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Timescales of the ocean thermal and carbon response to carbon forcing

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The climate response to any positive carbon forcing is regulated by how the ocean sequesters excess heat and carbon supplied to the climate system. This ocean heat and carbon uptake is to first order controlled by the ventilation mechanism, where heat and carbon are taken by the mixed layer and then transferred into the thermocline and the deep ocean. However, other mechanisms, including the ocean carbonate chemistry and the climate feedbacks also influence the ocean heat and carbon uptake. These other mechanisms lead to the thermal and carbon responses operating on different timescales from each other and from what would be expected from a passive, chemically inactive tracer. Here we provide a formulation for this intuitive view of the control of different ocean mechanisms on the climate response to carbon forcing that lead to a single similarity solution for both the carbon and thermal responses in an idealized atmosphere-ocean system. This similarity solution involves: i) a forcing, ii) a feedback, and iii) an ocean uptake driven by both the adjustment of the mixed layer and the ocean interior. The forcing for the carbon and thermal response is similarly controlled by the increase in the atmospheric CO_2. The adjustment of the mixed layer and the ocean interior to the supplied carbon and heat is also similarly controlled by the mixed layer volume and the ventilation of the ocean interior. However, the thermal and the carbon associated feedbacks differ as the thermal response is driven by the climate feedback, while the carbon response is driven by changes in the carbonate chemistry. This difference in the carbon and thermal associated feedbacks lead to the carbon and the thermal response operate on different timescales. The implications of these differences in the ocean carbon and thermal responses are discussed for the wider climate system.