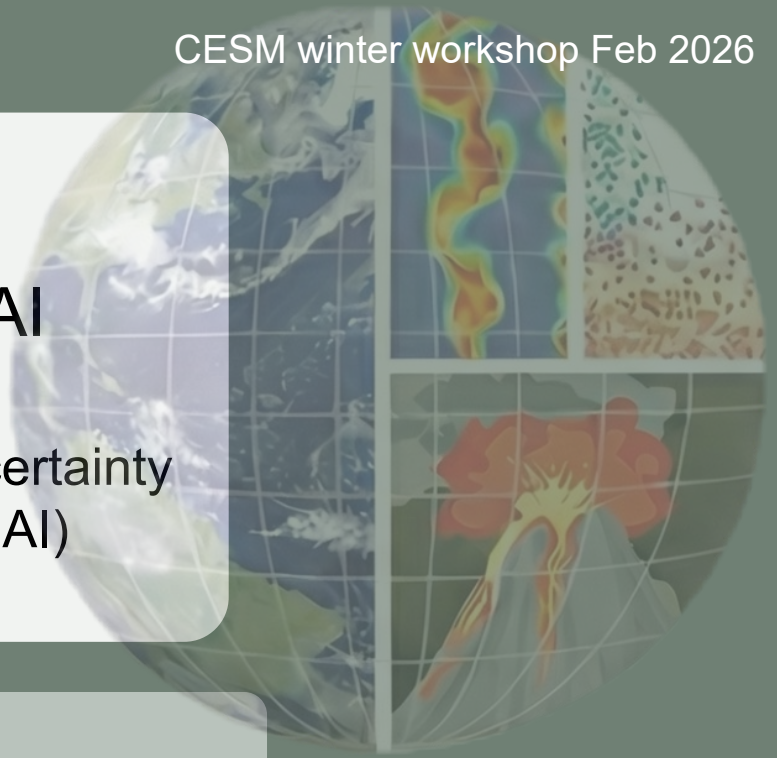
AIDE- SAI

AI- Driven Emulation for SAI

Disentangle and quantify cross- scale uncertainty in Stratospheric Aerosol Injection (SAI)



[1]**Reflective** , San Francisco, CA, USA
[2] **Cornell University** , Ithaca, NY, USA
[3] **Harvard University** , Cambridge, MA, USA
[4] **Scripps** , University of San Diego, San Diego, CA, USA
[5] **University of Wyoming** , Laramie, WY 82071, USA

