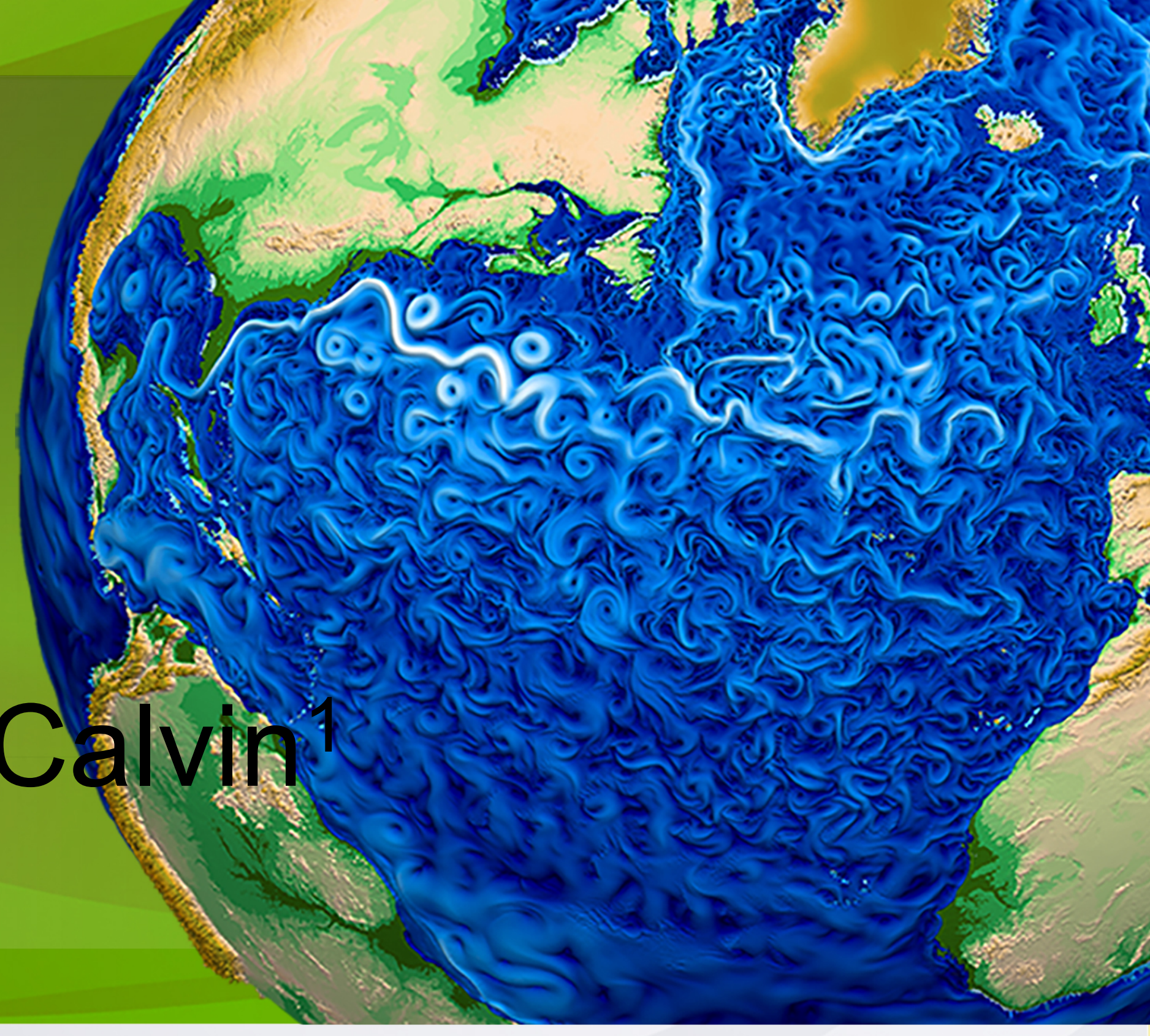
R: Effects of land model variability in a coupled ESM-IAM system



