Source or Sink?

Solar Radiation Management and Future Ocean Carbon Uptake

Holly Olivarez

NOAA Climate & Global Change Postdoctoral Fellow

UCAR | UCAR COMMUNITY PROGRAMS | CPAESS Cooperative Programs for the Advancement of Earth System Science

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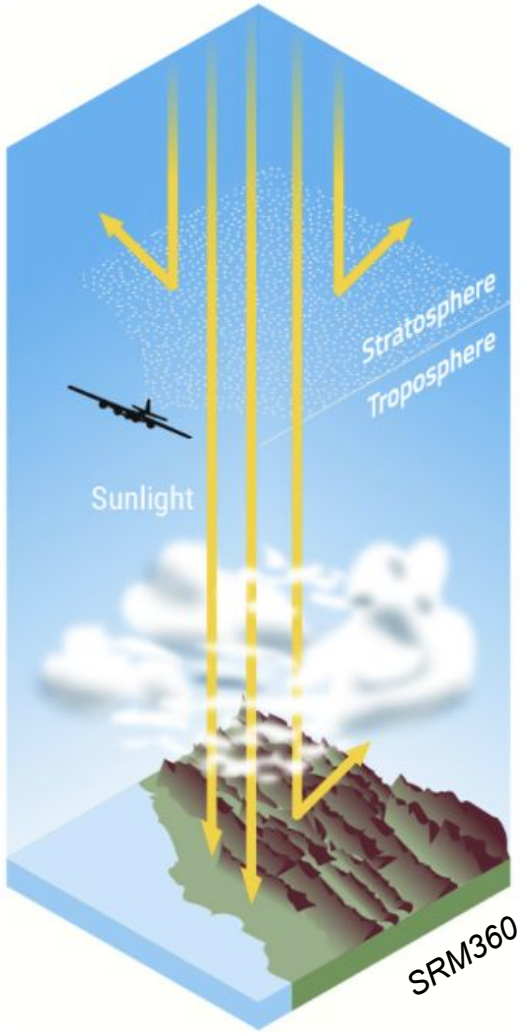
ARISE-SAI-1.5 simulations in CESM2(WACCM6)

Assessing Responses and Impacts of Solar intervention on the Earth system (ARISE) with Stratospheric Aerosol injection (SAI) that keeps global mean surface air temperature near 1.5°C above the pre-industrial value (ARISE-SAI-1.5)

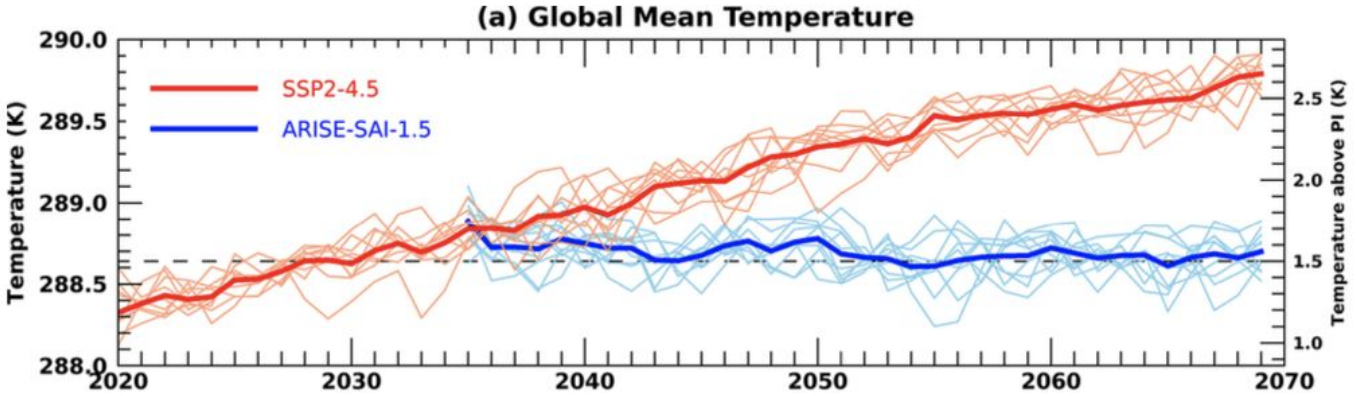
Richter et al. (2022)



ARISE-SAI-1.5 simulations in CESM2(WACCM6)

