Impact of air-sea flux perturbations on MOC and patterns of ocean heat uptake

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Abstract

- The spatial pattern of Ocean Heat Uptake depends on both local air-sea flux forcing and the ocean circulation [1].
- We investigate the ocean response, primarily of overturning and ocean heat uptake, to patterns of individual air-sea fluxes, whose future changes are uncertain [2].
- Looking at the transient adjustment over 100 years, a net-zero pattern change in the sensible heat flux leads to substantial changes in heat uptake and overturning. The strength of the ocean feedback is important, especially at latitudes north of 60°N, where the oceanic heat transport is altered as a response to the modifiedsurface flux.
- These results have implications for the spatial pattern of ocean heat uptake, and are important for understanding high latitude feedbacks.

The Experiment

- We run a global low-resolution MITgcm [3] configuration (2.8°, 15 vertical levels, excluding regions poleward of 80°) similar to [4] forced by surface heat and buoyancy fluxes and restoring to climatological SST and SSA. Potential temperature evolves as

$$\frac{\partial T}{\partial t} + \vec{u}\cdot\nabla T = \nabla\cdot(\kappa\nabla T) + F_{surf}$$

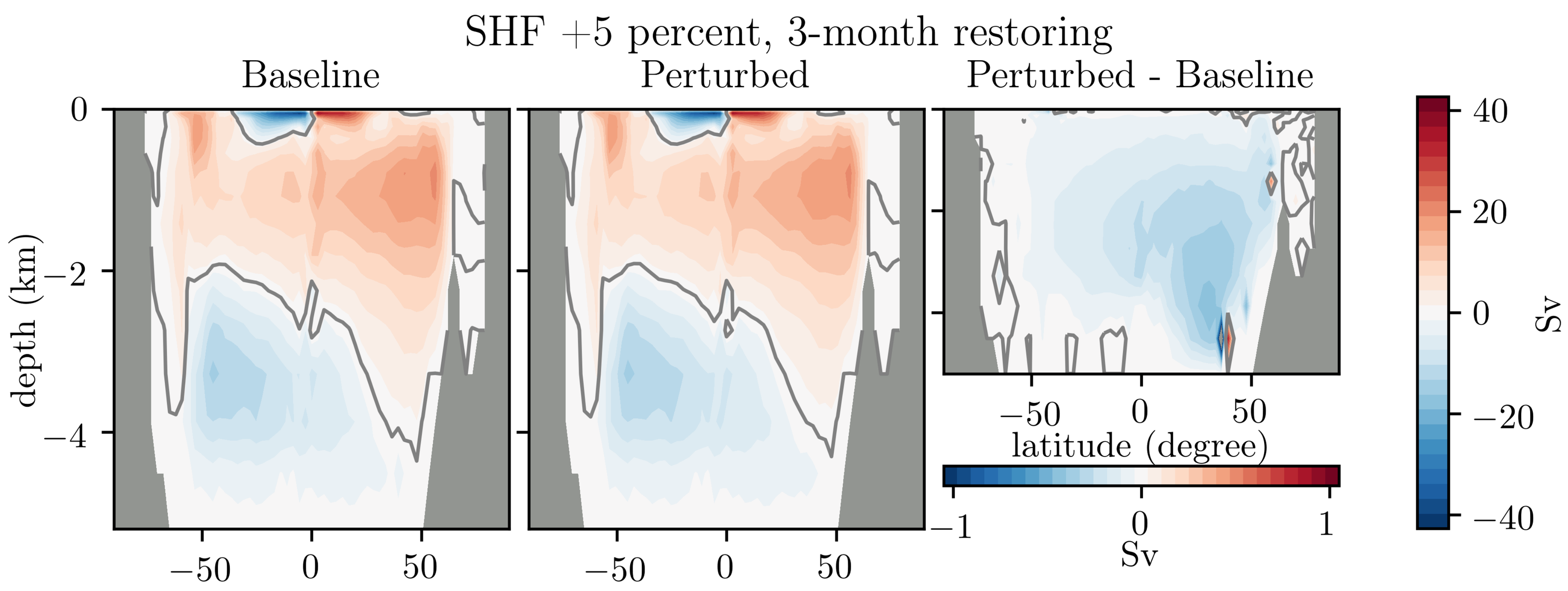
$$F_{surf} = Q_{net} + \lambda(T^* - T) + F_{freeze}$$

