Scenarios studying Climate Engineering

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- Model scenarios planned together with the SDWG, using the strategic geoengineering approach

- Model scenarios planned to run with CESM2 for CMIP6: GeoMIP

- What are addition/new model scenarios of interest to the community?
Sudden Termination Experiment (SDWG)

- Termination results in very quick climate change
Sudden Termination Experiment

Can geoengineering deal with “short-term” interruption?
How large will the effect be on temperature, and climate variability?
Sudden Termination Experiment

- 9 Experiments over an average 10 years
- 3 different periods of termination, 3 ensemble members each
Tier1 CMIP6 Scenarios for GeoMIP

Very useful experiment to understand the larger scale response of global solar dimming. (1% ramp up experiment also proposed)

Kravitz et al., 2015
Tier1 CMIP6 Scenarios for GeoMIP

As difficult as G3 experiment. Will be possibly performed using the feedback strategy. Would a lower scenario make more sense?

Kravitz et al., 2015
Tier1 CMIP6 Scenarios for GeoMIP

G7cirrus (reducing cirrus clouds optical depth)

Kravitz et al., 2015
Tier1 CMIP6 Scenarios for GeoMIP

Other Experiments:

<table>
<thead>
<tr>
<th>G1ocean-albedo</th>
<th>Balance $4 \times \text{CO}_2$ via ocean albedo increase</th>
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<tbody>
<tr>
<td>G2</td>
<td>Balance $1% \text{CO}_2$ increase per year via solar irradiance reduction</td>
</tr>
<tr>
<td>G3</td>
<td>Keep TOA radiative flux at 2020 levels against RCP4.5 via stratospheric sulfate aerosols</td>
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<tr>
<td>G4</td>
<td>Injection of 5 Tg SO$_2$ into lower stratosphere per year</td>
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<tr>
<td>G4cdnc</td>
<td>Increase CDNC (cloud droplet number concentration) in marine low clouds by 50% against a background of RCP4.5</td>
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<tr>
<td>G4sea-salt</td>
<td>Inject sea salt aerosols into tropical marine boundary layer to achieve ERF* of $-2.0 \text{Wm}^{-2}$ against a background of RCP4.5</td>
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<tr>
<td>G5</td>
<td>Identical setup as G3 but using sea salt injection into marine low clouds (IMPLICC experiment; named SALT in Niemeier et al., 2013)</td>
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Tier2 CMIP6 Scenarios for GeoMIP
(these are currently not a high priority for us)

Time-slice Experiments to all Tier 1 experiments with fixed SSTs

G4SSA prescribed aerosol experiments; use H2SO4 injections

GeoLandAlbedo: Increase albedo by 0.1 for all urban and agricultural areas

Kravitz et al., 2015
Tier2 CMIP6 Scenarios for GeoMIP

Overshoot Experiment: CESM1 Experiment

- Example of temporary Solar Radiation Management used as a method to reduce worst impacts of climate change, avoid tipping points:
  - requires 160 years of injections

*Tilmes et al., 2016*

Combined Mitigation and Solar Radiation Management Approach

-> Differences between RCP2.6 and Geoengineering could be identified
Results: Impact on Precipitation and Aridity

% Changes compared to 1986-2005

20% significance level

Global Land

RCP8.5
Overshoot
Geo 2.5
Geo 2.0
RPC2.6
Discussion

• What geoengineering-related questions are we would be interesting to pursue using CESM?

• How could CESM be used to investigate climate impacts unique to geoengineering?

• What are the priorities in terms of scenarios?

• What developments are needed for specific studies

• Who is interested in pursuing geoengineering research involving CESM? How would this research look like?
Previous Experiments
GeoMIP (Geoengineering Model Intercomparison Project)

Well defined sensitivity experiments G1-G4, based on CMIP5 experiments to study the impact of solar radiation management (SRM) on the Earth’s system.

*Initiators:* Ben Kravitz, Alan Robock, Olivier Boucher, Hauke Schmidt, Karl Taylor, Georgiy Stenchikov, Michael Schulz

**G1, G2:** balancing incoming LW forcing with reduced solar constant

**G1:** Baseline: CMIP 4xCO₂, *Geoeng.*: radiative forcing on top of the atmosphere is balanced (model specific based on the planetary albedo, could effects etc): **3.5-5.0% reduction necessary**

**G2:** Baseline: CMIP 1% /yr CO₂ increase, *Geoeng.*: as G1, derived forcing from G1 experiment, termination after 50 years
GeoMIP (Geoengineering Model Intercomparison Project)

Well defined sensitivity experiments G1-G4, based on CMIP5 experiments to study the impact of solar radiation management (SRM) on the Earth’s system.

**G3, G4:** balancing incoming LW forcing with stratospheric aerosol injection

**G3: Baseline:** RCP4.5, **Geoeng.:** stratospheric aerosols in 2020 is increased gradually to balance the LW forcing, equatorial injection, termination after 50 years

**G4: Baseline:** RCP4.5, **Geoeng.:** fixed aerosol injection of 5 Tg SO$_2$ per year, termination after 50 years

Technical limitations of sulfure injection have been not addressed
GeoMIP (Geoengineering Model Intercomparison Project)

Well defined sensitivity experiments G1-G4, based on CMIP5 experiments to study the impact of solar radiation management (SRM) on the Earth’s system.

**G3, G4**: balancing incoming LW forcing with stratospheric aerosol injection

**G3**: Baseline solar: RCP4.5, Geoeng.
As G3 but balance is achieved with solar reduction, rather than sulfate aerosols. Anthropogenic radiative forcing is taken from the RCP4.5 experiment setup.
Next GeoMIP experiments: Sea Spray Experiments

Kravitz et al., submitted: Sea Spray Geoengineering Experiments in (GeoMIP): Experimental Design and Preliminary Results

1. **G1ocean-albedo**: Baseline: CMIP5 4xCO₂, Geoeng.: effective radiative forcing is balanced by an increase in ocean albedo, after 50 yrs termination of albedo reduction

2./3. **Baseline**: CMIP5 RCP4.5

2. **G4cdnc**: 50% increase of cloud droplet number concentration in marine low clouds, cessation after 50yrs

3. **G4 sea alt**: 100 Tg/yr of sea salt emission increase into marine boundary layer (30S-30N), cessation after 50yrs