*Simulation years 2035-2070

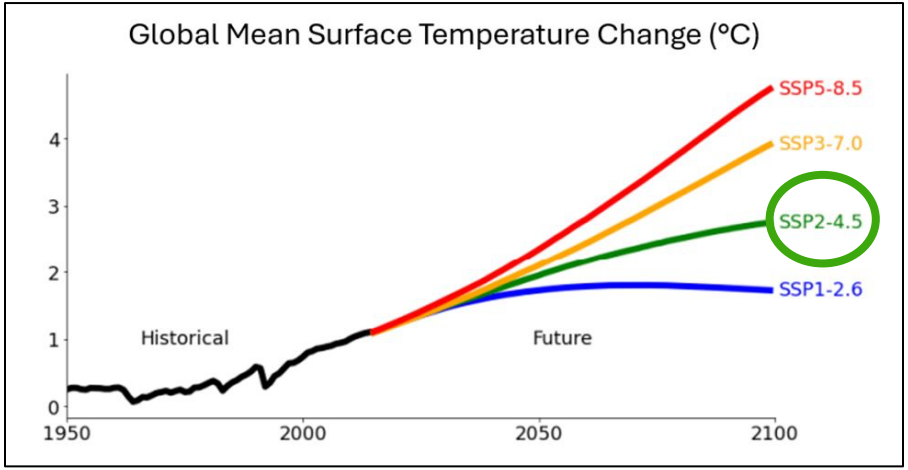
*6 ensemble members each for ARISE-SAI-1.5 and SSP2-4.5 runs



Richter et al. (2022)

ARISE-SAI-1.5 simulations in CESM2(WACCM6)

*Uses the “middle of the road” SSP2-4.5 where greenhouse gas emissions continue but start declining mid-century, leading to roughly 2.7°C warming by the year 2100

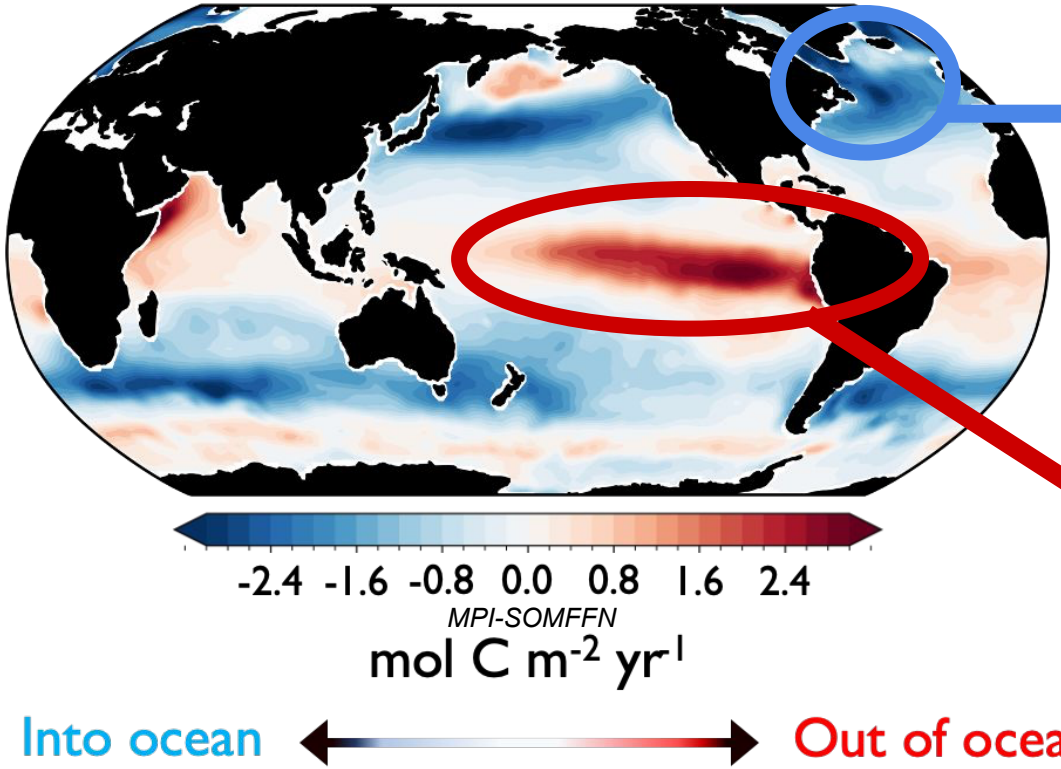


Climate Data Canada

*SSP2-4.5 refers to 4.5 Wm^{-2} radiative forcing level by 2100

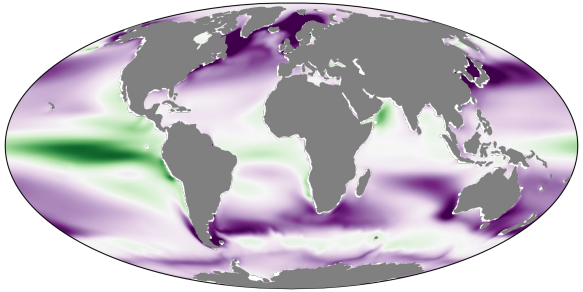
Recent historical Sea-Air CO_2 Flux: Sink