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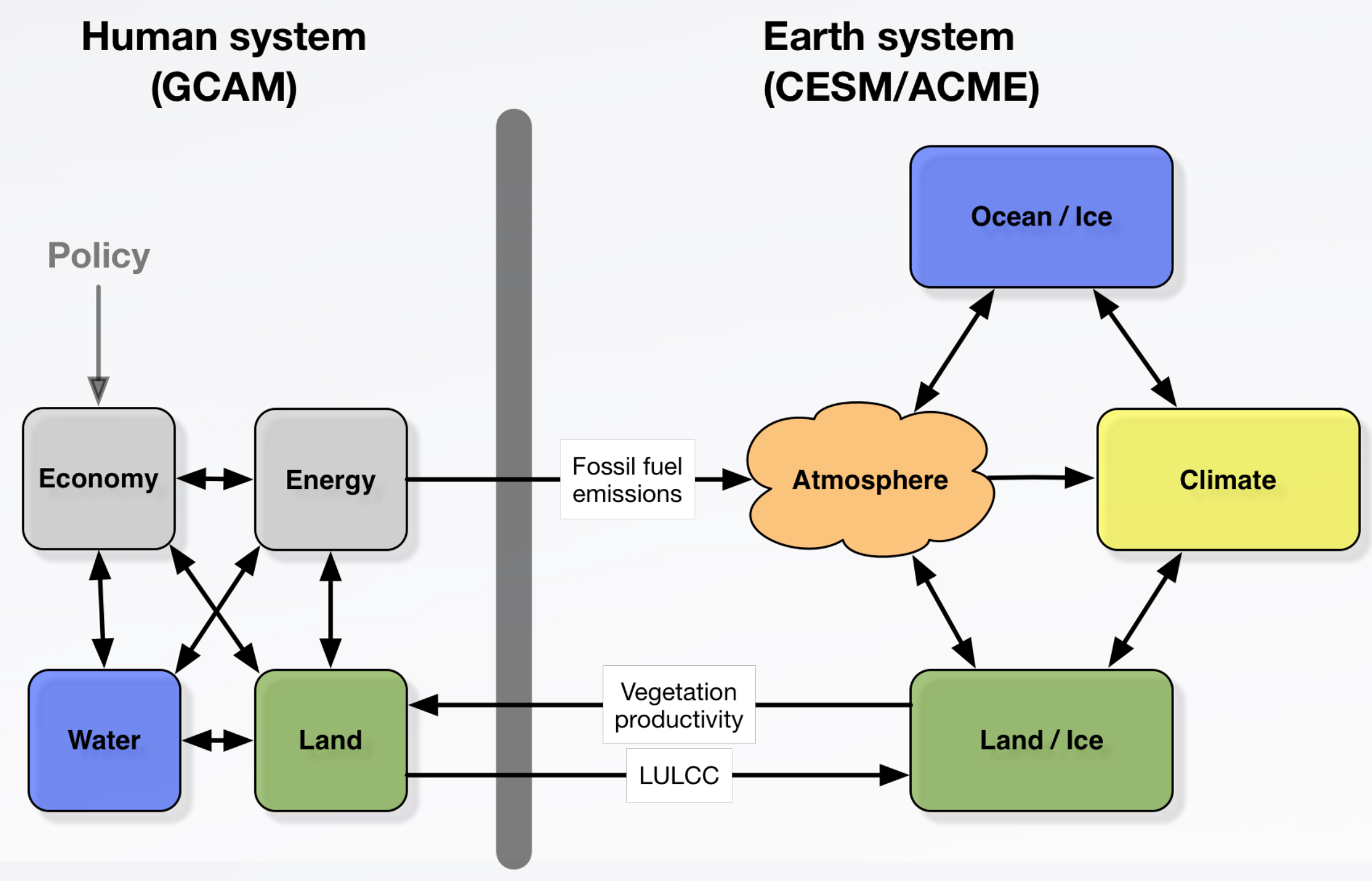
Objective

Coupling a Earth System and Integrated Assessment Model

The previous Integrated Earth System Model (iESM, Collins et al., 2015) project linked an Earth System Model (CESM) with GCAM, an integrated assessment (human systems) model. It found that climate feedbacks on the terrestrial system increased ecosystem productivity, resulting in declines in cropland extent and increases in bioenergy production and forest cover. Similarly, ACME includes experiments to understand interactions between climate and human systems in both the carbon and water cycles.

It remains unclear, however, how dependent these older iESM results are on the particular land surface model coupled to GCAM. **Here we use a one-way coupling to examine how sensitive GCAM outputs are to the choice of driving model.** This allows us to both quantify and decompose the variability in GCAM outputs across a wide range of ESM conditions.



