Evaluating land surface models during drought

A. Ukkola[a], A. Pitman[a,b], M. Decker[a,b], M. De Kauwe[c], G. Abramowitz[a,b], J. Kala[a,d] and Y.-P. Wang[e]

[a] *ARC Centre of Excellence for Climate System Science, UNSW, Kensington, NSW 2052, Australia*
[b] *Climate Change Research Centre, UNSW, Kensington, NSW 2052, Australia*
[c] *Dept. of Biological Sciences, Macquarie University, North Ryde, NSW 2109, Australia*
[d] *School of Veterinary and Life Sciences, Environmental and Conservation Sciences, Murdoch University, Murdoch, WA 6150, Australia*
[e] *CSIRO Ocean and Atmosphere, Aspendale, Victoria 3195, Australia*
Email: a.ukkola@unsw.edu.au

Abstract: Surface fluxes from land surface models (LSM) have traditionally been evaluated against monthly, seasonal or annual mean states. The limited ability of LSMs to reproduce observed evaporative fluxes under water-stressed conditions has been previously noted, but very few studies have systematically evaluated these models during rainfall deficits.

We first evaluated latent heat flux simulated by the Community Atmosphere Biosphere Land Exchange (CABLE) LSM across six flux tower sites at sub-annual to inter-annual time scales, in particular focusing on model performance during seasonal-scale rainfall deficits. The importance of key model processes in capturing the latent heat flux was explored by employing alternative representations of hydrology, leaf area index, soil properties and stomatal conductance. We found that the representation of hydrological processes was critical for capturing observed declines in latent heat during rainfall deficits. By contrast, the effects of soil properties, LAI and stomatal conductance were shown to be highly site-specific. Whilst the standard model performs reasonably well at annual scales as measured by common metrics, it grossly underestimates latent heat during rainfall deficits. A new version of CABLE, with a more physically consistent representation of hydrology, captures the variation in the latent heat flux during seasonal-scale rainfall deficits better than earlier versions.

Comparison to twelve other LSMs revealed that the systematic biases typical to the standard version of CABLE are common amongst LSMs. Using one standard deviation below the observed mean as the drought threshold, we show that, on average, the LSMs spend 47 days/year longer in drought than was observed across the six flux tower sites. In addition to significantly overestimating drought duration, the LSMs also overestimate drought severity. On average, the LSMs produced 40 mm/year less evapotranspiration during drought than was observed.

Our results point to systematic biases in LSMs under water-stressed conditions. A major role for LSMs is to simulate feedbacks to the atmosphere associated with rainfall deficits. The overestimation of drought duration and intensity has implications not only for the simulation of hydrological processes but also other extremes, such as heat waves, in coupled climate models. Our results highlight the importance of formally testing LSMs against more extreme conditions, and in the context of specific phenomenon (e.g. drought or heatwave) is a necessary step to build confidence in the projections from climate models that utilise LSMs.

Keywords: *Drought, Land Surface Model, Evapotranspiration, Climate Extremes*