### Biogeochemistry–Climate Feedbacks

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**Emergent Constraint Discovered from Climate Change Simulations**

Combining 11 long-term in situ and satellite observational data sets, we examined natural and anthropogenic controls on terrestrial evapotranspiration (ET) changes from 1982 to 2010 in single- and multi-factor simulations from the Multi-Scale Synthesis and Terrestrial Model Intercomparison Project (MsTMIP).

**Disentangling Controls on Global Terrestrial ET Trends**

- **Figure 1:** Reconstructed carbon inventory estimates from observations and CMIP5 Earth system models (ESMs).
- **Figure 2:** We applied contemporary observations to constrain future projections of atmospheric CO$_2$ from ESMs.
- **Figure 3:** By correcting contemporary bias, we reduced projections of future atmospheric CO$_2$ and uncertainties.

**International Land Model Benchmarking (ILAMB) Project**

The BGC Feedbacks SFA project is developing an Open Source benchmarking software package for use by the international Earth system modeling community.

**Climate–Carbon Feedbacks Intensify Over Time?**

We used CESM1(BGC) to assess long term carbon cycle dynamics to understand how land and ocean contributions to climate–carbon feedbacks evolve over time from 1850 to 2300.

**Figure 4:** Spatial distribution of dominant drivers for ET. (a) Changing climate was the dominant control on spatiotemporal variations in ET. (b) Rising atmospheric CO$_2$ levels drive the human-induced decreasing trend in ET.

- **Figure 5:** Changes in surface air temperature and ocean and land carbon at year 2300 from RCP 8.5 and ECP 8.5.

**Figure 6:** The BGC Feedbacks SFA integrates the modeling and measurement communities.

- The package is being contributed to ILAMB, a model–data intercomparison activity designed to reduce uncertainties associated with key land surface process representations and inform the design of new measurement campaigns.

**Figure 7:** Model performance is scored based on comparisons with observational data.

**Figure 8:** Simulated global annual mean vegetation productivity is compared with an observational estimate.

**Figure 9:** Regional comparisons show differences in seasonal timing of maximum productivity.