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Multiple Observation Types Jointly Constrain Australian Terrestrial Carbon and Water Cycles

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Information about the carbon cycle potentially constrains the water cycle, and vice versa. This paper explores the utility of multiple observation sets to constrain carbon and water fluxes and stores in a land surface model, and a resulting determination of the Australian terrestrial carbon budget. Observations include streamflow from 416 gauged catchments, measurements of evapotranspiration (ET) and net ecosystem production (NEP) from 12 eddy-flux sites, litterfall data, and data on carbon pools. The model is a version of CABLE (the Community Atmosphere-Biosphere-Land Exchange model), coupled with CASAcnp (a biogeochemical model) and SLI (Soil-Litter-Iso, a soil hydrology model including liquid and vapour water fluxes and the effects of litter).

By projecting observation-prediction residuals onto model uncertainty, we find that eddy flux measurements provide a significantly tighter constraint on Australian continental net primary production (NPP) than the other data types. However, simultaneous constraint by multiple data types is important for mitigating bias from any single type.

Results emerging from the multiply-constrained model are as follows (with all values applying over 1990-2011 and all ranges denoting ± 1 standard error): (1) on the Australian continent, a predominantly semi-arid region, over half (0.64 ± 0.05) of the water loss through ET occurs through soil evaporation and bypasses plants entirely; (2) mean Australian NPP is 2200 ± 400 TgC/y, making the NPP/precipitation ratio about the same for Australia as the global land average; (3) annually cyclic ("grassy") vegetation and persistent ("woody") vegetation respectively account for 0.56 ± 0.14 and 0.43 ± 0.14 of NPP across Australia; (4) the average interannual variability of Australia's NEP (± 180 TgC/y) is larger than Australia's total anthropogenic greenhouse gas emissions in 2011 (149 TgCeq/y), and is dominated by variability in desert and savannah regions.

The mean carbon budget over 1990-2011 reveals that climate variability and rising CO_2 respectively contributed 12 ± 29 and 68 ± 35 TgC/y to Net Biosphere Productivity (NBP, positive to land). However these terrestrial carbon gains were partially offset by fire and land use change (mainly clearing of woody savannah), which caused net losses of 26 ± 4 TgC/y and 18 ± 7 TgC/y respectively. The resultant overall NBP of 36 ± 35 TgC/y offset fossil fuel emissions (95 ± 6 TgC/y) by $32 \pm 36\%$. However, territorial fossil fuel emissions are increasingly being dwarfed by fossil fuel exports: in 2009-2010, Australia exported 2.5 times more carbon in fossil fuels than it emitted by burning fossil fuels for domestic use.