Soil Moisture-Climate Coupling under Model Simulations of Solar Geoengineering

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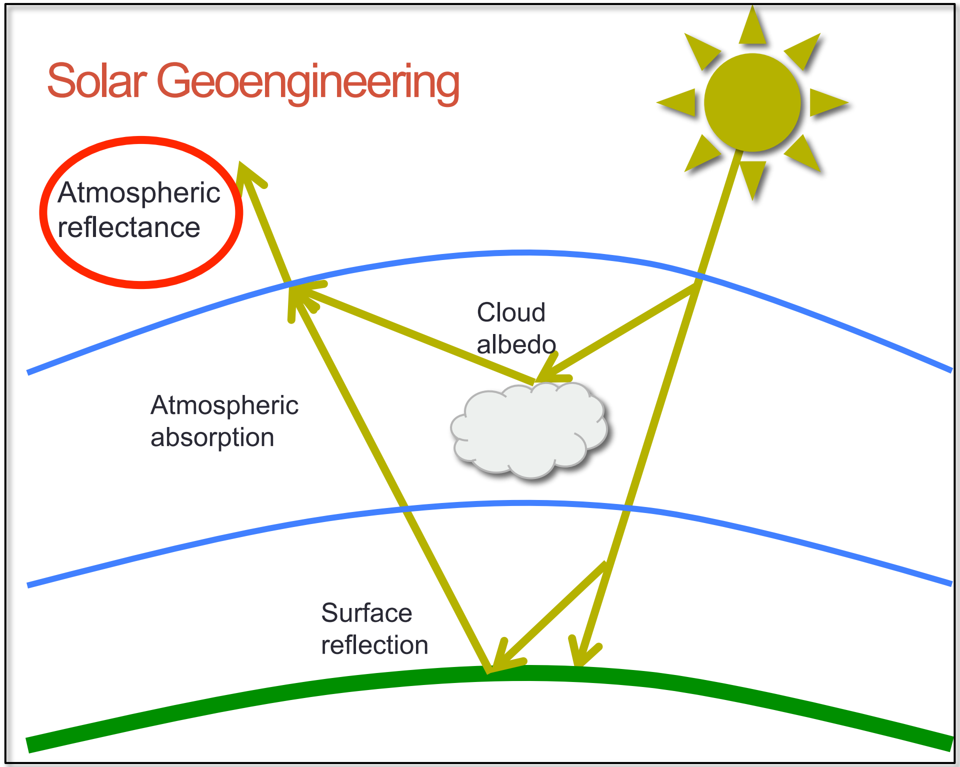
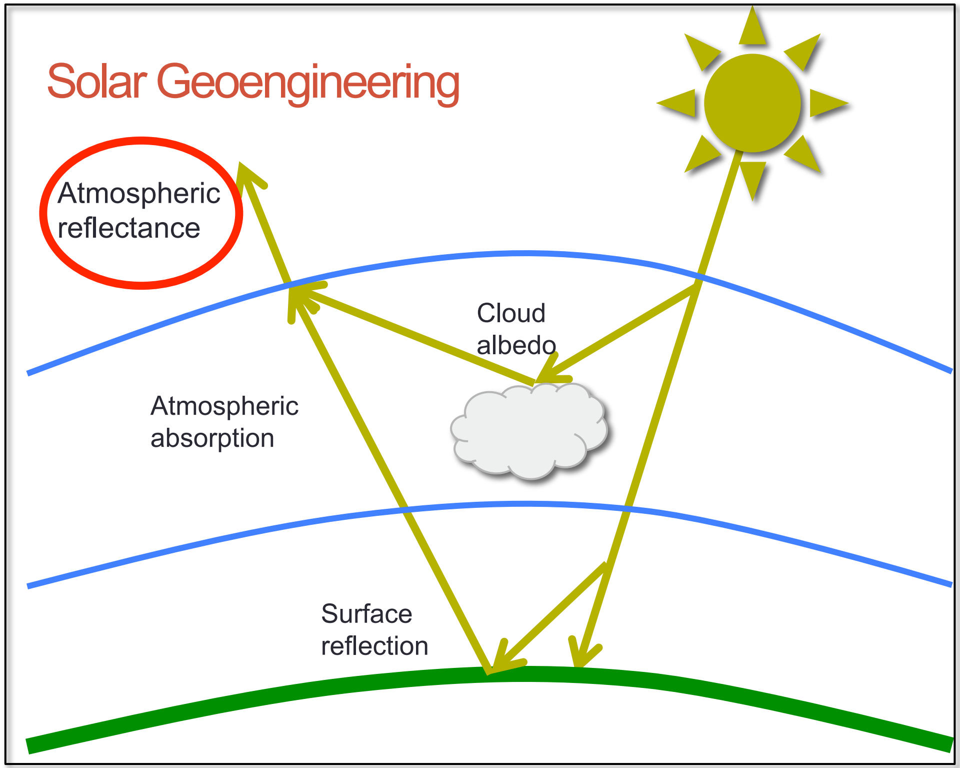
Outline

1. Introduction to Solar Geoengineering; Previous Work
2. Soil Moisture-Climate Coupling
3. Description of Model Simulations
4. Preliminary Results



Adapted from The Royal Society



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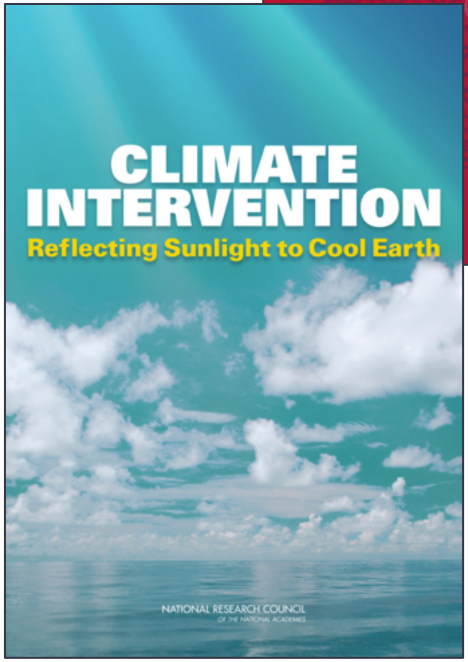


