade) during 1980–2020 calculated in response to EastFF. (b) and (c): As in (a), but showing results for WestFF and FF, respectively. (d) Linear addition of panels (a) and (b). Stippled regions indicate insignificant values at the 90% confidence level based on a two-sided t-test.

Changes

We add the significance test in all panels.

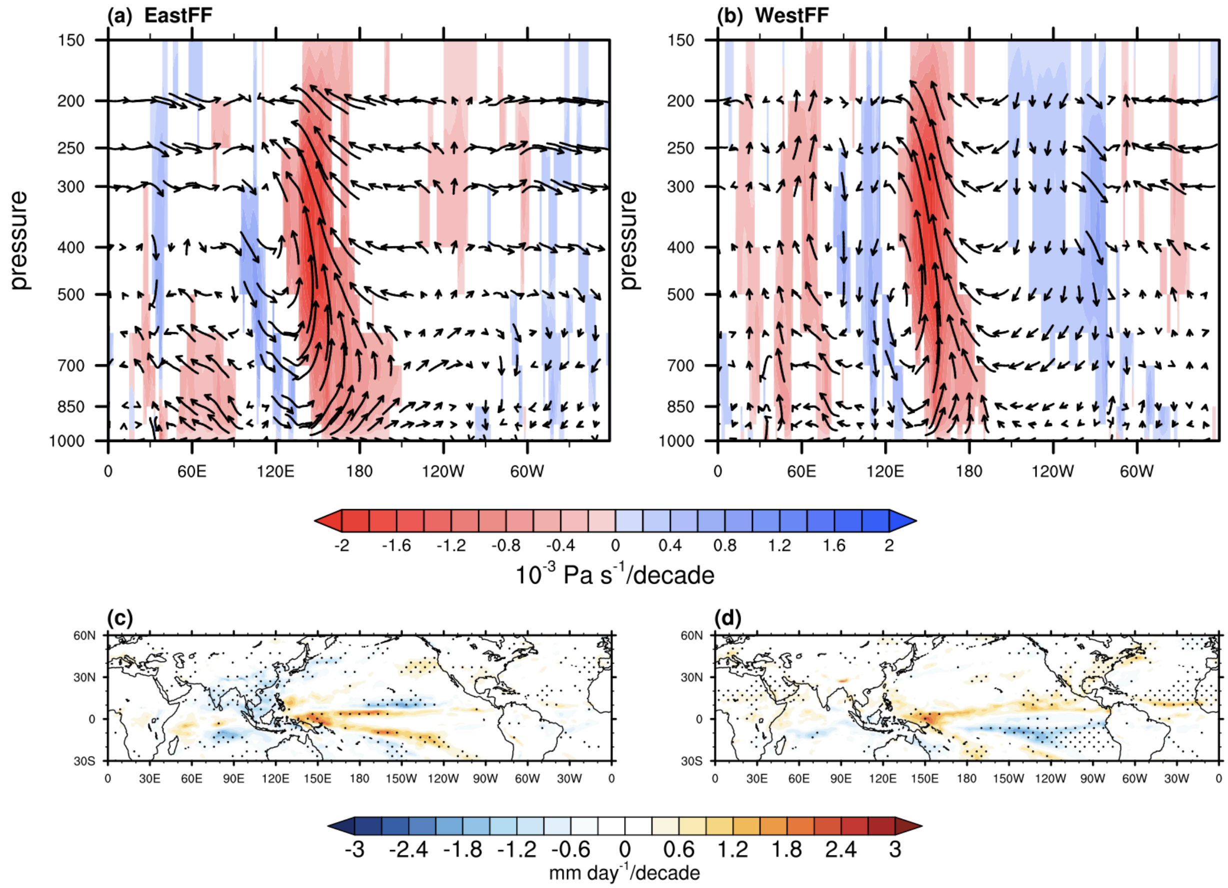

Figure 4 Changes in the tropical circulation.

(a) Decadal changes in cross-section of winds averaged from 5° S–5° N (vectors; The vertical component of the velocity vectors is scaled by a factor of 300) and vertical motion (shading; Pa s-1 in response to EastFF. Blue shading indicates downward motions; red shading indicates upward motions). Regions that fail to pass the significance test (90% confidence level based on a two-sided t test) are masked in white. (b) As in panel (a) but for WestFF. (c) Changes in tropical Precipitation (mm day-1 per decade) in response to EastFF. (d) As in (c), but for WestFF. Stippled regions in (c) and (d) indicate insignificant values at the 90% confidence level based on a two-sided t-test.