Human system (GCAM)

Earth system (CESM/ACME)

Policy

Economy

Energy

Water

Land

Fossil fuel emissions

Atmosphere

Ocean / Ice

Climate

Land / Ice

Vegetation productivity

LULCC

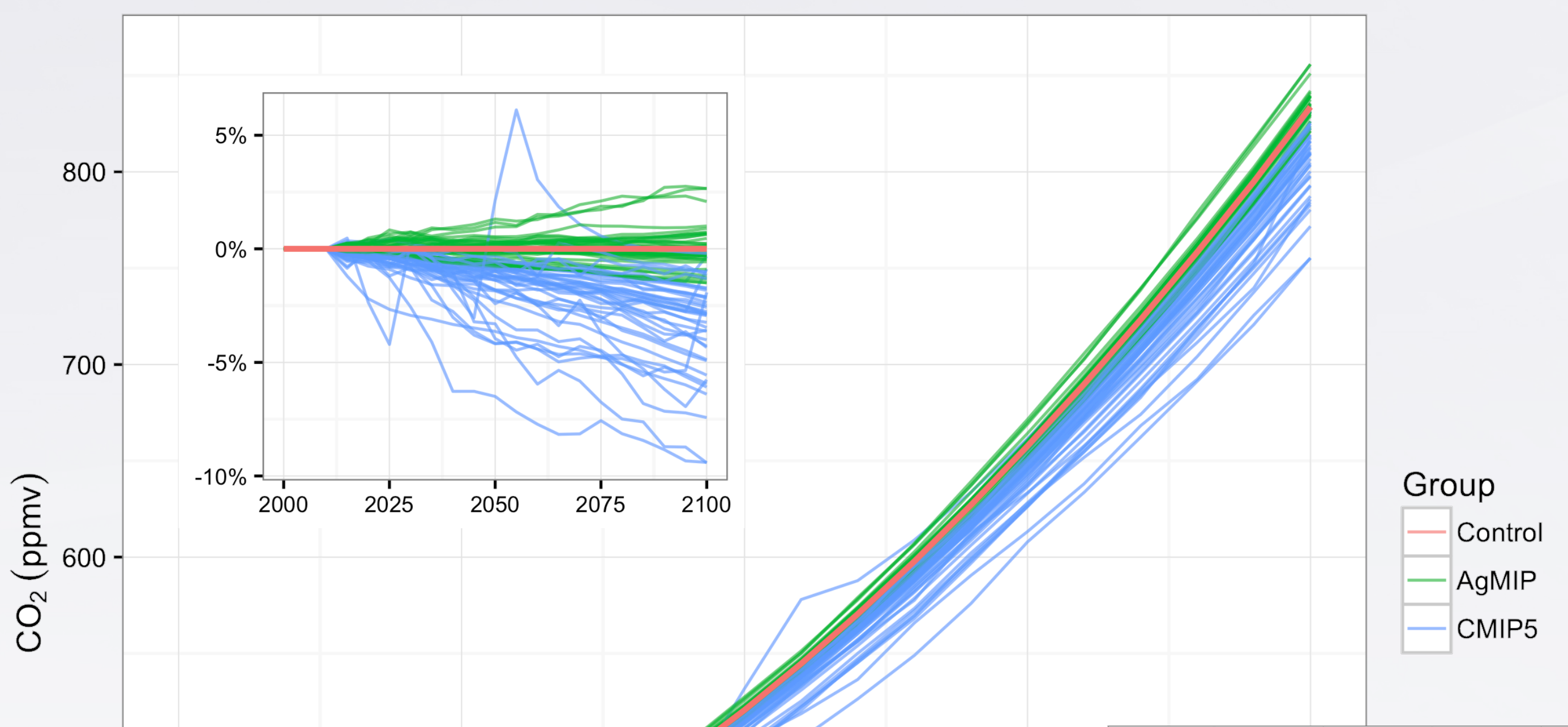


Figure 3 (left). GCAM-produced atmospheric CO2, as computed by MAGICC. Each line shows a different GCAM run driven by AgMIP and CMIP5 model outputs. Insert box shows normalized (relative to the control run) data.