Example of trends: 1982-2015

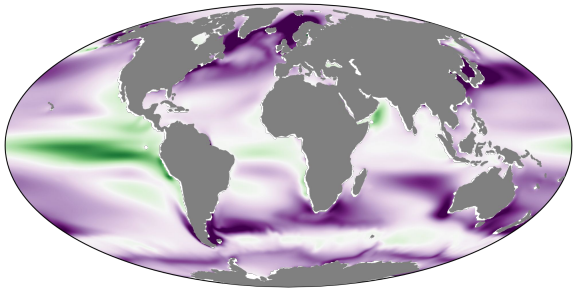


Sink: Experiment years compared to present decade

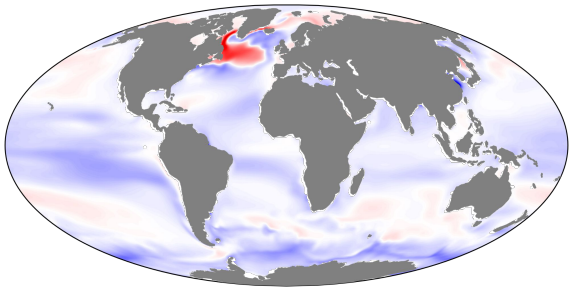
Present

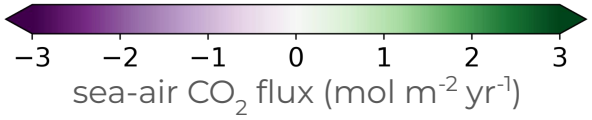


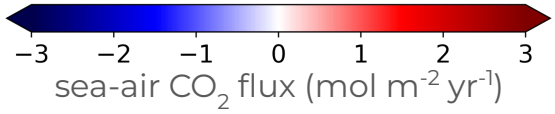
SAI experiment years

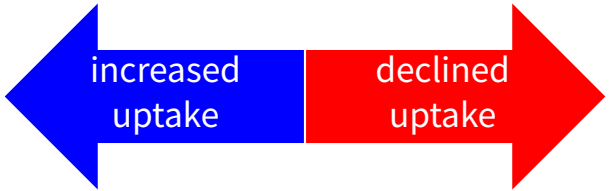


Differences





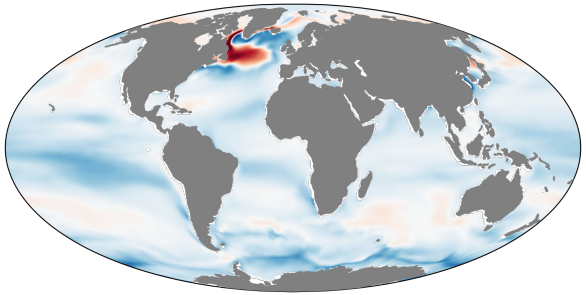




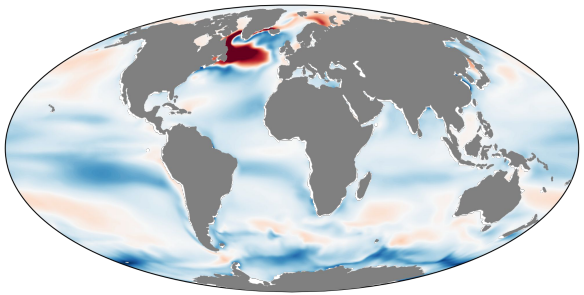
Present: 2015-2024 SAI experiment years: 2035-2070

