Eco-hydrological implications of long-term vegetation responses to CO₂ fertilization: More or less streamflow?

Yuting Yang^{1,2,3}, Tim R. McVicar¹, Randall J. Donohue¹ and Michael L. Roderick²

1 CSIRO Land and Water, Canberra, Australia

2 Research School of Earth Science, Australian National University, Canberra, Australia 3 Department of Hydraulic Engineering, Tsinghua University, Beijing, China

Anthropogenic activities are increasing atmospheric CO₂ concentrations. Amongst the many observed and expected impacts of this on our climate and biosphere, one is the so-called CO₂ fertilization effect. In this effect, the efficiency with which plants can use carbon relative to water increases proportionally with the CO₂ concentration. Greater water use efficiency has implications for carbon and water balances, as plants can either capture more carbon for the same amount of transpired water loss or can transpire less water for the same amount of carbon captured (or some combination thereof). The recent historical rise in CO₂ concentrations is now large enough that some of these responses can be observed globally and are affecting all vegetated terrestrial ecosystems, with findings that CO₂ fertilization altered continental river flows.

How vegetation responds to increasing atmospheric CO₂ concentration can impact catchment-level water use in (at least) three main mechanisms. Firstly, directly by reducing stomatal conductance and thus reducing leaf-level transpiration, so changing the soil moisture dynamics in the soil profile. Secondly, indirectly by vegetation adapting to changing resource availability by increasing its above-ground leaf area (i.e., greening). Thirdly, indirectly by vegetation increasing its rooting depth thus allowing vegetation to access more water during dry spells. It is very unlikely that three mechanisms will have the same impact across all landscapes / climate conditions globally. So, how important are these three mechanisms in different landscapes given different limitations to vegetation growth? Using a 'carbon assimilation-water use' framework, where water-use efficiency is the linking process between the carbon cycle and the water cycle, we hypothesis that the catchmentlevel hydrological responses will be different for energy-limited (when precipitation exceeds potential evaporation) vs. water-limited (when potential evaporation exceeds precipitation) landscapes vs. 'equitant' where potential evaporation is close to precipitation, with their ratio straddling 1.0 and changing seasonally). Also if energy-limited due to cold conditions for much of the year (e.g., boreal regions) there may be a different response than if energylimited due to very high precipitation rates (e.g., tropical evergreen landscapes). Recent findings from satellite vegetation and streamflow data used in the: (i) 'carbon assimilationwater use' framework'; and (ii) statistical models will be drawn together to help unravel the interacting changing processes and provide guidance on how expected hydrological change may vary with landscape / climate type. Knowledge gaps will also be identified.