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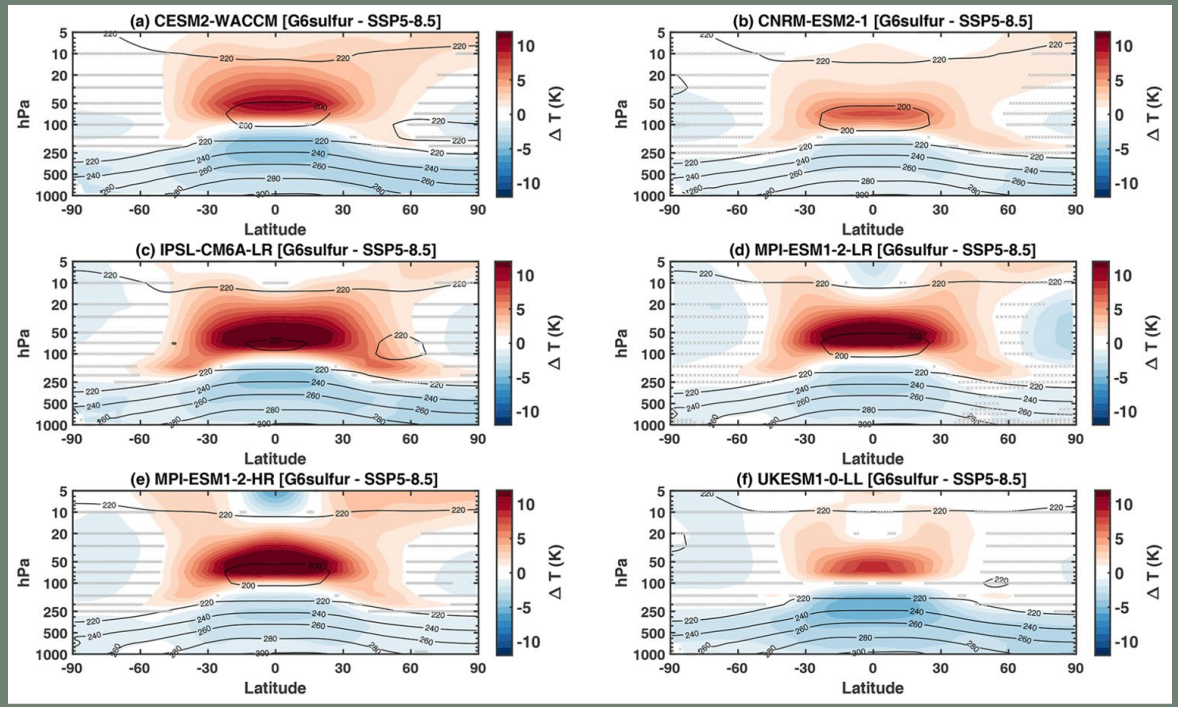
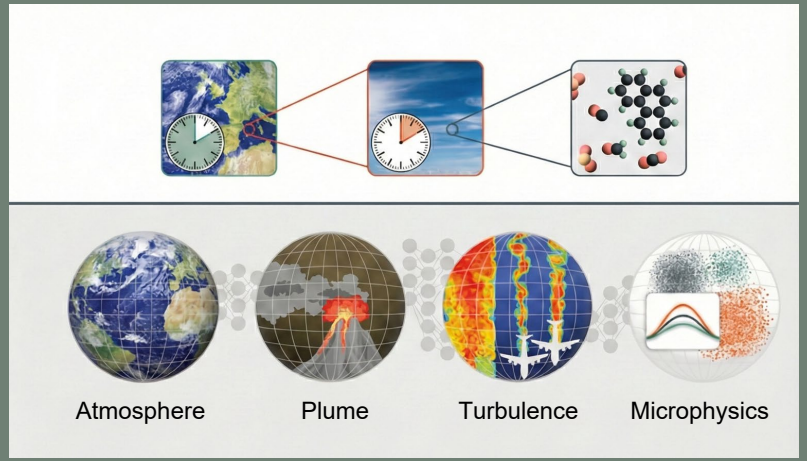
Large uncertainties around chemistry feedback on stratospheric temperature and tracer transport



Tilmes et al. 2022:
Zonal mean temperature changes (2080-2099) between G6sulfur and SSP5-8.5

Reflective

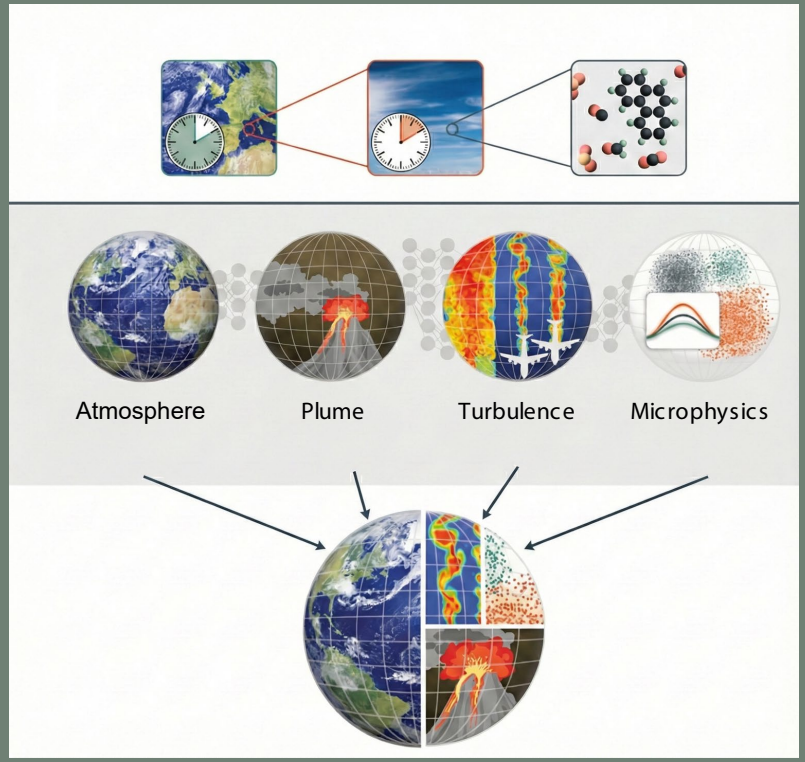
There are multiple spatial and temporal scales involved



