Capturing connections between the water, energy, and carbon cycles with the NASA GEOS

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Introduction

Studying biosphere-atmosphere interactions is complex as water, energy and carbon cycles and their feedback processes have to be integrated. At NASA GMAO, we investigate these interactions with an Earth system model that allows us to explore and quantify relevant feedbacks associated with the exchanges of carbon, water, and energy fluxes within the atmosphere, within the land, and across the land-atmosphere interface.

Coupled carbon cycle model in the NASA GEOS

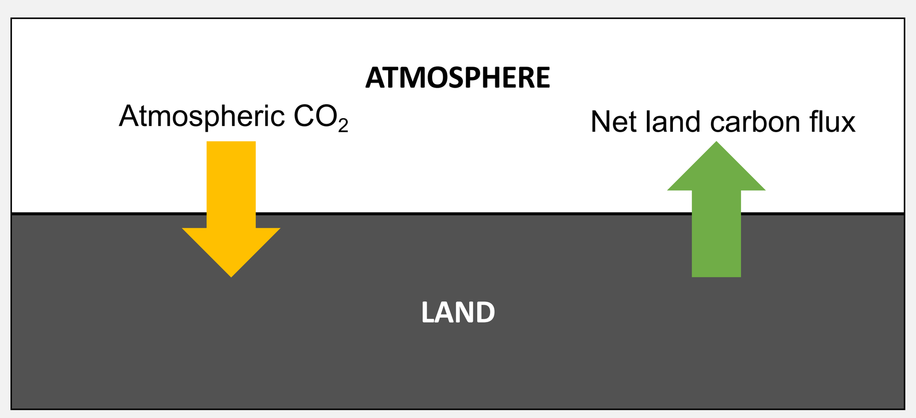


Figure 1. Interactive CO_2 coupling between the atmosphere and the land in the NASA GEOS Earth System Model

A coupled land-atmosphere model in the NASA GEOS system:

(i) allows modeled atmospheric CO_2 to affect land surface carbon uptake

(ii) uses modeled net CO_2 uptake at the land surface as a source or sink for the atmospheric CO_2

(iii) enables **carbon cycle feedbacks** alongside **water & energy cycle feedbacks**

Research aims

- To investigate the mechanisms of the interactions between the land-atmospheric carbons and the climate
- To explore the carbon feedback intertwined with the water cycle

Validation of Catchment-CN's carbon fluxes

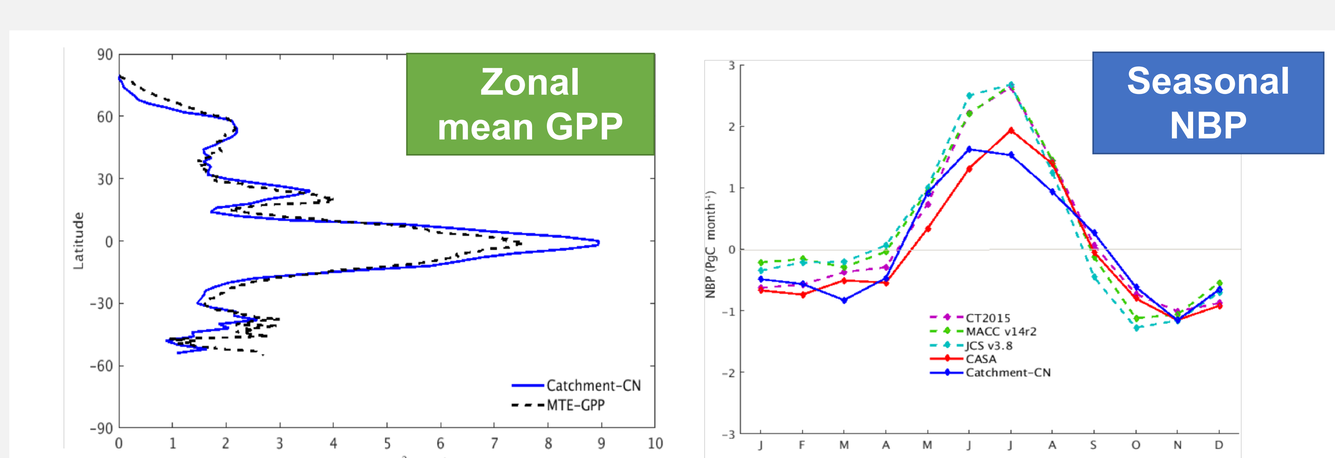
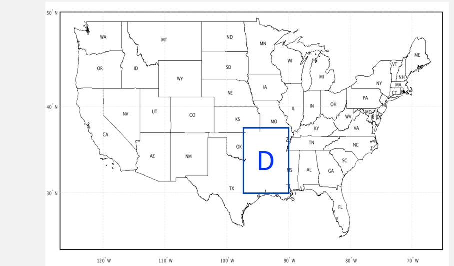