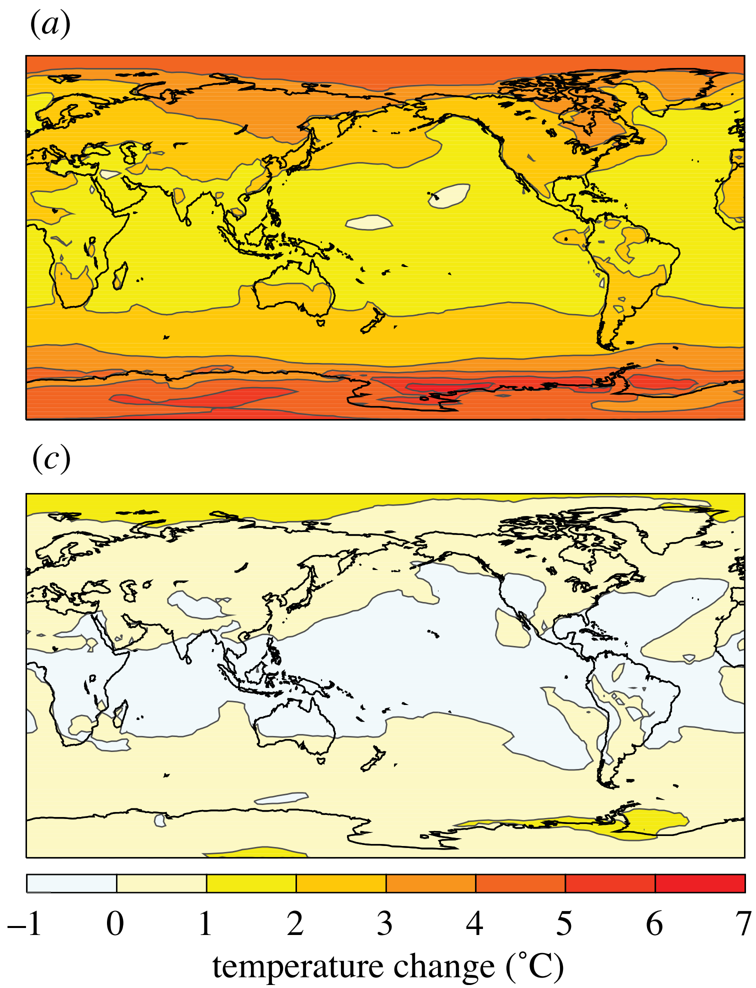
- Solar geoengineering has the potential to help manage impacts of climate change but not enough is known about the unintended side effects.

Potential of Solar Geoengineering

Caldeira & Wood (2008): 1.8% reduction in top of the atmosphere solar radiation compensates roughly for doubled CO_2 induced temperature changes.

$2xCO_2$

$2xCO_2$ & -1.8% solar



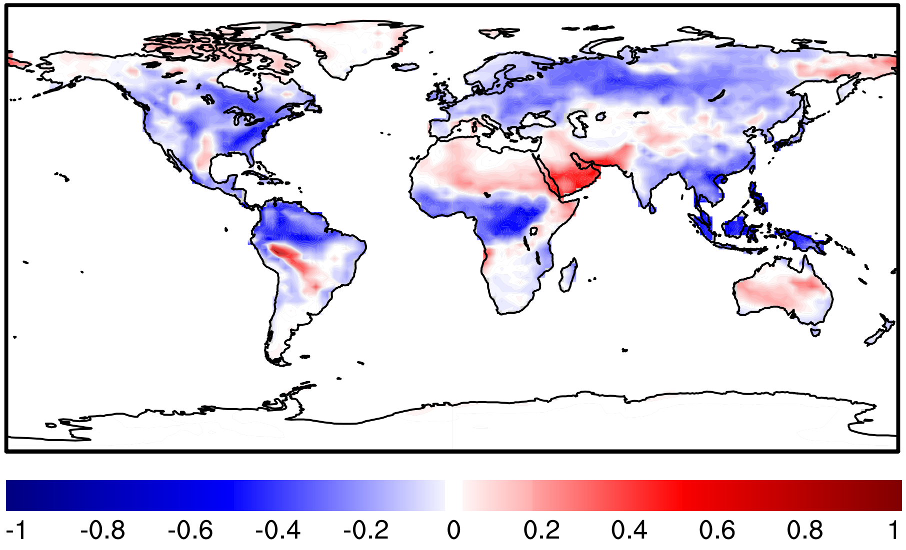
Model: CAM3; doubled CO_2 concentration relative to present-day; 1.8% reduction in solar constant

Showing **annual mean** changes relative to **present-day**.

Impacts on Terrestrial Water Cycling

Dagon & Schrag (2016): Evapotranspiration over land decreases under model simulations of solar geoengineering.

2xCO_2 &
-2% solar



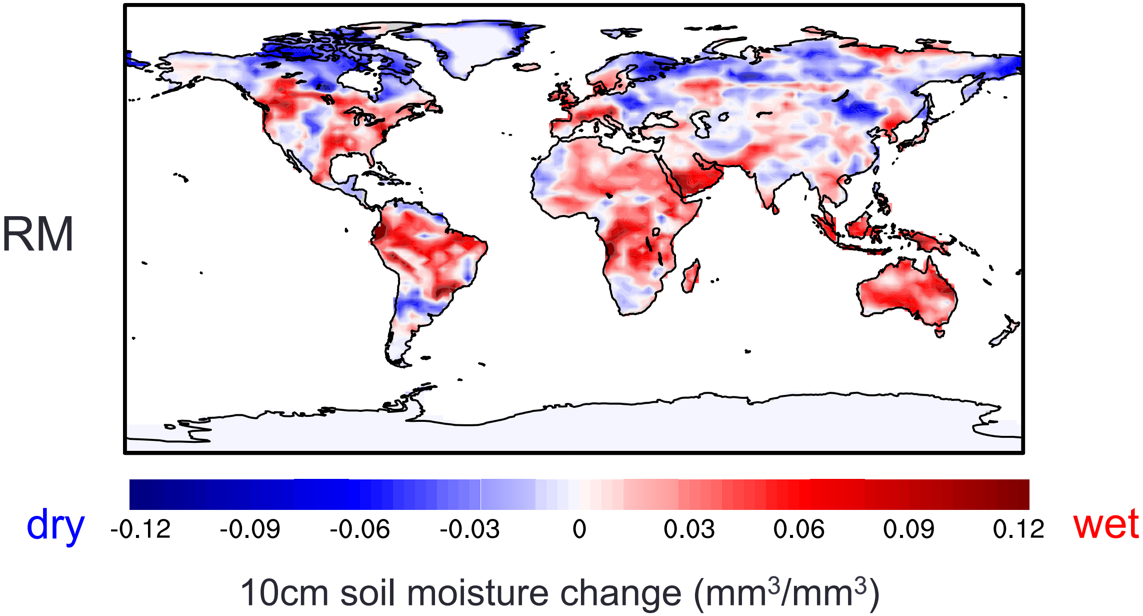
Model: CAM4-CLM4; doubled CO_2 concentration relative to present-day; 2% reduction in solar constant