Reflective

Vision

An emulator that couples processes across spatial and temporal scales
→ faster, more precise exploration of key physical uncertainties in SAI



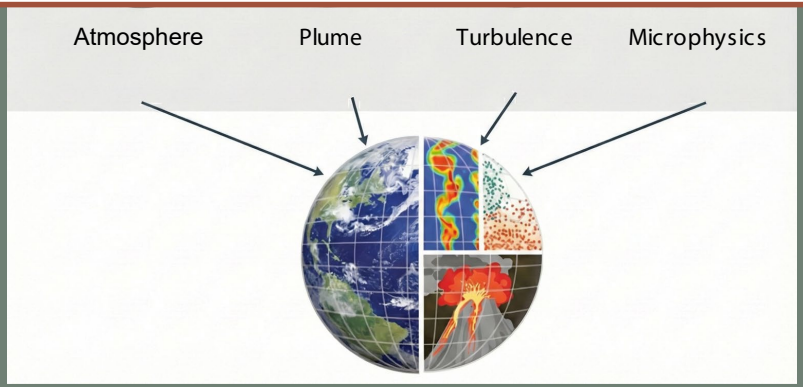
Reflective

Vision

An emulator that couples processes across spatial and temporal scales
→ faster, more precise exploration of key physical uncertainties in SAI

AIDE- SAI

An open - source tool to disentangle and quantify cross - scale uncertainty in stratospheric processes related to SAI

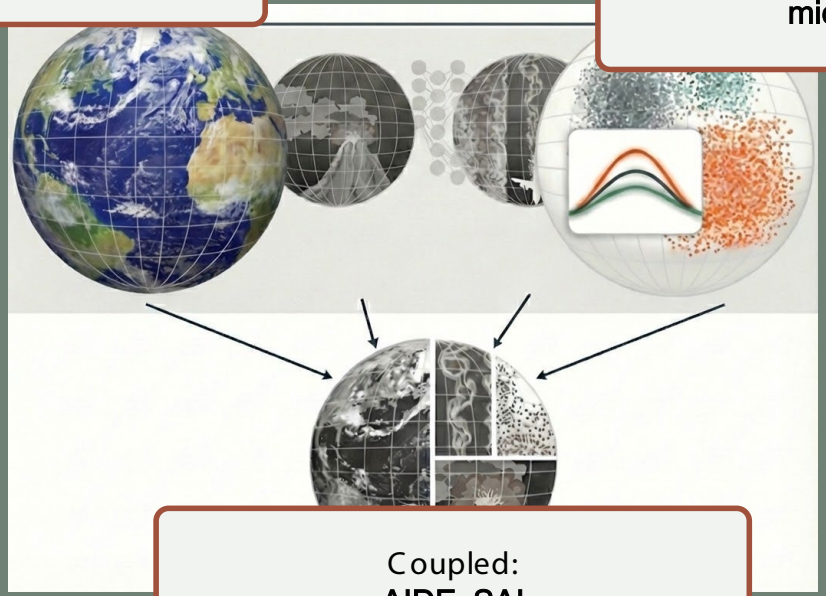


Reflective

Focus on **smallest** and **largest** scales first

Atmospheric scale: **AIDE-WACCM**

Microphysics scale: **AIDE-microphysics**



Coupled:
AIDE- SAI

Reflective

AIDE- WACCM

Emulate stratospheric dynamics

AIDE- WACCM

Emulate stratospheric dynamics

30x faster than baseline model

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Large multi- member ensemble for **scenario space** analysis