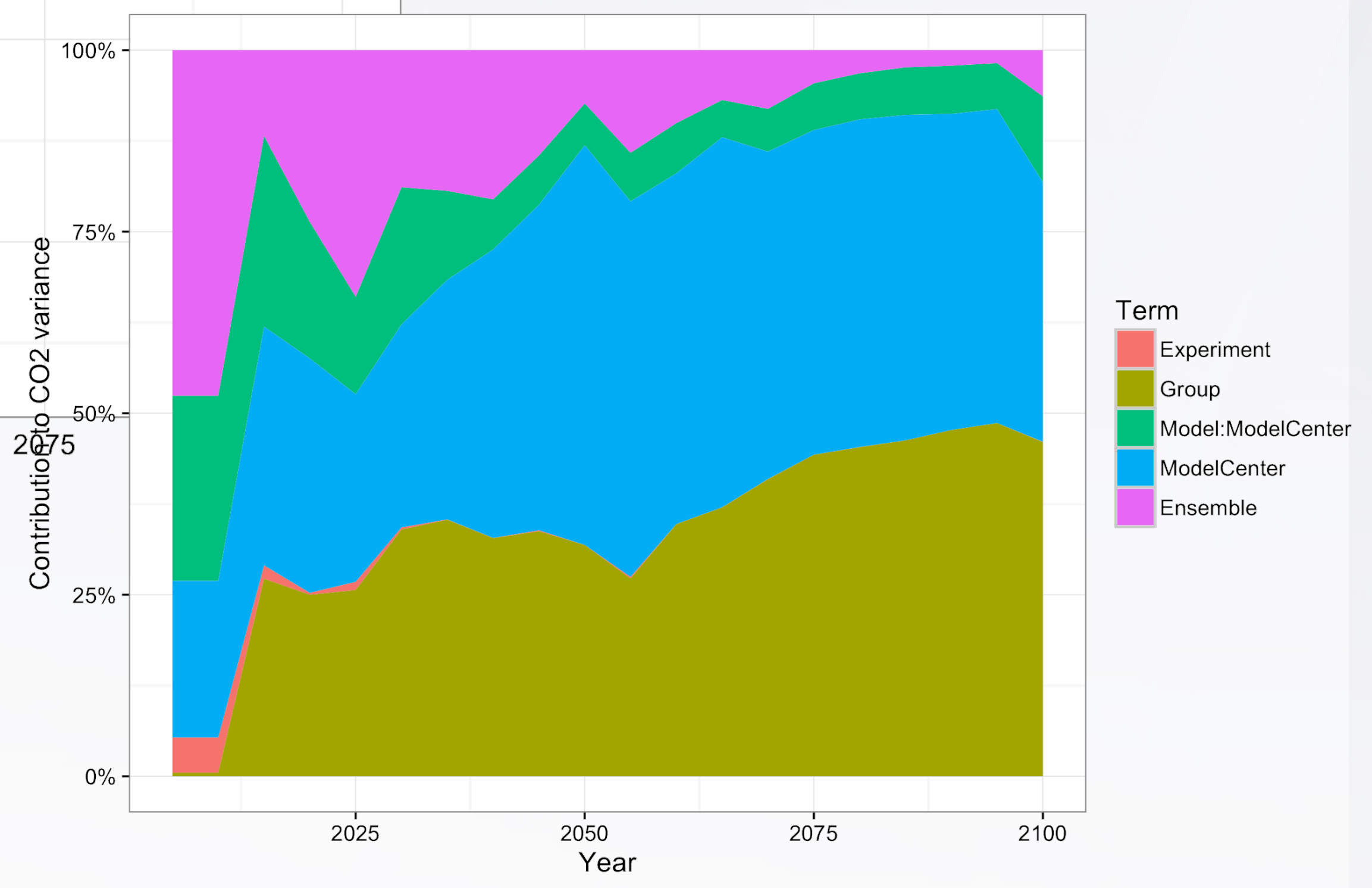


Figure 4 (right). Analysis of variance for CO2. Terms include *experiment* (concentration- vs. emissions-driven RCP 8.5); *group* (AgMIP versus CMIP5); *model* (e.g. CESM-CAM5 versus CESM-BGC); *model center* (e.g. CESM versus GISS); and CMIP5 *ensemble*.