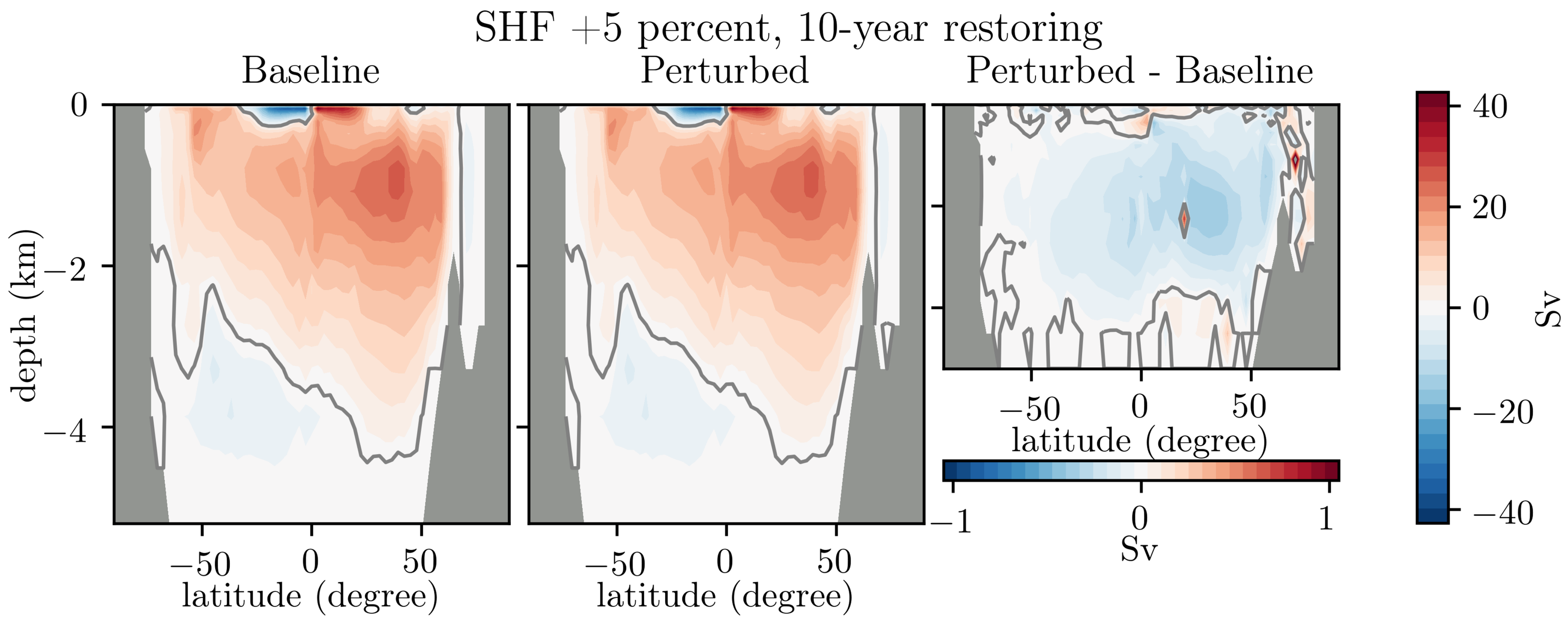
$$Q_{net} = SW + LW + SHF + LHF$$

- Two cases are investigated, applying a strong $\lambda = 1/(3\ \mathrm{month})$ or weak $\lambda = 1/(10\ \mathrm{year})$ restoring, to represent **ocean feedbacks**.
- The air-sea flux is perturbed by the scaled-down ($\alpha = 0.05$), net-zero pattern of the **sensible heat flux**. $SHF \to SHF + SHF'$