Showing **boreal summer (JJA)** changes relative to **present-day**.

Impacts on Terrestrial Water Cycling

Dagon & Schrag (2016): Soil moisture largely increases as evapotranspiration decreases.

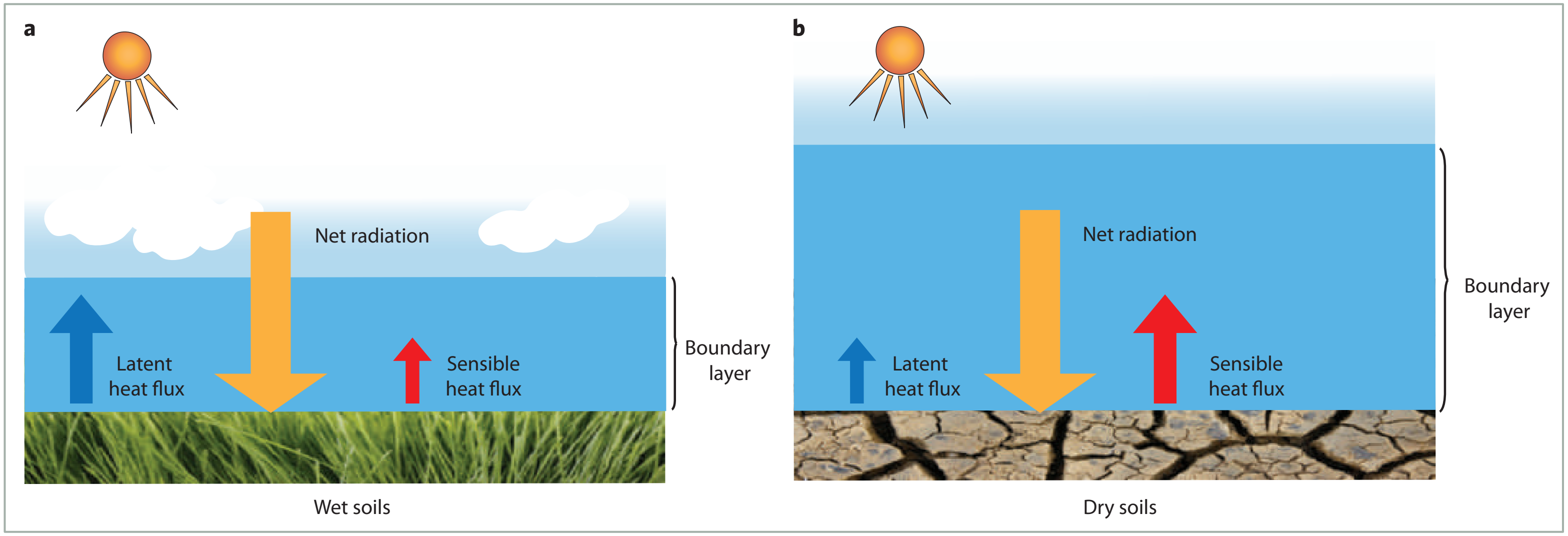
$2xCO_2$+2%SRM



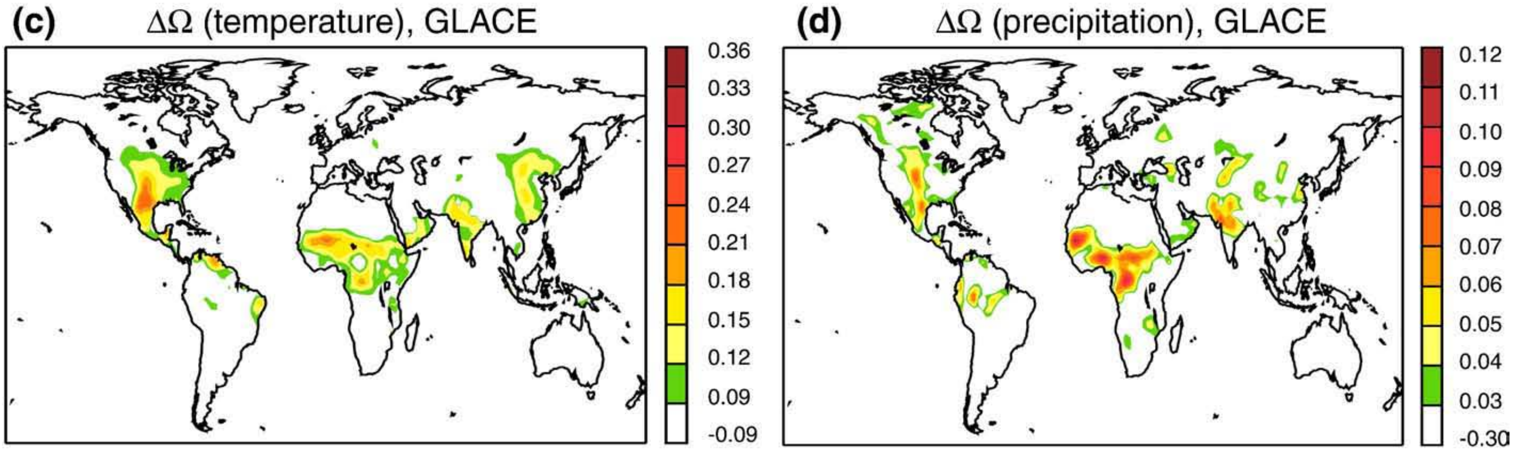
Model: CAM4-CLM4; doubled CO_2 concentration relative to present-day; 2% reduction in solar constant

Showing **boreal summer (JJA)** changes relative to **present-day**.

