Climate Engineering Research with WACCM

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Earlier Approaches

Demonstrated ability to counteract global mean temperatures

Examine Impacts

Dim Sun, Prescribe Aerosols, or Inject SO₂

Unintended Side Effects / Risks:
- Overcooling in the Tropics
- Warmer temperatures in high latitudes
- Reduced precipitation
- Shifts in rain patterns
- Arctic sea-ice still melting

Kravitz et al. 2016

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Our Approach

**Goals:**
1. Global temperature
2. Equator-to-pole temperature gradient
3. Pole-to-pole temperature gradient

*Approach demonstrated with solar dimming in CAM, Kravitz et al. 2016*
Whole Atmosphere Community Climate Model, version 5

Atmospheric Chemistry
158 solution species, 117 photolysis reactions, 332 other reactions

Prognostic Aerosols

Mills et al. 2017 (submitted)

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System Identification

Single Injection Matrix Experiments

WACCM Control:
• RCP8.5 Scenario

Matrix Simulations:
• Inject in Year 2040
• 10 year simulations
• Constant injection amount every year

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System Identification

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Tilmes et al. 2017 (revised)

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Combined Injections

- Response is nonlinear, but
- Nonlinearities of order 20%; can be managed using feedback

MacMartin et al. 2017 (submitted)

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Implementation of Feedback in WACCM

1. Run WACCM for 1 year
2. Run feedback algorithm to determine amount and locations of injection
3. Calculate deviation from objectives
Feedback Simulation with WACCM

Kravitz et al. 2017 (under revision)
Feedback Simulation with WACCM

RCP8.5 (2080-2099) – (2010-2030)

Annual

Feedback

Kravitz et al. 2017 (under revision)
September Arctic Sea-Ice

Recovery of September Arctic Sea-Ice due to cooler Temperatures in high northern latitudes

Kravitz et al. 2017 (under revision)
Geoengineering Large Ensemble

To build confidence and identify regional impacts and side effects

• **RCP8.5 2010-2030** (reference period):
  20 ensemble members

• **RPC8.5 2010-2100**
  3 ensemble members

• **Feedback simulation**: 2020-2100:
  20 ensemble members branching from 20 control experiments in 2020
Geoengineering Large Ensemble

Tilmes et al. 2017 (in preparation)

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Key Outcomes

Tilmes et al. 2017 (in preparation)

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Stratospheric T Changes

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All simulations will be available to community

Help us evaluate risks & side effects!

Questions:
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Needed Injections

Tilmes et al. 2017 (in preparation)