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Using observations to evaluate biosphere-atmosphere interactions in models

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Biosphere-atmosphere interactions influence the hydrologic cycle by altering climate and weather patterns (Charney, 1975; Koster et al., 2006; Seneviratne et al., 2006), contributing up to 30% of precipitation and radiation variability in certain regions (Green et al., 2017). They have been shown to contribute to the persistence of drought in Europe (Seneviratne et al., 2006), as well as to increase rainfall in the Amazon (Spracklen et al., 2012). Thus, a true representation of these feedbacks in Earth System Models (ESMs) is crucial for accurate forecasting and planning. However, it has been difficult to validate the performance of ESMs since often-times surface and atmospheric flux data are scarce and/or difficult to observe.

In this study, we use the results of a new global observational study (using remotely sensed solar-induced fluorescence to represent the biosphere flux) (Green et al., 2017) to determine how well a suite of 13 ESMs capture biosphere-atmosphere feedbacks. We perform a Conditional Multivariate Granger Causality analysis in the frequency domain with radiation, precipitation and temperature as atmospheric inputs and GPP as the biospheric input. Performing the analysis in the frequency domain allows for separation of feedbacks at different time-scales (subseasonal, seasonal or interannual).

Our findings can be used to determine whether there is agreement between models, as well as, to pinpoint regions or time-scales of model bias or inaccuracy, which will provide insight on potential improvement. We demonstrate that in addition to the well-known problem of convective parameterization over land in models, the main issue in representing feedbacks between the land and the atmosphere is due to the misrepresentation of water stress. These results provide a direct quantitative assessment of feedbacks in models and how to improve them.

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