R: Carbon–climate–human interactions

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Objective

The C⁴MIP and CMIP5 results highlighted large uncertainties in climate projections, driven by the interactions between the terrestrial carbon cycle and climate feedbacks. These feedbacks are dominated by uncertainties in soil processes, disturbance dynamics, ecosystem response to climate change, agriculture, and land-use change.

The previous Integrated Earth System Model (iESM, Collins et al., 2015) project linked CESM with GCAM, an integrated assessment (human systems) model. It found that the inclusion of climate feedbacks on the terrestrial system increased ecosystem productivity, resulting in declines in cropland extent and increases in bioenergy production and forest cover.

The ACME project includes experiments designed to better understand interactions between climate and human systems in both the carbon and water cycles. **Here we examine the interaction between the carbon cycle, climate system, and human interactions, aiming to extend the iESM results and understand how robust and consistent they are.**

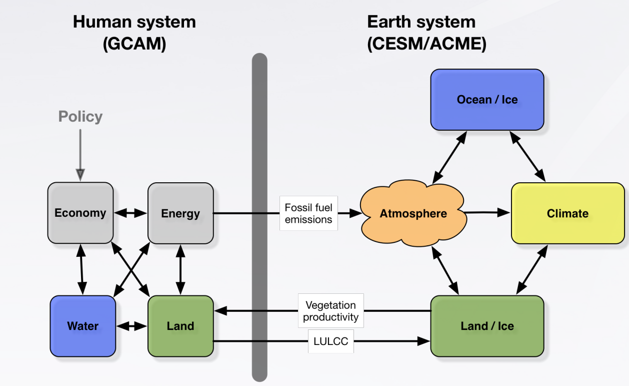

Figure 0. The iESM system. The integrated assessment model GCAM (left side) is coupled in real time with CESM (right side). This allows land cover and land use (LULCC) decisions and emissions to affect CLM, while vegetation productivity from CLM influences GCAM land use. This indirectly affects GCAM's fossil fuel emissions, which are fed back into CAM.

Approach

1. How consistent are the iESM results across different levels of climate change?

We performed additional RCP8.5 simulations using the iESM model, with and without feedbacks on the terrestrial system (**Figure 1**), to quantify differences between two RCPs.

2. What is the relative contribution of CO_2 fertilization and climate change?

We are completing a suite of experiments to isolate the effects of CO_2 fertilization, climate, and humans (**Figure 2**), allowing attribution of effects in the coupled iESM system.

3. How robust are the results across different models and methods?

We are running a suite of GCAM-only experiments using changes in ecosystem productivity derived from the CMIP5 archive and the Agricultural Model Intercomparison Project (**Figure 3**).

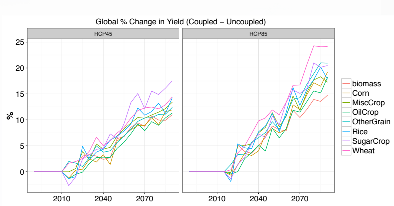

Figure 1. Comparison of iESM crop productivity changes in under RCP 4.5 (left panel) versus RCP 8.5 (right panel). In RCP 8.5, climate change effects from CLM exert even stronger effects on GCAM's crop productivities and thus land allocation decisions.

Impact

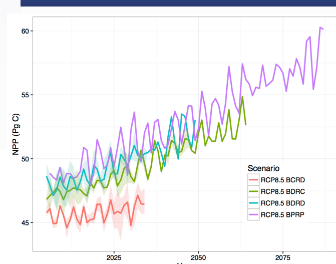

Figure 2. Fully coupled iESM runs (not yet complete) exploring CO_2 versus climate effects on net primary production (NPP) for RCP 8.5. Constant CO_2 and diagnostic (evolving) climate (BCRD); diagnostic CO_2 and fixed climate (BDRC); diagnostic CO_2 and climate (BDRD); fully prognostic (BPRP). Shading shows ensemble variability.

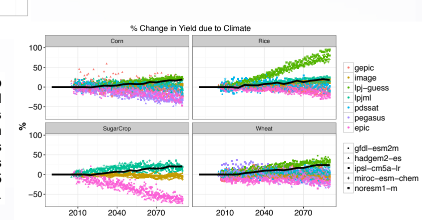

Figure 3. Comparison of crop productivity changes in iESM (black line) versus AgMIP models (color). The coupled iESM system exhibits NPP and yield changes consistent with AgMIP models as well as uncoupled CLM and CMIP5 models (not shown).

ACME Accelerated Climate Modeling for Energy

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