Soil Moisture-Climate Coupling

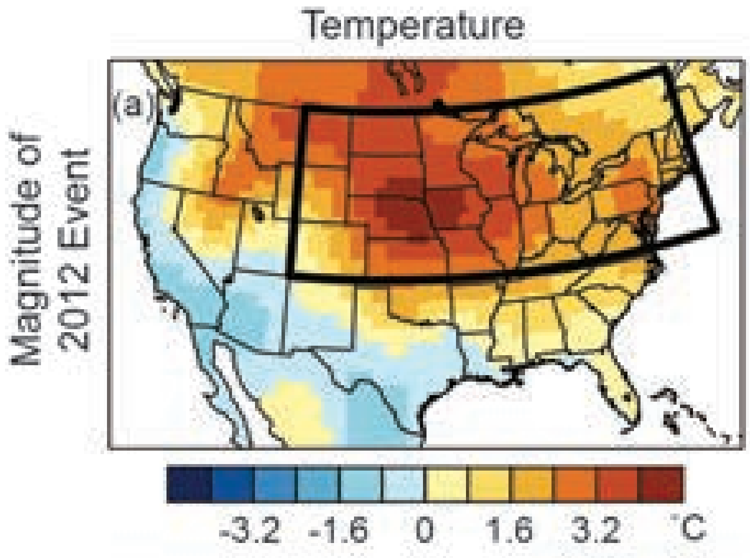


Alexander 2011



Seneviratne et al. 2010, after Koster et al. 2004, 2006

July 2012 U.S. Heat Wave

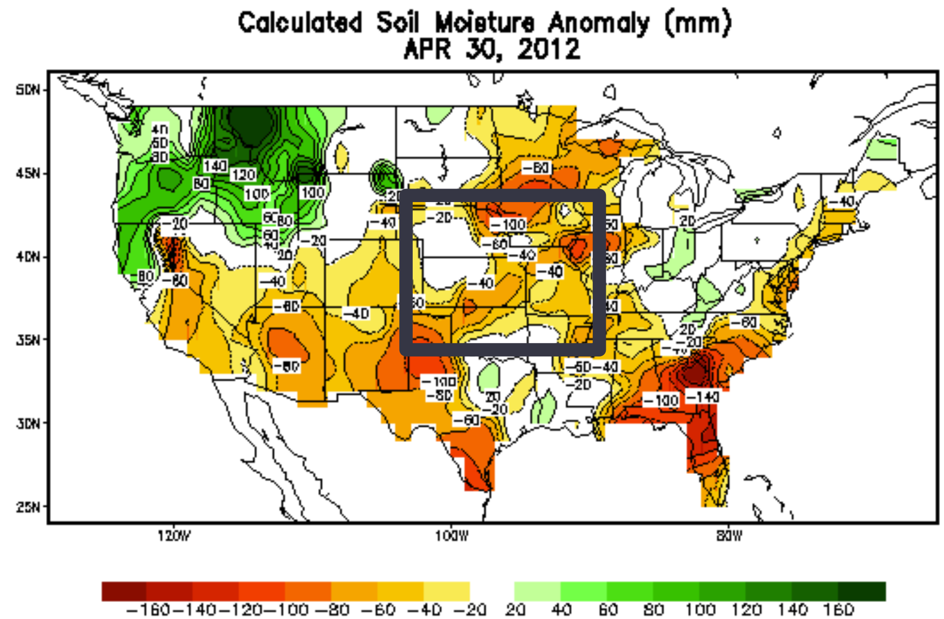


July 2012 was the warmest month on record for contiguous U.S.

Figure: Diffenbaugh & Scherer (2013)

What did the central U.S. soil moisture anomaly look like in April 2012?

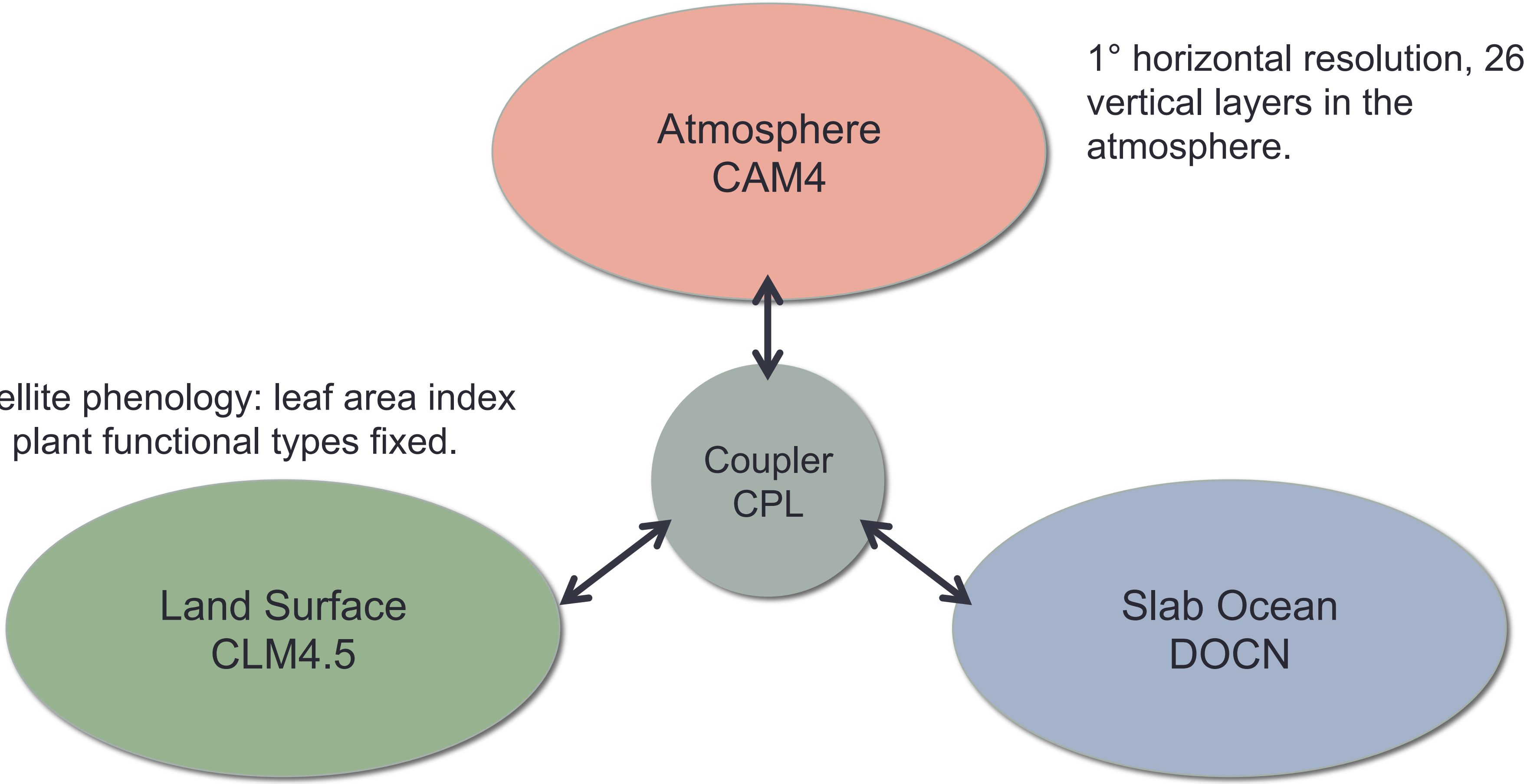
10-25% reduction with respect to 1979-2000 climatology.



