EGU21-4083
https://doi.org/10.5194/egusphere-egu21-4083
EGU General Assembly 2021

Evaluating a land surface model at a water-limited site: implications for land surface contributions to droughts and heatwaves

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Land surface models underpin coupled climate model projections of droughts and heatwaves. However, the lack of simultaneous observations of individual components of evapotranspiration, concurrent with root-zone soil moisture, has limited previous model evaluations. Here, we use a comprehensive set of observations from a water-limited site in southeastern Australia including both evapotranspiration and soil moisture to a depth of 4.5 m to evaluate the Community Atmosphere-Biosphere Land Exchange (CABLE) land surface model. We demonstrate that alternative process representations within CABLE had the capacity to improve simulated evapotranspiration, but not necessarily soil moisture dynamics - highlighting problems of model evaluations against water fluxes alone. Our best simulation was achieved by resolving a soil evaporation bias; a more realistic initialisation of the groundwater aquifer state; higher vertical soil resolution informed by observed soil properties; and further calibrating soil hydraulic conductivity. Despite these improvements, the role of the empirical soil moisture stress function in influencing the simulated water fluxes remained important: using a site calibrated function reduced the soil water stress on plants by 36 % during drought and 23 % at other times. These changes in CABLE not only improve the seasonal cycle of evapotranspiration, but also affect the latent and sensible heat fluxes during droughts and heatwaves. The range of parameterisations tested led to differences of ~150 W m^{-2} in the simulated latent heat flux during a heatwave, implying a strong impact of parameterisations on the capacity for evaporative cooling and feedbacks to the boundary layer (when coupled). Overall, our results highlight the opportunity to advance the capability of land surface models to capture water cycle processes, particularly during meteorological extremes, when sufficient observations of both evapotranspiration fluxes and soil moisture profiles are available.