

Climate Intervention Dynamical Emulator (CIDER) for Scenario Space Exploration

CESM Workshop 2025

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What is an emulator?

For this talk:

- An emulator is a reduced-order model that mimics some behavior of a more complex system.
- Can be AI/ML or not (this one isn't)

CIDER will seek to mimic CESM2's time-varying responses in temperature and precipitation to SAI forcing.

Why an Emulator?

• Initially: Uncoordinated deployments of SAI

What is a Coordinated Deployment of SAI?

• One "actor" deploying global SAI

• One climate goal or set of compatible goals

• One strategy to achieve goals, with access to needed injection sites

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Example of Coordinated Deployment: ARISE



- Maintain surface temperature and its gradients to 2020-2039 baseline.
- Use mixture of 30°N, 15°N, 15°S, 30°S.

Uncoordinated deployments can get a little more complicated.

• Philanthropists backed by their home country retrofit a fleet of existing aircraft to deploy Arctic SAI and restore sea ice to 2020 levels. They begin in 2035.

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- Elsewhere, a nation burdened by heat stress builds a fleet of new aircraft to deploy SAI at the equator to restore the world's mean temperature to an even earlier date, 2000.

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- A third country notices the imbalance of cooling and scrambles to deploy in the southern hemisphere to restore the ITCZ its pre-SAI levels (2035).

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- Nefarious actors >:) sabotage deployment and create a termination shock.

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- Factors:

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- Factors: # of Actors

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- Factors: # of Actors, Target Variable

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 - Factors: # of Actors, Target Variable, Target Goal

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And each choice made by one actor affects the others

Uncoordinated Scenarios: Main Difficulties

- 1. Many possible combinations
- 2. Widely varying responses
- 3. Earth System Models are expensive

How do you explore this scenario space? One way: use a simpler model (an emulator)

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Dynamically Emulating SAI







Example	Actor 1 @ 60°N starting in 2035 to bring Arctic temperatures to 2020 levels.
Uncoordinated :	Actor 2 @ 0°N starting in 2040 to bring global temperature to 2000 levels. Terminate in 2053.
Scenario	Actor 3 @ 30°S starting in 2042 to bring the N-S temperature gradient to 2035 levels.

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Why an Emulator?

- Initially: Uncoordinated deployments of SAI
- More broadly: Exploring SAI scenarios
 - Integration with economic or geopolitical models
 - Integration with games and workshops
 - Accessibility to those without supercomputer access
- More more broadly: YOU explore SAI scenarios
 - Right now!*
 - * site fails on mobile devices and eduroam wifi

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Web Integration

https://simulator.reflective.org/

N Reflective



Impacts of SAI deployment

Learn more about the simulator



411

Planes in 2100

\$67B-90B

Direct costs annually

194-288%

Pinatubo annually

30.00

Ta SO₂ in 2100

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- CIDER and data from the example uncoordinated SAI simulation can be found at <u>https://github.com/jf678-cornell/CIDER</u>.

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