Source: NOAA CPC

How does solar geoengineering impact U.S. mid-latitude heat waves?

CESM 1.2

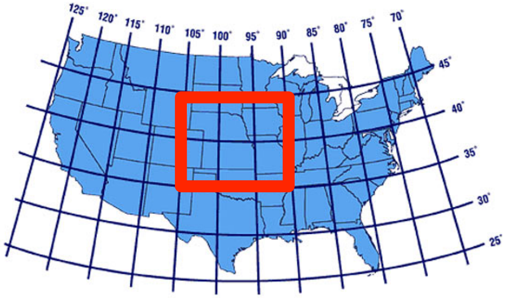


1° horizontal resolution, 26 vertical layers in the atmosphere.

Satellite phenology: leaf area index and plant functional types fixed.

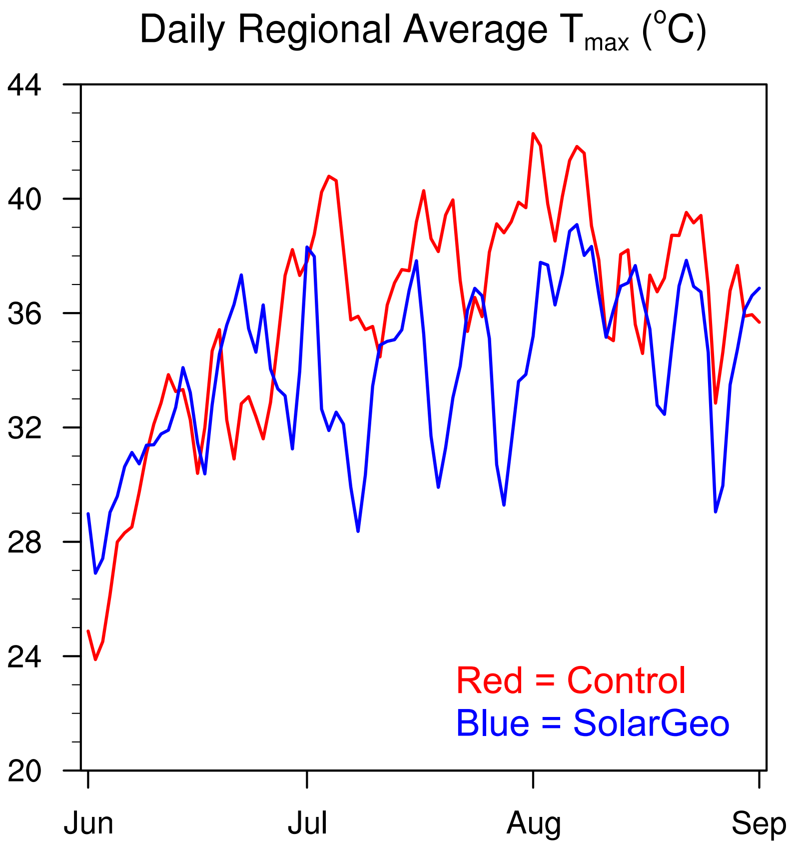
Simulation design

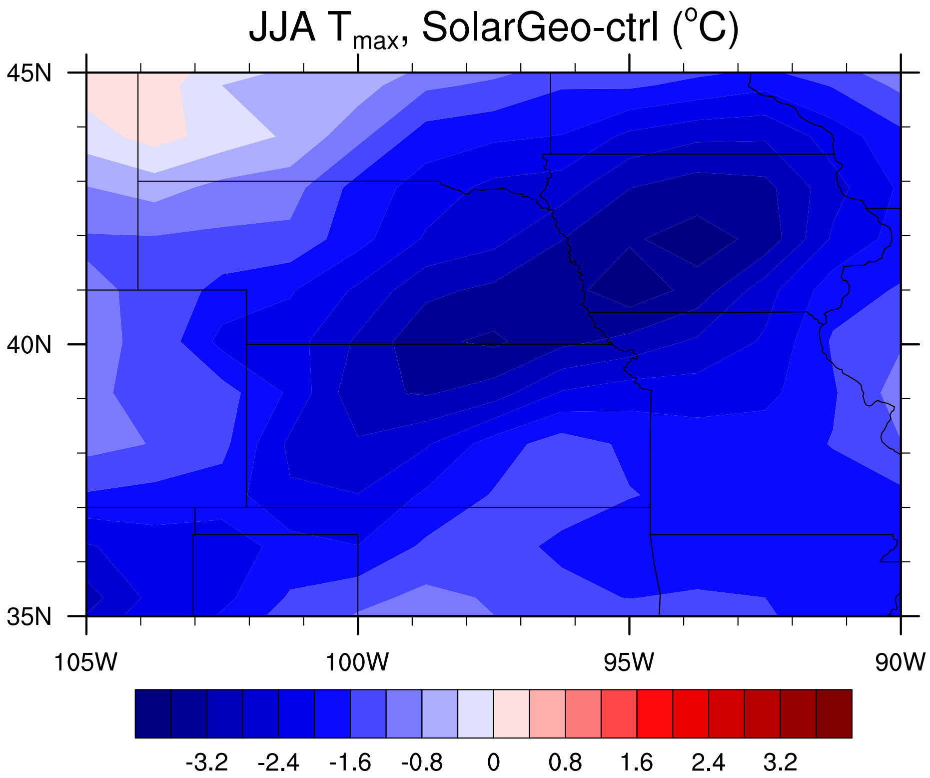
- Initialize the model with a 5-year, 3-month spin up ending March 31
- Two simulations run for 5 months, April through August:
    1. Control (CO_2 = 367 ppm)
    2. SolarGeo (CO_2 = 734 ppm, solar constant decreased by 2.2%)
- April 1 soil moisture reduced by 5% in the central U.S. (35-45°N, 105-90°W) for both simulations