Sink: Decadal means compared to present decade

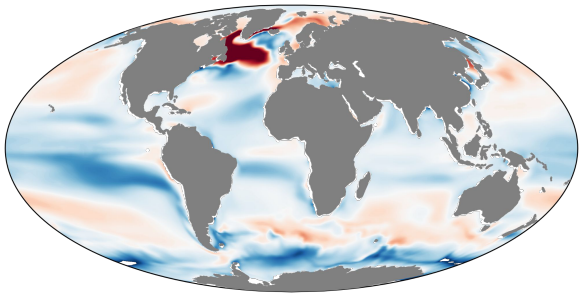
2040s vs present

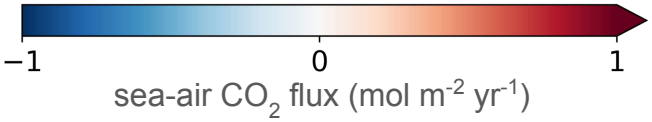


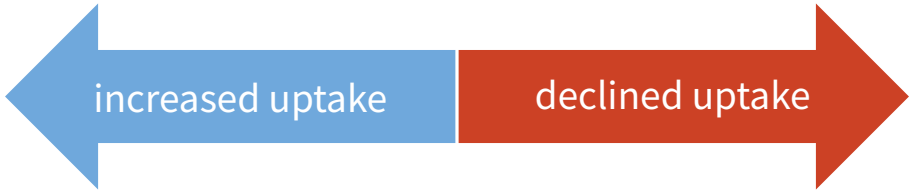
2050s vs present



2060s vs present



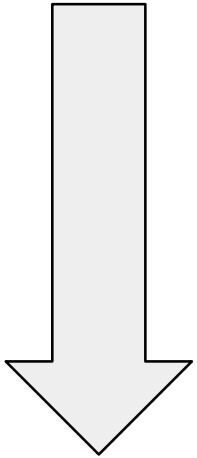


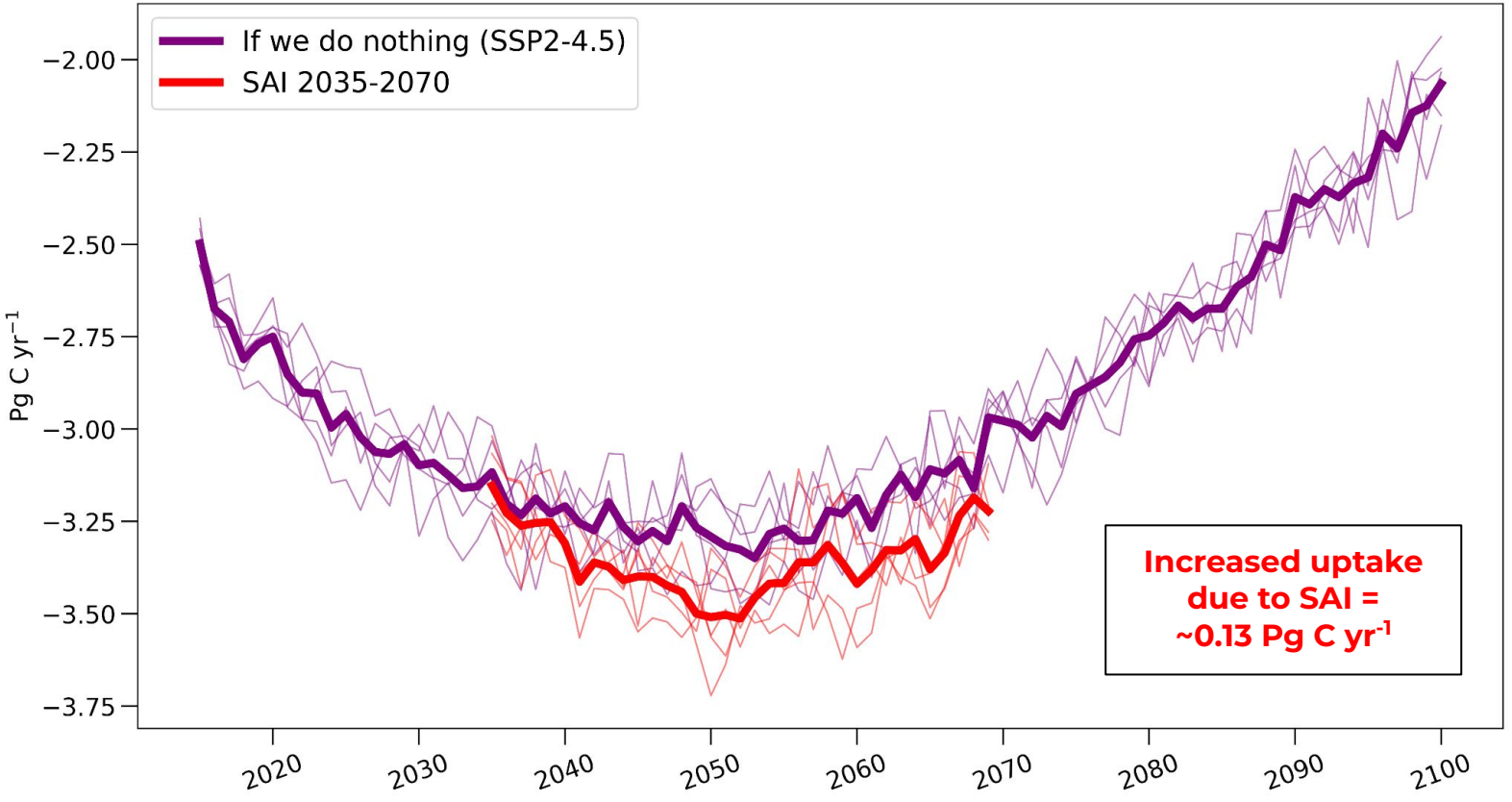


Present: 2015-2024
SAI experiment years: 2035-2070

Sink? Uptake increases under SAI, but with questions

Increase of carbon going into the ocean





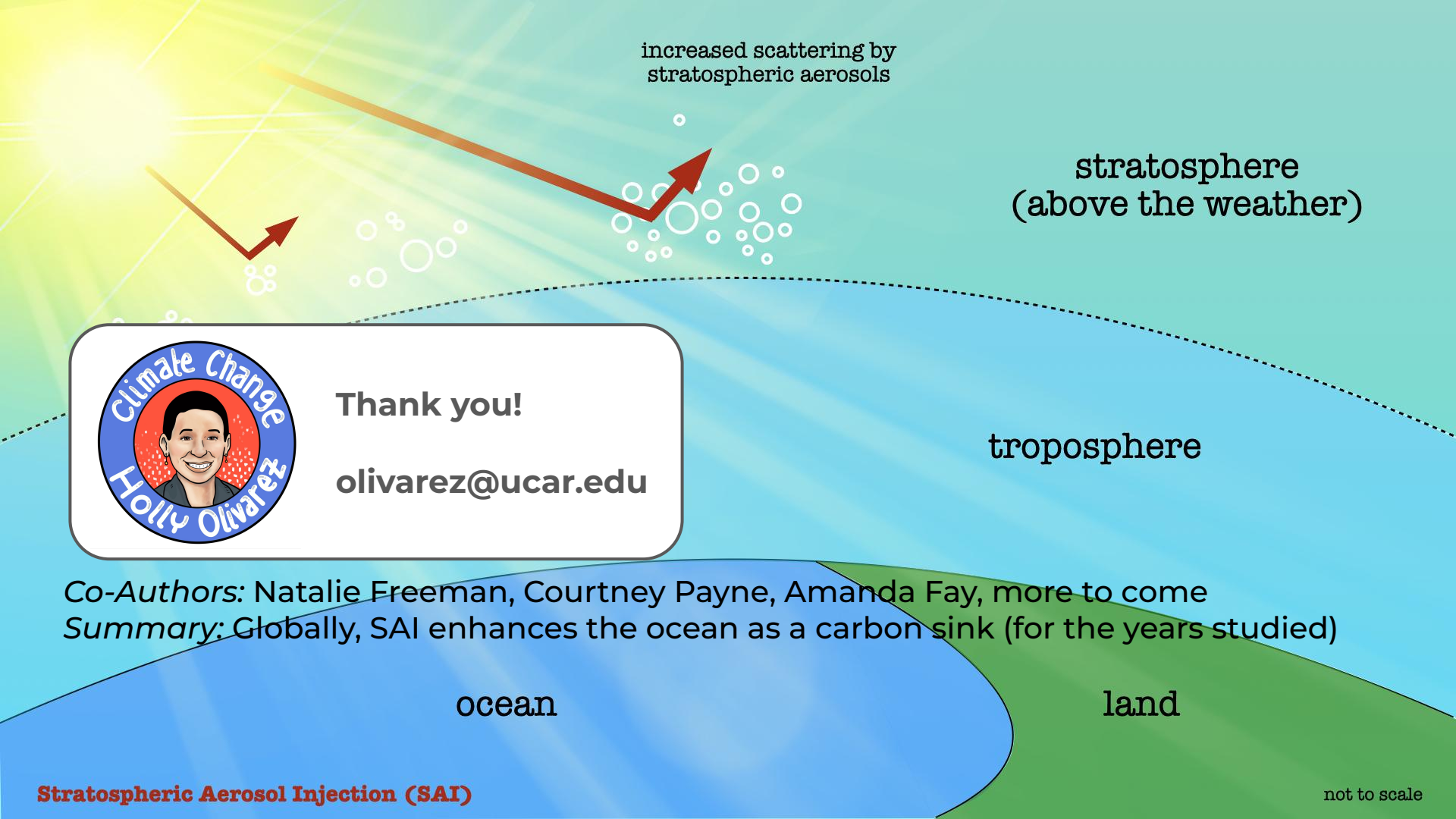
Motivation
the real world work

Let's create space for Indigenous and other researchers for co-productions of experiments and communications to their and our communities.

The least polluters are often not in positions to change the systems and policies that perpetuate inequities

They are also the ones who have and are already coping/ adapting by caring for one another

Join me!



Co-Authors: Natalie Freeman, Courtney Payne, Amanda Fay, more to come
Summary: Globally, SAI enhances the ocean as a carbon sink (for the years studied)