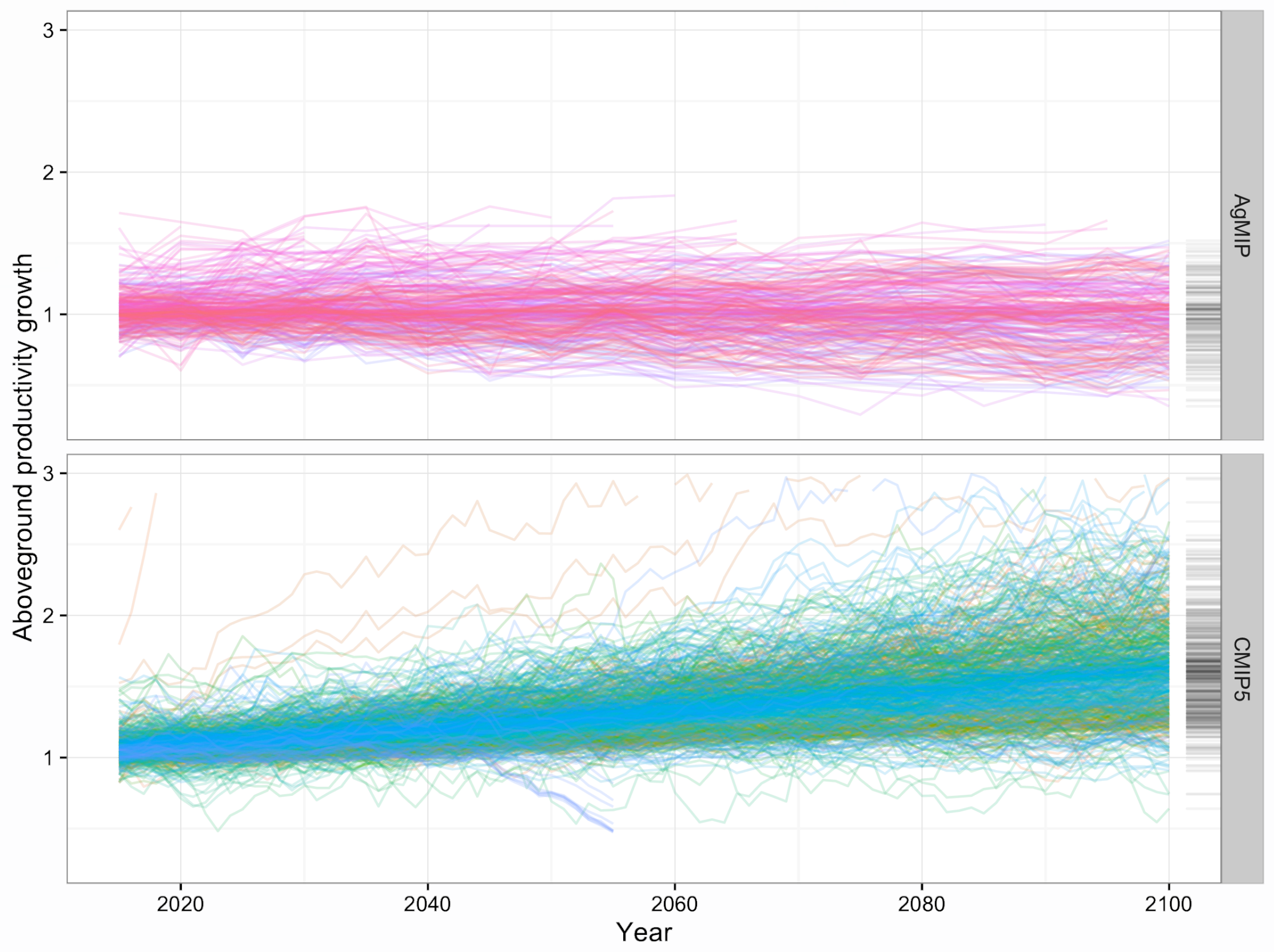
Approach

GCAM driven by CMIP5 and AgMIP model outputs

The Agricultural Model Intercomparison Project (AgMIP) provides globally gridded yield projections generated by seven different crop models, forced with five different climate models. The Couple Model Intercomparison Project (CMIP5) includes both emissions- and concentration driven ESM runs following RCP 8.5.

Yield indices computed from from the AgMIP and CMIP5 model outputs were passed into GCAM, Version 4.2. GCAM is a global integrated assessment that simulates the economy, energy system, agriculture system, land use, and the climate system in an internally consistent fashion. GCAM climate outputs are based on MAGICC.

Figure 2. Raw scalar data (aboveground productivity change, i.e. NPP change from 2005) passed into GCAM. Each line is a single model, ensemble, and experiment combination for AgMIP (top panel) and CMIP5 (bottom).