➢ What is the resulting summertime temperature response?

Preliminary Results

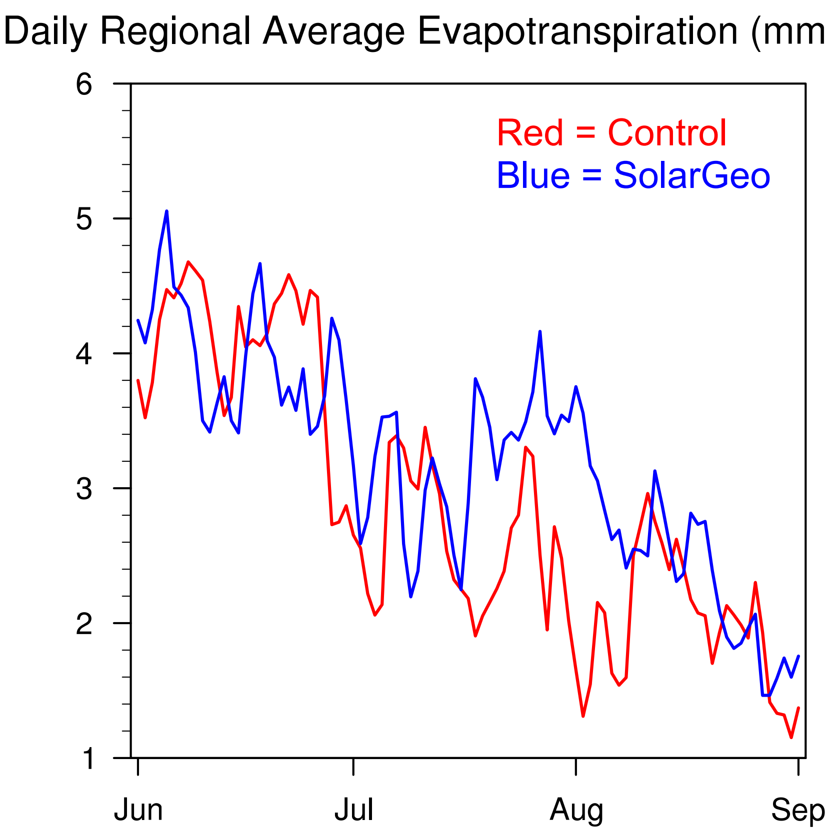


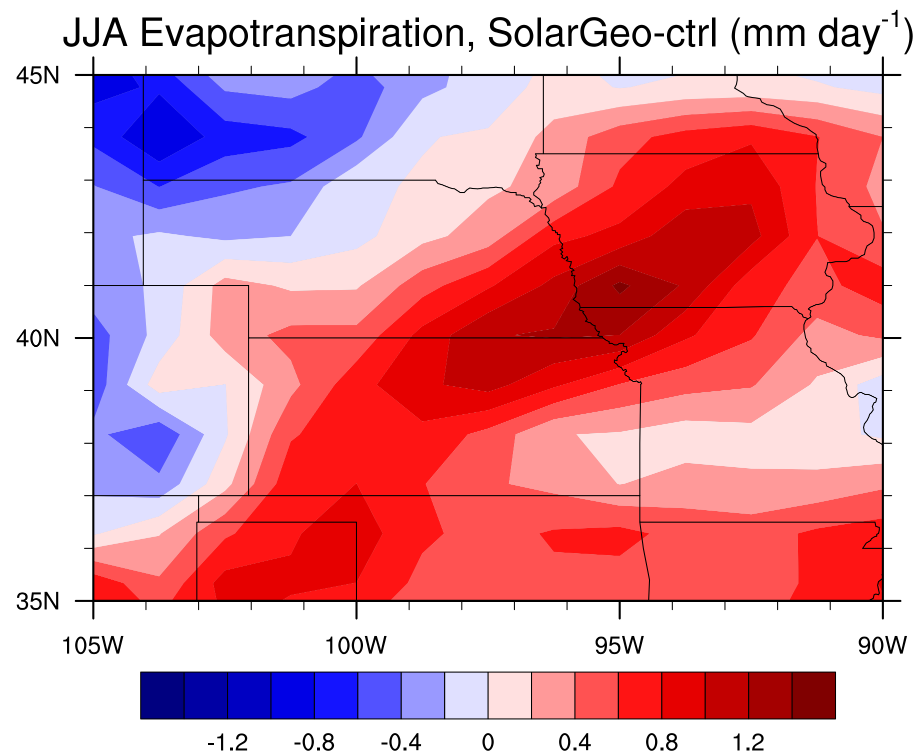


Large heat wave present in control simulation (35 consecutive days with $T_{max} \geq 35°C$)

