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Understanding land-sea warming contrast in response to increasing greenhouse gases: Equilibrium response

Buwen Dong[†]; Rowan Sutton; Jonathan Gregory
[†] University of Reading, United Kingdom
Leading author: b.dong@reading.ac.uk

Climate model simulations consistently show that in response to greenhouse gas forcing surface air temperature over land increases more rapidly than over sea. Analysis of the IPCC/CMIP3 model integrations shows a land-sea warming ratio ranging from 1.36 to 1.84. Understanding the factors that govern this warming contrast is an important issue for climate projections, both because of the direct impacts of regional warming, and because of interactions between the land/sea warming contrast and atmospheric circulation on local and regional scales. In this study, the mechanisms responsible for enhanced land surface warming are elucidated using equilibrium sensitivity experiments carried out with an atmospheric general circulation model (AGCM). Results indicate that warming over land may be viewed partly as a direct response to CO2 change, and partly as an indirect response to warming of the sea. The processes responsible for the land surface warming in response to different forcings involve a local positive feedback between warming, relative humidity and cloud cover. The reduction of cloud cover enhances land surface warming in response to both CO2 change and imposed SST change through its effect on surface shortwave radiation. In addition to the land surface warming induced by the CO2 radiative effect, the CO2 induced stomatal response inhibits evapotranspiration, favouring near-surface warming, especially in summer when evapotranspiration is strongest. The increased net downward shortwave due to cloud changes further amplifies this near-surface warming. Results imply that the change in stomatal resistance in land surface schemes among different models in response to CO2 change is one factor that might be responsible for the uncertainty of land sea warming ratio seen in IPCC/CMIP3 models. The analysis of warming ratios in the multi AGCM experiments forced by the same SST and CO2 change shows that the range of warming ratios (1.54-1.78) is smaller than that obtained from IPCC/CMIP3 models, implying that another factor responsible for the spread of land sea warming ratio in response to greenhouse gas changes in IPCC/CMIP3 models is the uncertainty of the magnitude and spatial pattern of SST change in coupled models.