Changes

We add the significance test.

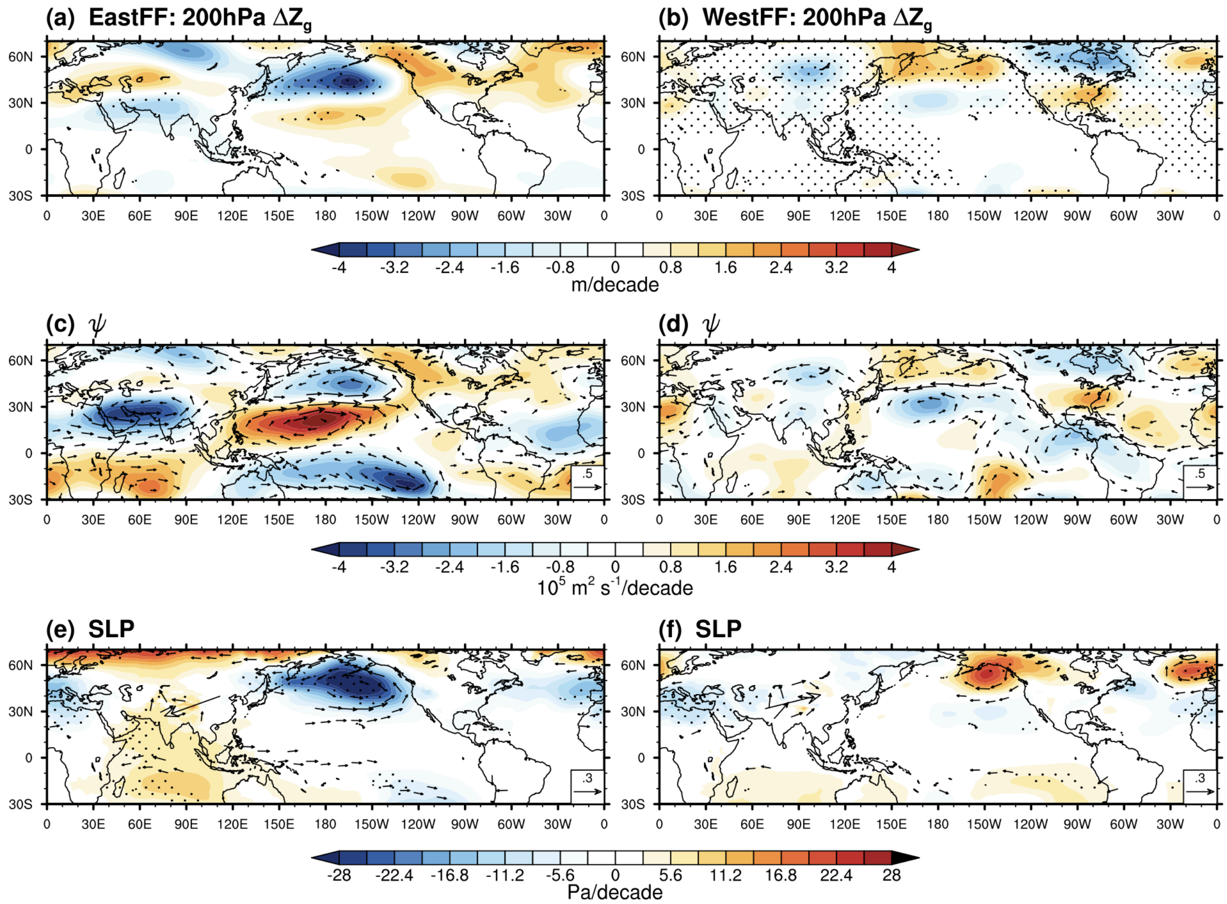

Figure 5

Left panels: EastFF-induced decadal changes of (a) 200 hPa eddy geopotential height (m per decade), (c) 250 hPa stream function (shading; m2 s-1 per decade), and wind (vectors; m s-1 per decade), and (e) sea level pressure (shading; Pa per decade) and 850 hPa low-level wind (vectors; m s-1 per decade). Right panels: same as Left panels, but due to WestFF. Stippled regions indicate insignificant values at the 90% confidence level based on a two-sided t-test.