Regional average difference, SolarGeo-ctrl = -1.91°C

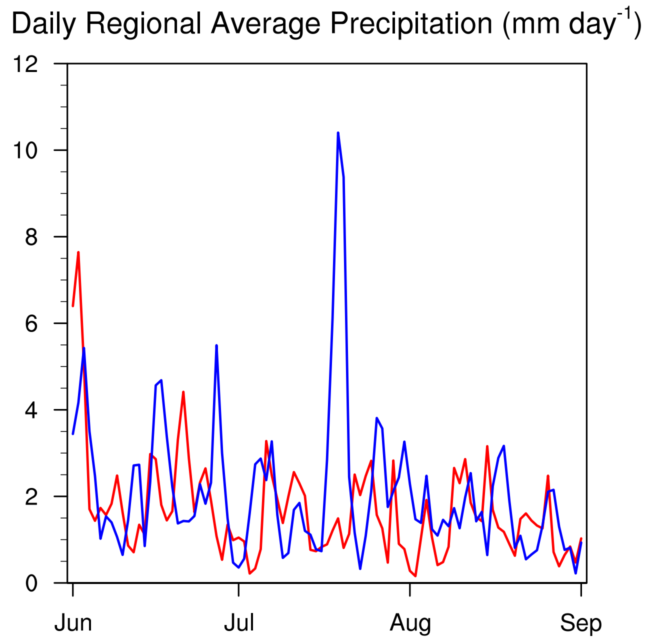
Preliminary Results

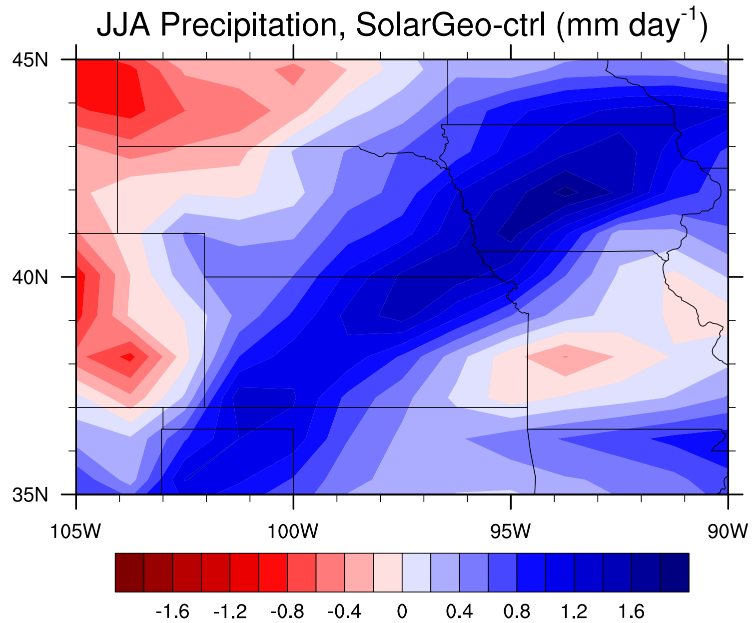


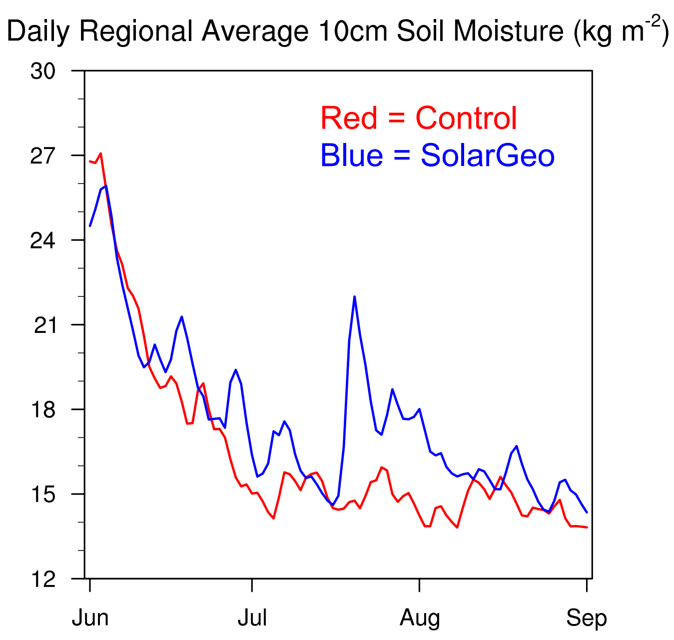


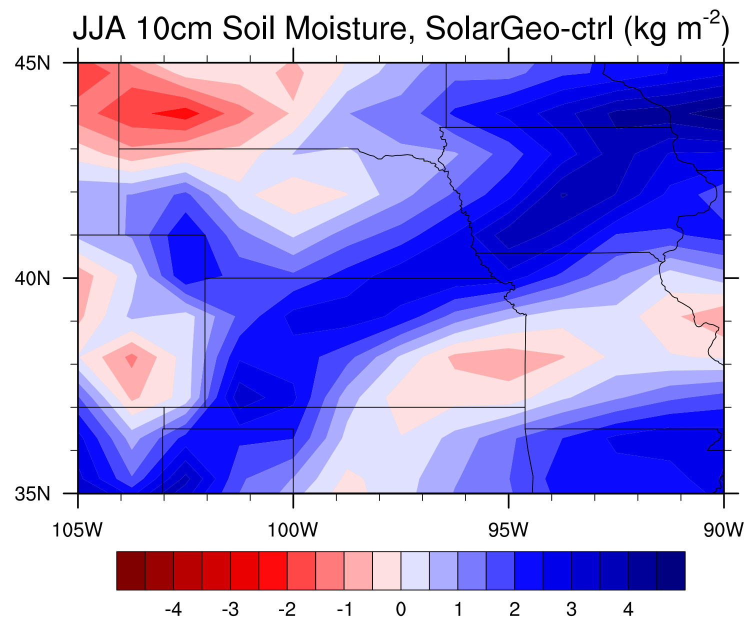
Increase in ET under SolarGeo, especially during the heat wave period in late July.

