Modelling coupled drought response and root water uptake in the CABLE land surface scheme

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In many global terrestrial carbon-cycle models, global gross primary production (GPP) and net biome production (NBP) are over-sensitive to precipitation anomalies. This was reported by Piao et al. [1] , and highlighted in the IPCC 5th Assessment Report: "Terrestrial carbon cycle models used in AR5 generally underestimate GPP in the water limited regions, implying that these models do not correctly simulate soil moisture conditions, or that they are too sensitive to changes in soil moisture (Jung et al., 2007). Most models (Table 6.7) estimated that the interannual precipitation sensitivity of the global land CO_2 sink to be higher than that of the observed residual land sink (–0.01 PgC yr^{-1} mm^{-1}; Figure 6.17)." [2].

CABLE is a global land surface model, which has been used extensively in offline and coupled simulations. In the standard CABLE2.0 configuration, simulations are impacted by decoupling of transpiration and photosynthesis fluxes under drying soil conditions, often leading to implausibly high water use efficiencies. Here we present a solution to this problem, ensuring that modeled transpiration is always consistent with modeled photosynthesis, while introducing a parsimonious single-parameter drought response function which is coupled to root water uptake and emulates optimal plant use of water resources. We further improve CABLE's simulation of coupled soil-canopy processes by introducing an alternative hydrology model with a physically accurate representation of coupled energy and water fluxes at the soil/air interface, including a more realistic formulation of transfer under atmospherically stable conditions within the canopy and in the presence of leaf litter.

The effects of these model developments are assessed using 101 site-years of data from 19 stations from the global FLUXNET network, selected to span a large climatic range. Results demonstrate marked improvements and highlight the important roles of deep soil moisture in mediating drought response, and litter in dampening soil evaporation.

We further demonstrate the applicability of the drought response formulation and SLI hydrology by assessment against multiple observation types, with wide spatial distribution across the Australian continent.

References

1 Piao, S. *et al.* Evaluation of terrestrial carbon cycle models for their response to climate variability and to CO2 trends. *Global Change Biology* **19**, 2117-2132, doi:10.1111/gcb.12187 (2013).

2 Ciais, P. *et al.* in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2013).

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