Additional slides

ARISE-SAI-1.5 simulations in CESM2

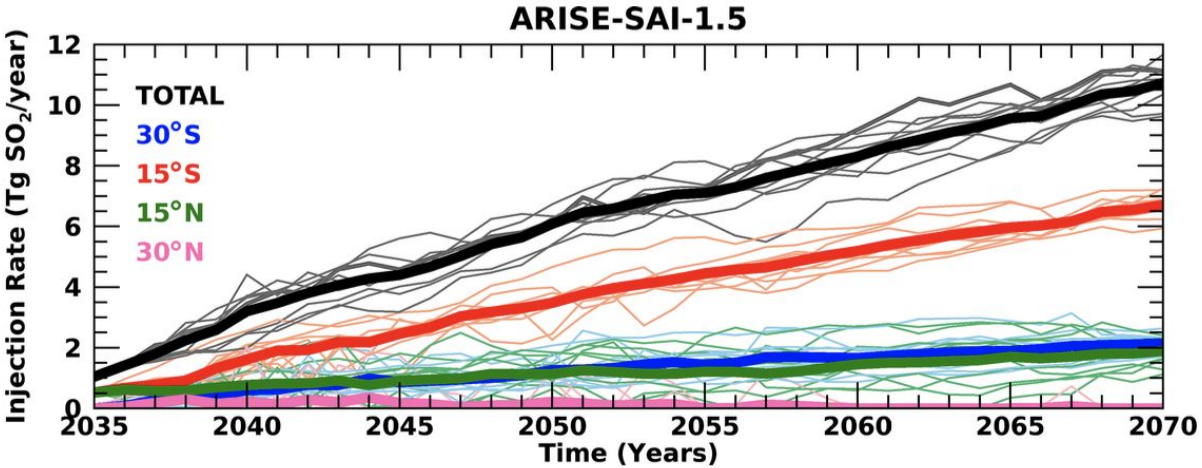


Figure 1. SO_2 injection rate as a function of time in ARISE-SAI-1.5 simulations at 30° S (blue), 15° S (red), 15° N (green), 30° N (pink), and total (black). Thin lighter-colored lines represent individual ensemble members, whereas thick lines show the 10-member ensemble mean.

CO_2 flux is calculated using pCO_2

$$CO_2 \text{ flux} = k \bullet S_o \bullet (pCO_2^{oc} - pCO_2^{atm})$$

k = gas exchange velocity (a function of wind speed, sea surface temperature, and salinity)

S_o = solubility of CO_2 in seawater at a given temperature and salinity

What controls pCO_2?

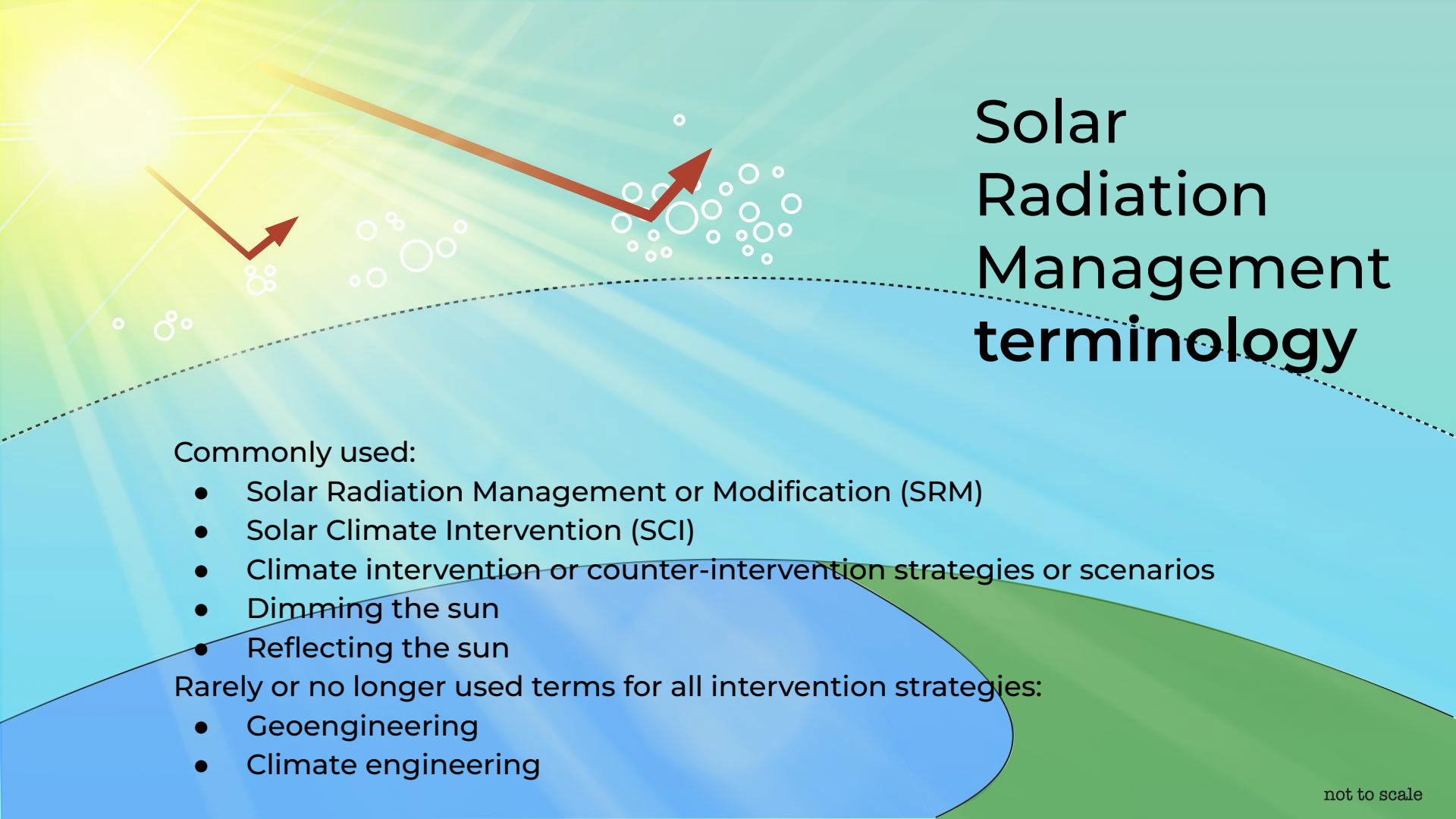
$$pCO_2 \approx \frac{K_2}{K_0 \cdot K_1} \cdot \frac{(2 \cdot DIC - Alk)^2}{Alk - DIC}$$