Changes

We add the significance test.

The colormap in panels e and f is reversed for better comparison, as suggested by reviewer's suggestion.

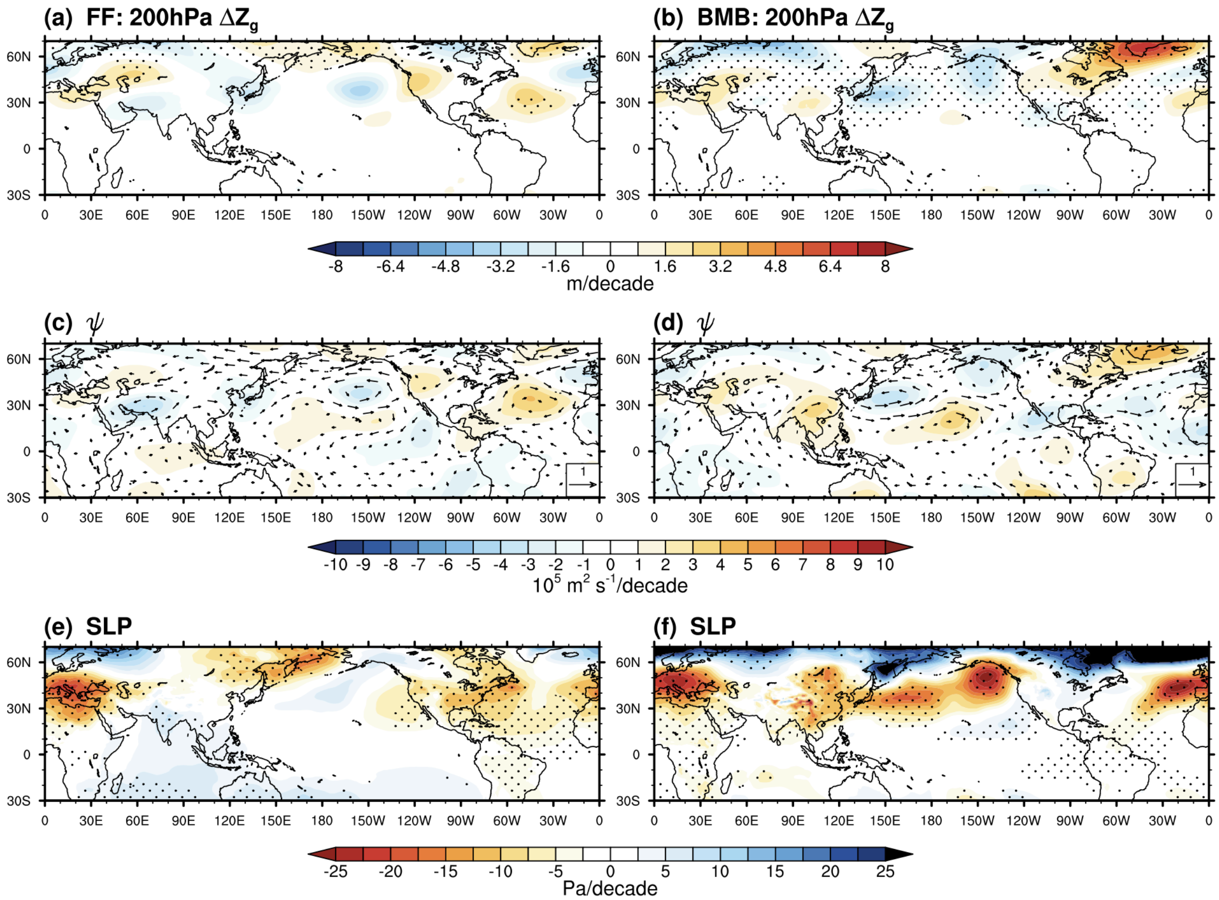

Figure 6

Left panels: FF-induced decadal changes (1980–2020) of (a) 200 hPa eddy geopotential height (m per decade), (c) 250 hPa stream function (shading; $m^2\ s^{-1}$ per decade), and wind (vectors; $m\ s^{-1}$ per decade), and (e) sea level pressure (shading; Pa per decade) and 850 hPa low-level wind (vectors; $m\ s^{-1}$ per decade). Right panels: same as Left panels, but due to Biomass burning (BMB) simulations. Stippled regions indicate insignificant values at the 90% confidence level based on a two-sided t-test.

