The role of carbon cycle feedback uncertainty in future concentration and warming outcomes

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Three main uncertainties in future warming

Emissions

CO2 emissions in CMIP6 scenarios

- Historical
- SSP1-1.9
- SSP1-2.6
- SSP4-3.4
- SSP5-3.4OS
- SSP2-4.5
- SSP4-6.0
Three main uncertainties in future warming

Climate Sensitivity

CMIP6 models show a wider range of climate sensitivity

- **IPCC AR5 Range**: 1.5
- **CMIP5 models**: 2.1
- **CMIP6 models**: 1.8, 4.7, 5.6
Three main uncertainties in future warming

Carbon cycle feedbacks
Standard future warming projections ignore carbon cycle feedback uncertainties

Warming by scenario in current CMIP6 model runs
For currently available runs, from 1880-1900 to 2090-2100.
Carbon cycle feedbacks in CMIP

- MAGICC used to translate emission scenarios into fixed concentrations/forcings.
- MAGICC uses results of prior C4MIP efforts to provide a best-estimate of carbon cycle feedbacks.
- These estimates both lag current models and exclude large uncertainties.
Accounting for carbon cycle feedback uncertainties

Two readily available modeling efforts:

• C4MIP
  – multiple models participating, but an ensemble of opportunity with one estimate per model.

• PPE
  – one climate model (HadCM3C) with a wide range of possible parameters for the land and ocean biogeochemical processes
  – Constrained analysis to select only those variants (27 out of 57) that matched historical observations.
Limited emissions scenarios available

- C4MIP runs only done for RCP8.5 (which is problematic).
- PPE runs done for RCP2.6, RCP8.5, and SRES A1B.
Estimating carbon cycle feedback uncertainties by scenario

CO2 concentrations from carbon-cycle feedback experiments

Using estimates from C4MIP and the HadCM3 PPE experiments.
Change in CO2 concentrations when including carbon-cycle feedback uncertainties

Using estimates from C4MIP and the HadCM3 PPE experiments.
Estimating impacts on future warming

• Used the range of carbon cycle feedback estimates from C4MIP and the PPE.

• Perturbed each CMIP5 2100 model warming estimate using the difference from prescribed RCP concentrations and model TCR.
Warming estimates based on carbon-cycle feedback experiments

CMIP5 global mean temperature changes with carbon-cycle feedback uncertainty based on C4MIP and the HadCM3 PPE experiments.

Degrees C warming from 1861-1899 to 2091-2100

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<tr>
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<th>CMIP5</th>
<th>C4MIP</th>
<th>PPE</th>
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Results

• Under the highest estimate of carbon cycle feedbacks in the literature, a more current-policy RCP6.0 world could yield concentrations consistent with a worst-case RCP8.5 scenario.

• Including carbon cycle feedback uncertainties could result in up to 25% more warming than in the main IPCC projections.

• Uncertainties are highly non-symmetric; much more risk on the high-end in current estimates.

• Current models (CMIP5 C4MIP, PPE) still miss important factors permafrost thaw, nitrogen cycle changes and dynamic vegetation.