Cooling the Seas, Curbing the Weeds: Modeling SAI-Driven PAR and SSTA Changes to Suppress Sargassum Growth in CESM2 Simulations

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Motivating Question

How do solar geoengineering interventions along the equator in the Atlantic Ocean, specifically varying levels of Stratospheric Aerosol Injections (SAI), alter environmental drivers of Sargassum proliferation and growth rate in the Great Atlantic Sargassum Belt, particularly through changes in PAR?

Falsifiable Hypothesis

Higher quantities of SAI will cause a larger regional reduction in PAR compared to lower quantities, resulting in proportionally decreased Sargassum growth rates due to limited UV radiation and nutrient uptake via cooler SSTs.

Methods

Since it's difficult to model Sargassum growth rates directly, I will be utilizing a similar approach to Hirasawa et al. (2023) that looks at indirect variables, such as PAR and SSTA. They localized this to three regions and ran scenarios to establish SST and Precip anomalies.

1. **Modeling**: I'll be using Community Earth System Model version 2 (CESM2)
    a. ***Control***: Utilize baseline future projection under SSP2-4.5 from 2020-2050
    b. ***Ensembles***: Include 3-5 ensemble members for each scenario outlined below

2. **SAI Scenario**: I'm looking to inject varying amounts of SO_2 aerosols per year into the tropical stratosphere
    a. ***Low SAI***: Inject 10 Tg/year of SO_2 aerosols into the tropical stratosphere to achieve ~0.5 W/m^2 global radiative forcing reduction
    b. ***Medium SAI***: Inject 30 Tg/year of SO_2 for ~1 W/m^2 forcing reduction
    c. ***High SAI***: Inject 50 Tg/year of SO_2 for ~2 W/m^2 forcing reduction

3. **Variable extraction**: Mainly looking to extract spatial fields for PAR (downward shortwave radiation at surface, for 400-700 nm) and SSTA differences for the Sargassum belt region
    a. **PAR**: Still figuring this part out, but the general idea is to compute PAR differential anomalies (PAR_diff = PAR_SAI – PAR_control)
    b. **SST Anomalies**: Compute anomalies relative to control to determine regional averages over the Sargassum belt

Data & Software

- Utilizing the CESM2 pre-industrial and SSP2-4.5 baseline outputs via netcdf files for the atmospheric/oceanic components
- GeoMIP SAI experiment datasets
    - Variable injection rate profiles from CMIP6/GeoMIP archives

Hypothesis Testing via Analysis

The analysis tests if higher SAI doses reduce PAR and Sargassum growth proportionally. The idea is to indirectly model Sargassum growth rates and proliferation by establishing varying SAI quantities to PAR changes for photosynthesis and SSTA to nutrient uptake (more research required on Sargassum for this). CESM2 simulations will compare PAR changes across low (10 Tg/year), medium (30 Tg/year) and high (50 Tg/year) SAI scenarios against a control baseline from SSP2-4.5. Regression analysis checks if PAR drops scale with injection. Potentially could do a growth model that uses PAR_diff to predict biomass.