Figure 2. GPP and NBP from offline Catchment-CN, driven by MERRA-2 meteorology, compared with observations (Lee et al., 2018)

GPP and NBP of the offline Catchment-CN agree well with observations

Drought impact on carbon in a coupled system

- Six-month **free running** AGCM simulations
- **Control** ensemble is with no imposed drought
- **Drought** ensemble is with an artificially imposed meteorological drought over 7º x 7º domain in US (boxed area as defined in Koster et al., (2015)) from April to June, followed by a 3-month recovery period
- Each suite consists of **80-member ensembles**
- 2012 SST for all members; Slightly perturbed atmospheric (temperature and humidity) initial conditions



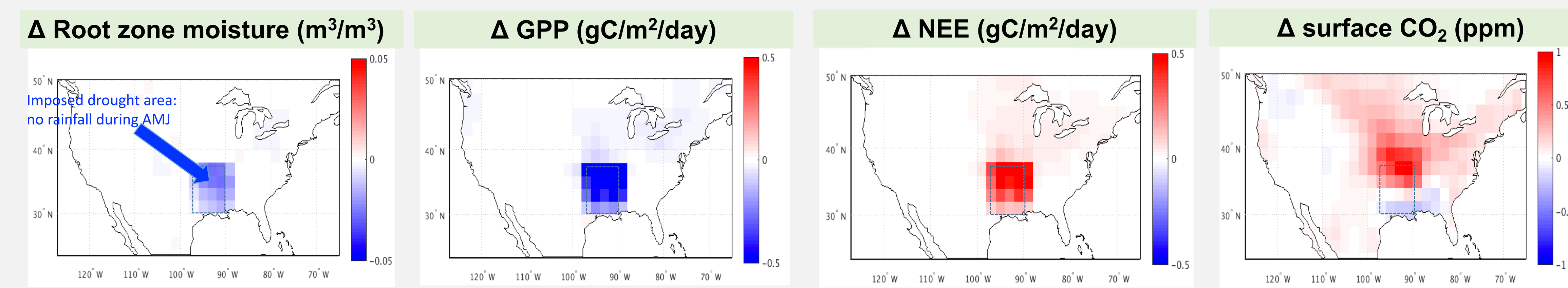
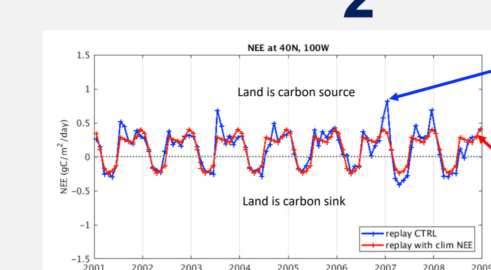


Figure 3. Anomalies (Drought – CTRL) of root zone moisture, GPP, NEE and atmospheric CO_2 near land surface

The impact is seen both inside and outside the imposed drought region. Atmospheric transport moves the extra CO_2 around.