$$SHF' = \alpha SHF - \iint \alpha SHF \ \mathrm{d}A \ \mathrm{d}t$$

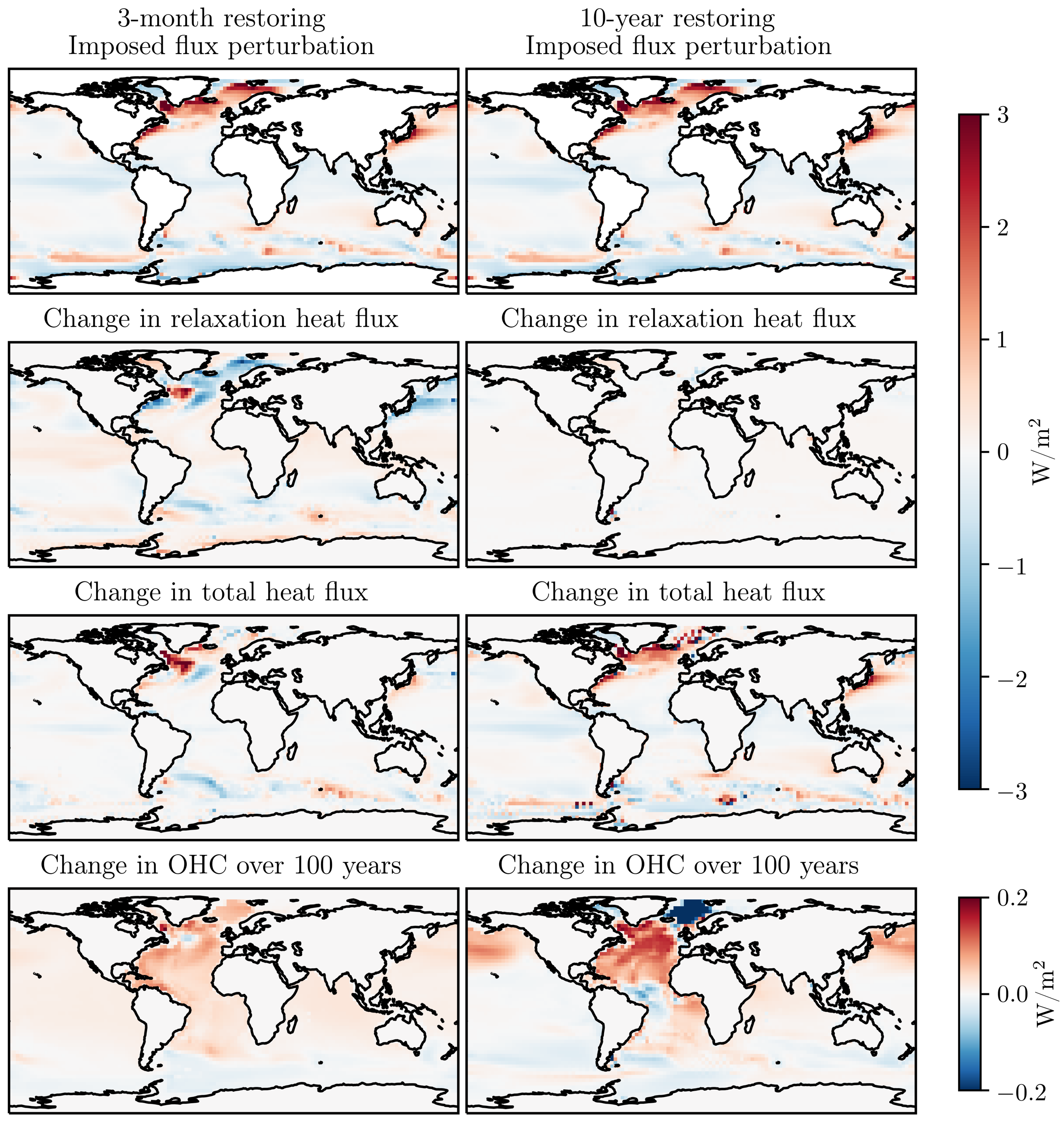
MOC changes



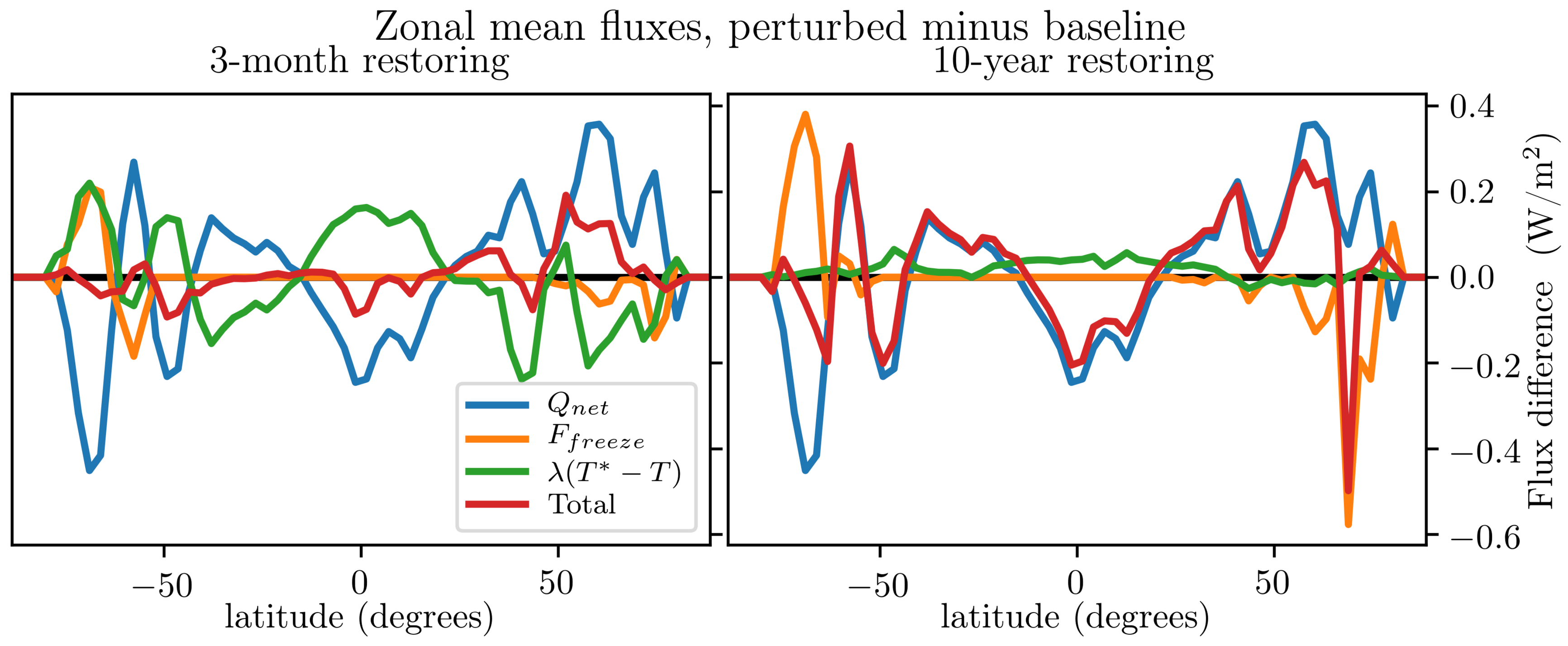


- The top overturning cell (AMOC) weakens by 1-2% as response to the flux perturbation for both strong and weak restoring, while the pattern varies.
- The percentage change is roughly comparable to the perturbation size, and tests have shown that the response is fairly linear to the perturbation magnitude.
- For weak restoring the change is more in the upper cell, for strong restoring more in the bottom cell. The change north of 60° is significantly different.

Ocean Heat Uptake



- The ocean feedback is compensating for a large part of the imposed perturbation.
- The circulation responds by advecting less heat into the North Atlantic ("warming hole") and more into the GIN seas.
- The ocean feedback is mostly suppressed so the total flux change varies more strongly with latitude.
- In the GIN seas, reduced sea ice formation and meridional heat transport lead to a negative OHC change.



- With weak restoring, the ocean can compensate much less of the perturbation, resulting in much larger zonal variations in the total flux and hence, heat uptake.

Summary

- **First results show the transient sensitivity of overturning and heat uptake to net-zero flux perturbations, and highlight the role of ocean feedbacks.**
- **The ocean feedback has a strong control on the heat uptake pattern, with its strength regionally setting the sign. More changes are observed in the northern hemisphere.**
- **Further work will investigate sensitivities to different flux component patterns, perturbation amplitudes, and baselines, in the context of FAFMIP [5].**
- **Those results will serve as input to study the impact of ocean heat uptake patterns on the atmosphere.**

Acknowledgements
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