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Diagnosing atmosphere–land feedbacks in CMIP5 climate models

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Human-made transformations to the environment, and in particular the land surface, are having a large impact on the distribution (in both time and space) of rainfall, upon which all life is reliant. Focusing on precipitation, soil moisture and near-surface temperature, we compare data from Phase 5 of the Climate Modelling Intercomparison Project (CMIP5), as well as blended observational–satellite data, to see how the interaction between rainfall and the land surface differs (or agrees) between the models and reality, at daily timescales.

As expected, the results suggest a strong positive relationship between precipitation and soil moisture when precipitation leads and is concurrent with soil moisture estimates, for the tropics as a whole.
Conversely a negative relationship is shown when soil moisture leads rainfall by a day or more. A weak positive relationship between precipitation and temperature is shown when either leads by one day, whereas a weak negative relationship is shown over the same time period between soil moisture and temperature. Temporally, in terms of lag and lead relationships, the models appear to be in agreement on the overall patterns of correlation between rainfall and soil moisture. However, in terms of spatial patterns, a comparison of these relationships across all available models reveals considerable variability in the ability of the models to reproduce the correlations between precipitation and soil moisture. There is also a difference in the timings of the correlations, with some models showing the highest positive correlations when precipitation leads soil moisture by one day. Finally, the results suggest that there are 'hotspots' of high linear gradients between precipitation and soil moisture, corresponding to regions experiencing heavy rainfall.

These results point to an inability of the CMIP5 models to simulate a positive feedback between soil moisture and precipitation at daily timescales. Longer timescale comparisons, such as 10- or 30-day periods, are expected to improve process understanding further, and preliminary results from this analysis are presented here.