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Improved Analysis of Earth System Models and Observations using Simple Climate Models

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First-principles-based Earth System Models (ESMs) are central to both improving our understanding of the climate system and developing climate projections. Nevertheless, given the diversity of climate simulated by the various ESMs and the intense computational burden associated with running such models, simple climate models (SCMs) are key to being able to compare ESMs and the climates they simulate in a dynamically meaningful fashion. We present some preliminary work along these lines. In an application of an SCM to compare different ESMs and observations, we demonstrate a deficiency in the commonly-used upwelling-diffusion (UD) energy balance model (EBM). When we consider the vertical distribution of ocean heat uptake, the lack of representation of processes such as deep water formation and subduction in the UD-EBM precludes a reasonable representation of the vertical distribution of heat uptake in that model. We then demonstrate how the problem can be remedied by introducing a parameterization of such processes in the UD-EBM. With further development, it is anticipated that this approach of ESM inter-comparison using simple physics-based models will lead to further insights into aspects of the climate response such as its stability and sensitivity, uncertainty and predictability, and underlying flow structure and topology.