Changes

We add the significance test.

The colormap in panels e and f is reversed for better comparison, as suggested by reviewer's suggestion.

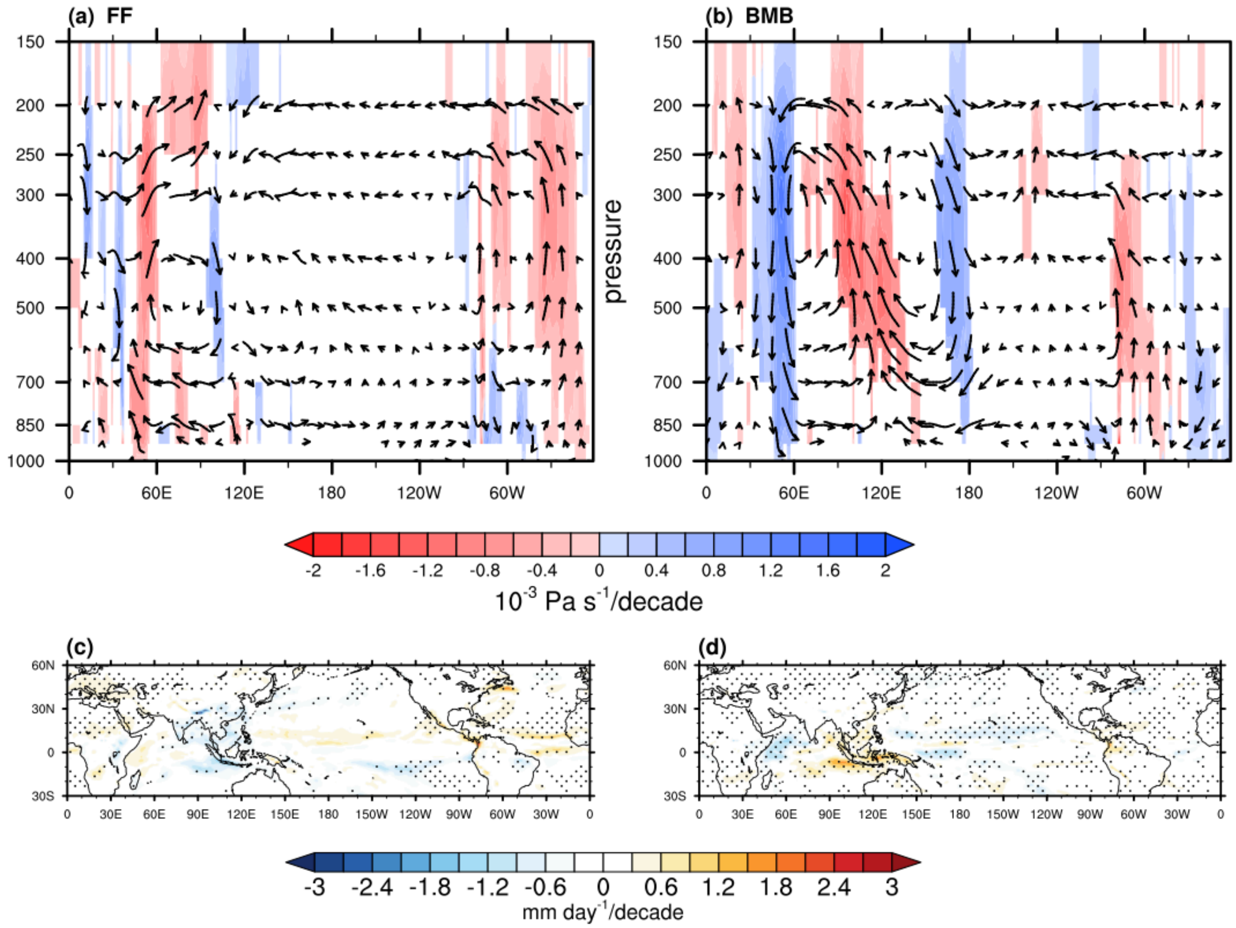

Figure S1 (new figure)

So as Fig. 4 but for (left) FF, and (right) BMB responses.