<u>equilibrium constants</u>

- temperature
- salinity

<u>conservative tracers</u>

- gas exchange
- biology



Solar Radiation Management **terminology**

Commonly used:

- Solar Radiation Management or Modification (SRM)
- Solar Climate Intervention (SCI)
- Climate intervention or counter-intervention strategies or scenarios
- Dimming the sun
- Reflecting the sun

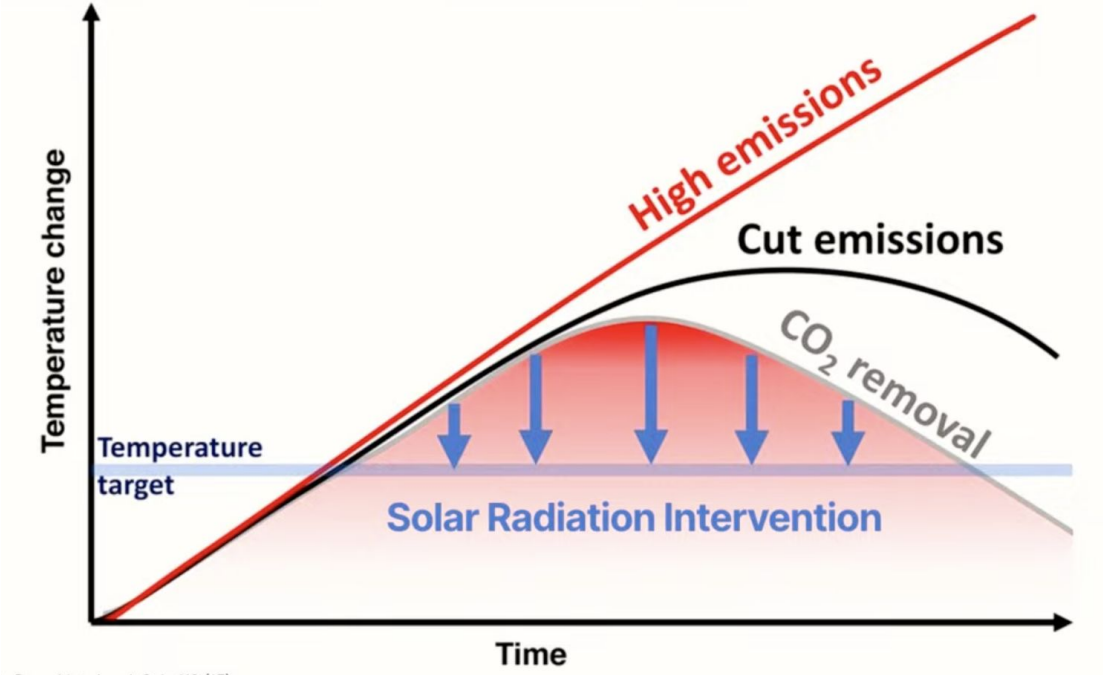
Rarely or no longer used terms for all intervention strategies:

- Geoengineering
- Climate engineering

not to scale

Mitigation may be too slow

the reason for ‘risk reduction’ research



Zarnetske et al., 2021

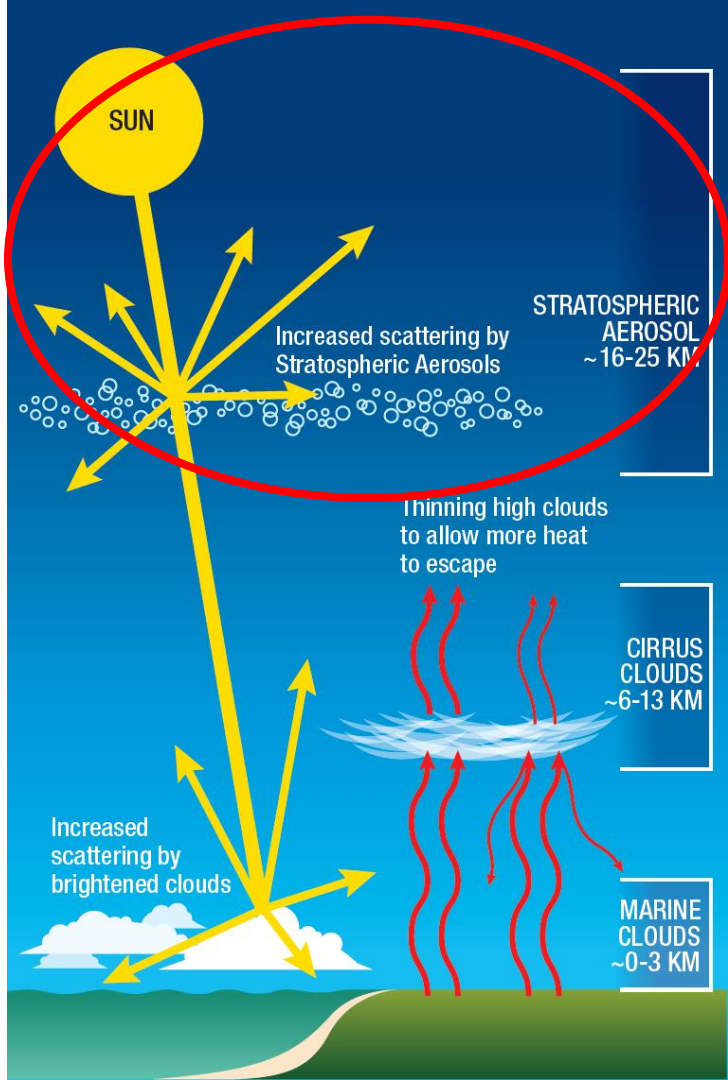
Solar Radiation Management **strategies**

Propose limiting the amount of solar radiation reaching Earth's surface

Main proposed interventions:

- Stratospheric Aerosol Injections (SAI)
- Marine Cloud Brightening (MCB)
- Cirrus Cloud Thinning (CCT)

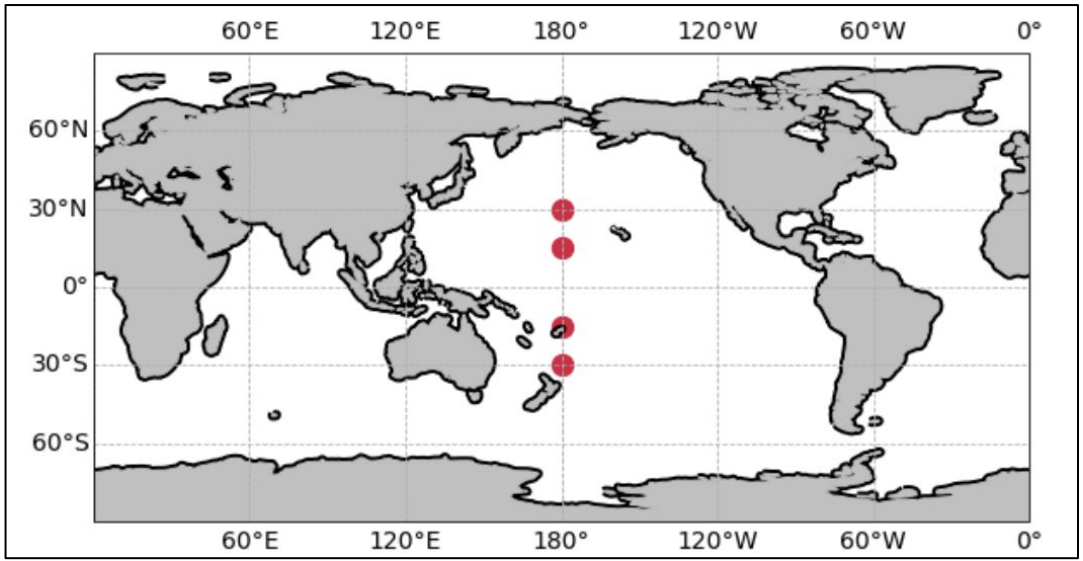
National Academies, 2021



ARISE-SAI-1.5 simulations in CESM2(WACCM6)

*Sulfur dioxide (SO_2) injected into the stratosphere annually at 30°S, 15°S, 15°N and 30°N at 180° longitude symmetrical at 21 km (~69000 feet or 13 miles)

*Annual values of injections determined by ”controller” algorithm



Sulfur dioxide (SO_2) injection points in ARISE-SAI-1.5 (red)