Land C vs. atmospheric transport on CO_2 variability

- 2001-2015 replay AGCM simulations
- The "**replay**" mode forces the model to reproduce the weather systems captured by the MERRA-2 reanalysis (a unique capability of the NASA GEOS model)
- **Control** uses simulated land NEE from Catchment-CN in the NASA GEOS
- **Experiment** uses prescribed,15-year climatological NEE from Control in order to reduce the interannual variability of land carbon flux



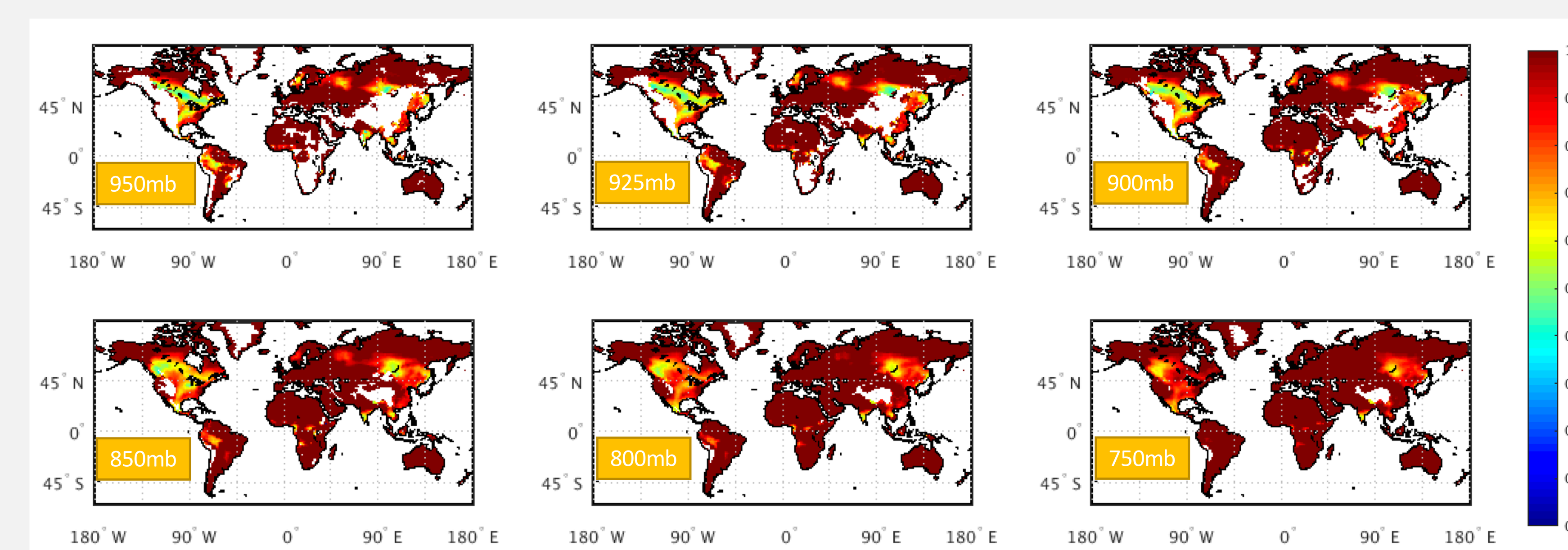


Figure 4. Ratio (EXP/CTRL) of the standard deviations of detrended CO_2 anomalies for six chosen pressure levels

Variations in land carbon flux influence CO_2 variability in the lower and middle troposphere during the NH growing season. Also, CO_2 variability is controlled in large part by interannual atmospheric transport variability.

Ongoing work

Using the **new coupled carbon-climate modeling capability**, current efforts include forecasts of carbon and phenological state in S2S.

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Lee, E., Zeng, F.-W., Koster, R. D., Weir, B., Ott, L. E., & Poulter, B. (2018). The impact of spatiotemporal variability in atmospheric CO2 concentration on global terrestrial carbon fluxes. *Biogeosciences*, *15*(18), 5635–5652. https://doi.org/10.5194/bg-15-5635-2018

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