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A key role of surface atmospheric circulation changes in setting global ocean warming magnitude

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Surface air-sea feedbacks play a pivotal role in modulating the amplitude of global ocean warming. Zhang and Li (2014, ZL14) introduced a simple theoretical framework to identify the driving processes responsible for the Sea Surface Temperature (SST) increase under global warming. This method involves decomposing changes in latent and upwelling longwave surface heat fluxes into two parts: one tied to direct atmospheric forcing and the other directly associated with local (SST) changes, termed feedback. Applying this heat budget equation across 53 CMIP5 and 6 models underscores the pivotal role of increased surface downwelling longwave radiation (DLR) in steering the amplitude of future global ocean warming. However, ZL14 solely considered DLR as a direct forcing, overlooking its substantial feedback response to surface warming.

In this study, we employ a novel methodology from Shakespeare and Roderick (2022, SR22) to decompose DLR changes into a direct radiative forcing and SST-related feedbacks, evaluating the implications of integrating the DLR feedback in the ZL14 framework. Our analysis is in line with SR22's findings across 5 CMIP5 models, our results across 53 models indicate that roughly 90% of DLR increase emerges from feedbacks associated with the rising SST. The large ocean heat capacity transfers warming to the overlying atmosphere, increasing its DLR primarily through direct air temperature increase and the increasing greenhouse effect associated with increased water vapour.

Incorporating the DLR feedback in ZL14 framework yields a dominant effect of latent heat flux forcing on global ocean warming for both multi-model mean and intermodel diversity. This latent heat flux forcing is related to the evaporative cooling modulation associated with projected changes in the surface atmospheric circulation, and is highly correlated with the magnitude of the global average warming. This underscores the substantial influence of projected atmospheric circulation changes on the level of global average warming.