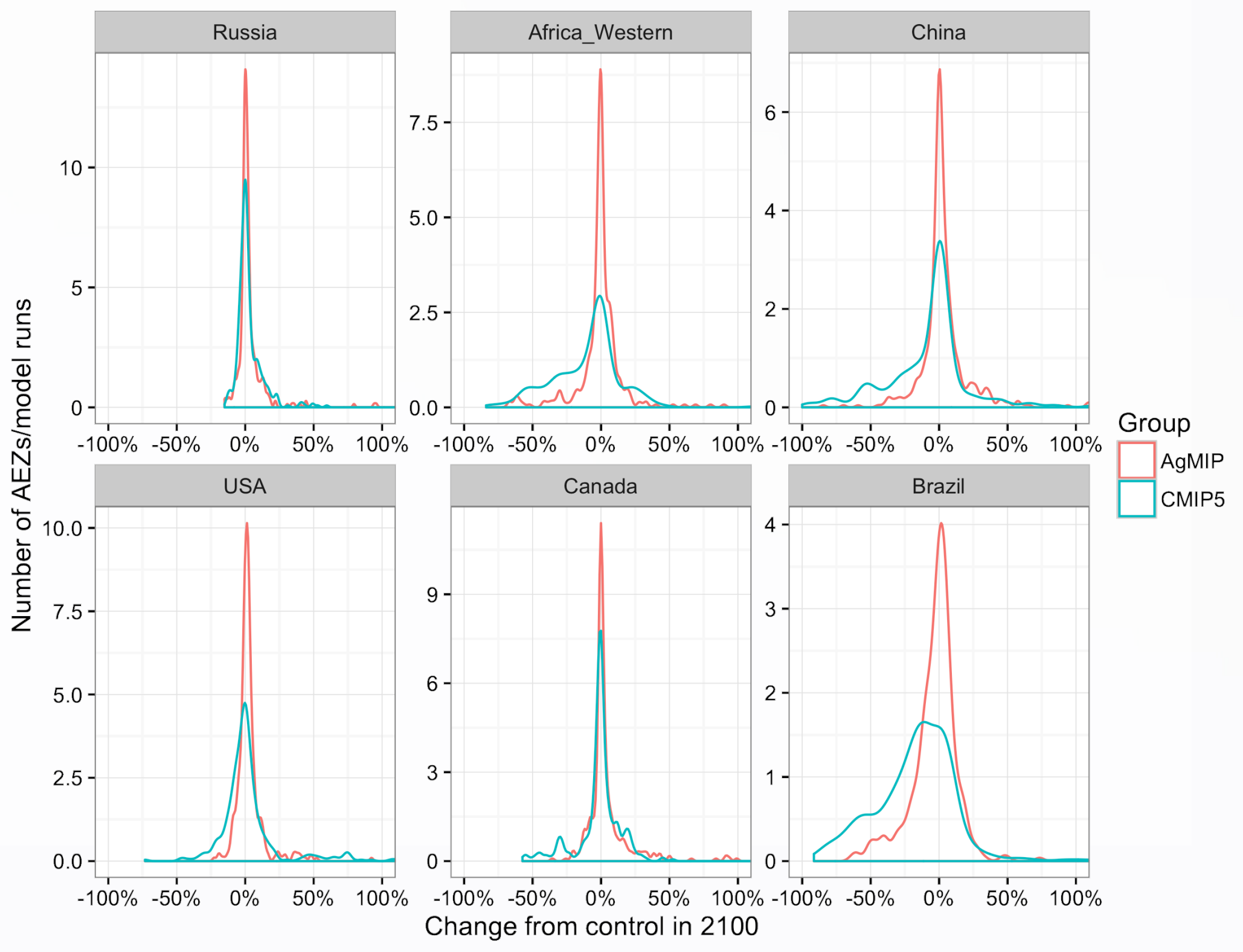


Impact

Significant changes in GCAM agricultural land allocation

GCAM consistently reallocated land from agriculture to other land-use types when driven by CMIP5 outputs. This is consistent with the CMIP5 models' increasing C storage, which allows GCAM to produce the same amount of food in smaller land areas. This effect varied considerably at the regional scale: tropical regions such as Brazil, west Africa, and southern China exhibited large allocation shifts (Figure 5); agricultural gains and losses in the the U.S. and Canada were relatively symmetrically distributed; and Russia's land allocation to agriculture expanded in many model runs. In all cases, AgMIP-driven runs clustered more evenly and tightly around the no-change control case.

Figure 5. Regional agricultural land cover changes in 2100. Each panel shows the distribution of 2100 agricultural area in GCAM driven by AgMIP and CMIP5 runs–for each model, experiment, and agro-ecological zone–compared to the control.



ACME Accelerated Climate Modeling for Energy

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