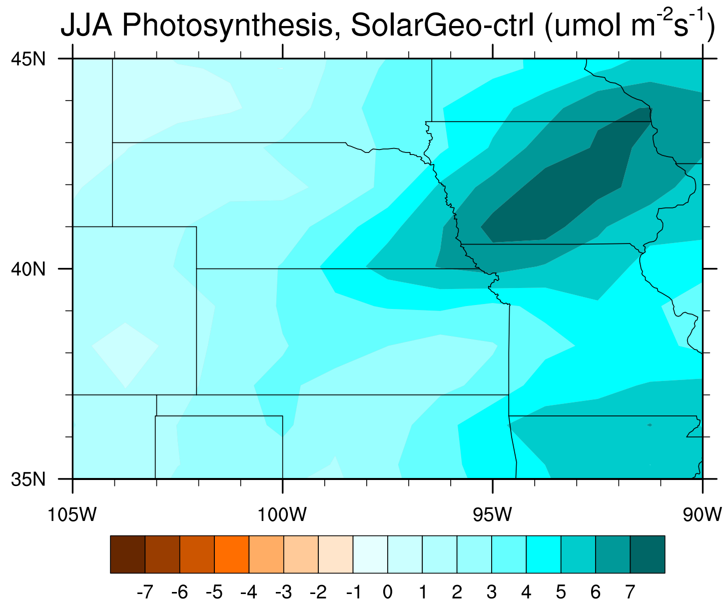
Regional average difference, SolarGeo-ctrl = 0.32 mm/day (18.42%)

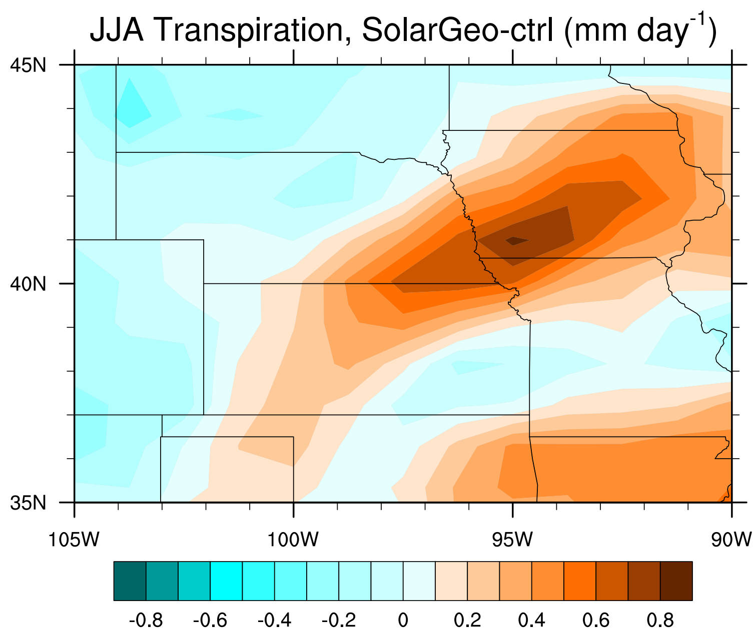

Daily Regional Average Precipitation (mm day-1)
12
10
8
6
4
2
0
Jun
Jul
Aug
Sep

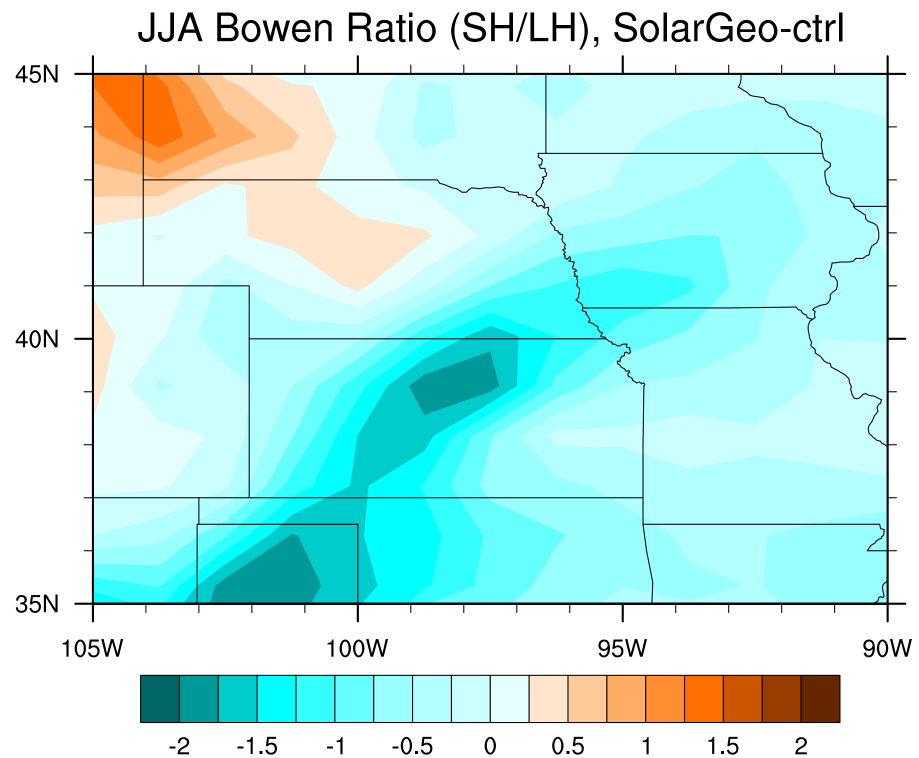

JJA Precipitation, SolarGeo-ctrl (mm day-1)
45N
40N
35N
105W
100W
95W
90W
-1.6 -1.2 -0.8 -0.4 0 0.4 0.8 1.2 1.6


Daily Regional Average 10cm Soil Moisture (kg m-2)
30
27
24
21
18
15
12
Red = Control
Blue = SolarGeo
Jun
Jul
Aug
Sep


JJA 10cm Soil Moisture, SolarGeo-ctrl (kg m-2)
45N
40N
35N
105W
100W
95W
90W
-4 -3 -2 -1 0 1 2 3 4







Shift in surface energy partitioning from sensible to latent heat explains cooling.

Summary and Future Work

- Solar geoengineering has the **potential to mitigate climate change** but there are **important side effects** to consider (e.g. the terrestrial hydrologic response).
- Known connection between **low soil moisture and heat waves**; the central U.S. is a **hot spot** for land-atmosphere coupling.
- Solar geoengineering shown to **reduce the duration and intensity** of a modeled regional heat wave event.
- **Future work:** continue to explore mechanisms, additional metrics for diagnosing heat wave events, consider extreme precipitation events.

Thanks!

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