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Satellites reveal a strong coupling between the land carbon sink and global changes in terrestrial water storage

Vincent Humphrey (1), Jakob Zscheischler (1), Philippe Ciais (2), Lukas Gudmundsson (1), Stephen Sitch (3), and Sonia Seneviratne (1)

(1) ETH Zürich, Institute for Atmospheric and Climate Science, Zürich, Switzerland (vincent.humphrey@env.ethz.ch), (2) Laboratoire des Sciences du Climat et de l'Environnement, CEA CNRS UVSQ, Gif-sur-Yvette, France., (3) College of Life and Environmental Sciences, University of Exeter, Exeter, United Kingdom.

Year-to-year variations in the atmospheric CO_2 growth rate are mostly due to fluctuating carbon uptake by land ecosystems. While these fluctuations have often been related to indices of large-scale atmospheric variability (e.g. ENSO) and tropical temperature, identifying the role of water availability has proven more elusive at the global scale. Due to the lack of direct observations, only time-lagged precipitation anomalies and drought indices could be used as proxies for water availability until now.

Here, we show that recent observations of terrestrial water storage derived from satellite gravimetry can be used to investigate carbon cycle variability at global to regional scales. Anomalies in terrestrial water storage derived from the Gravity Recovery And Climate Experiment (GRACE) mission represent direct observations of moisture availability at the ecosystem level. Unlike model estimates of root-zone soil moisture, these observations are not subject to biases introduced by errors in the precipitation forcing and do not depend on how dynamic global vegetation models represent complex hydrological processes. Instead, they implicitly integrate the different impacts of rainfall, evapotranspiration and runoff over different soil and vegetation types.

In this contribution, we show that the coupling between the CO_2 growth rate and land water storage is at least as important as with temperature at the global scale. We find that this relationship is underestimated by current carbon cycle models. These results suggest that the inter-annual variability of the land carbon sink can be constrained by independent observations of the water cycle, which may help reducing uncertainties in future carbon cycle projections. They also illustrate how recent developments in satellite observations of land water storage can offer a new and valuable perspective for the carbon cycle community.