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Modification of feedbacks through surface temperature patterns hampers predictability

Maria Rugenstein (1), Jonah Bloch-Johnson (2), and Reto Knutti (1)

(1) ETH Zürich, IAC, D-USYS, Zürich, Switzerland (maria.rugenstein@env.ethz.ch), (2) Department of the Geophysical Sciences, University of Chicago, Chicago, Illinois, USA

There is increasing evidence that sea surface temperature patterns shape and change atmospheric radiative feedbacks and thereby the evolution of the surface temperature (Rugenstein et al. 2016, Gregory and Andrews 2016, Zhou et al. 2016). This mechanism has been termed "pattern effect" (Stevens et al. 2016). We analyze the pattern effect for idealized forcing scenarios of CO_2 step forcings to understand its magnitude and potential impact on more realistic scenarios.

First, we show that the non-constancy of global feedbacks during the equilibration process of a complex coupled climate model can be reproduced with a series of slab ocean simulations. We bridge the important gap in model hierarchy between idealized aqua-planet and complex coupled climate models. We find that the evolution of the global feedback parameter through equilibration time can be attributed to the changing surface heat flux patterns. Subtle changes in heat uptake and, notably, heat release do change the low cloud cover enough to impact local, far field, and global temperatures.

Second, we present first results from a new, ongoing model intercomparison of equilibrated complex coupled (CMIP5-type) climate models (www.LongRunMIP.org). With this set of rare, millennia scale, model simulations, we show how the "true" equilibrium climate sensitivity differs from various estimates based on shorter time scales. This is the perfect testbed of current concepts of temperature evolution. The common assumption that global radiative feedbacks are constant and can can be extrapolated linearly to predict the long term temperature evolution does not hold in this set of models. We show how the pattern effect plays a role on decadal to millennia time scales and shapes different feedback processes.

Third, we link the findings from idealized step forcings to realistic scenarios and discuss which features of changing sea surface temperatures and heat fluxes do occur in historical and RCP-type scenarios. The magnitude of the pattern effect will determine the usefulness of GCM based feedbacks for the estimates of real-world temperature evolution which make us of the model based feedback parameter.

Rugenstein, Caldeira, Knutti, 2016: *Dependence of global radiative feedbacks on evolving patterns of surface heat fluxes*, GRL
Gregory and Andrews, 2016: *Variations in climate sensitivity and feedback parameters during the historical period*, GRL
Zhou, Zelinka, Klein, 2016: *Impact of decadal cloud variations on the Earth's energy budget*, Nature Geoscience
Stevens et al., 2016: *Prospects for Narrowing Bounds on Earth's Equilibrium Climate Sensitivity*, Earth's Future