1h historical- only training data with fixed SSTs from CESM2 WACCM6

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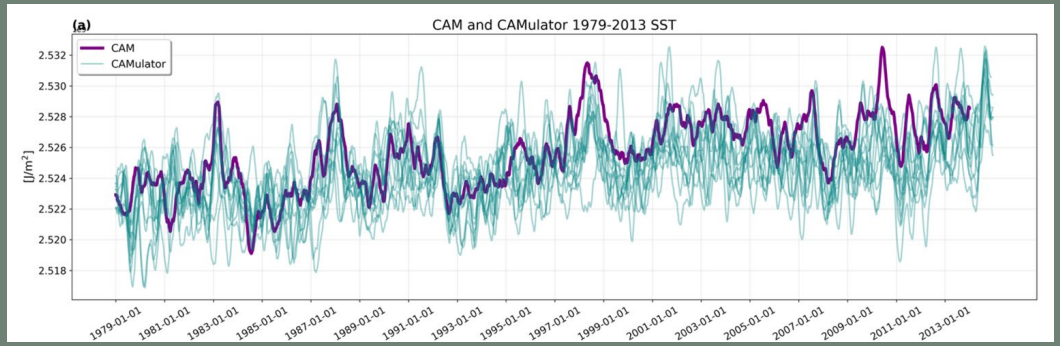

Example of atmospheric model result
@Chapman et al., 2025

AIDE- microphysics

Emulate aerosol nucleation, growth and size distribution from SO2 injections

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AIDE- microphysics

Emulate aerosol nucleation, growth and size distribution from SO2 injections

As accurate as sectional models, as fast as modal models

Reflective

AIDE- microphysics

Emulate aerosol nucleation, growth and size distribution from SO2 injections

As accurate as sectional models, as fast as modal models

Exploration of **chemistry and aerosol formation**

CARMA, TOMAS, AER3D with CESM2 WACCM6 boundary conditions

Reflective

Multi-Scale Modeling Framework

AIDE- WACCM

Emulate stratospheric dynamics

AIDE- microphysics

Emulate aerosol nucleation, growth and size distribution from SO2 injections

Target: 2027-2028

AIDE-plume

AIDE-turbulence

Coupling

AIDE- SAI

Reflective

Multi-Scale Modeling Framework

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Emulate stratospheric dynamics

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Emulate aerosol nucleation, growth and size distribution from SO2 injections

Target: 2027-2028

AIDE-plume

AIDE-turbulence

Coupling

AIDE- SAI

Evaluate performance on SAI forcing

Uncertainty analysis of stratospheric processes

Reflective

Multi-Scale Modeling Framework

AIDE- WACCM

Emulate stratospheric dynamics

AIDE- microphysics

Emulate aerosol nucleation, growth and size distribution from SO2 injections

Target: 2027- 2028

AIDE- plume

AIDE- turbulence

Coupling

AIDE- SAI

Evaluate performance on SAI forcing

Couple to ocean

Evaluate performance on SAI temperature

Target: 2027- 2028

Uncertainty analysis of stratospheric processes

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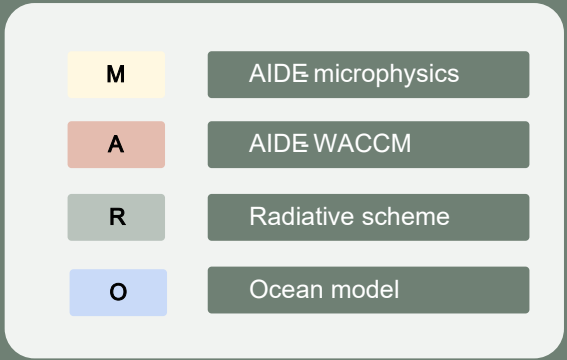
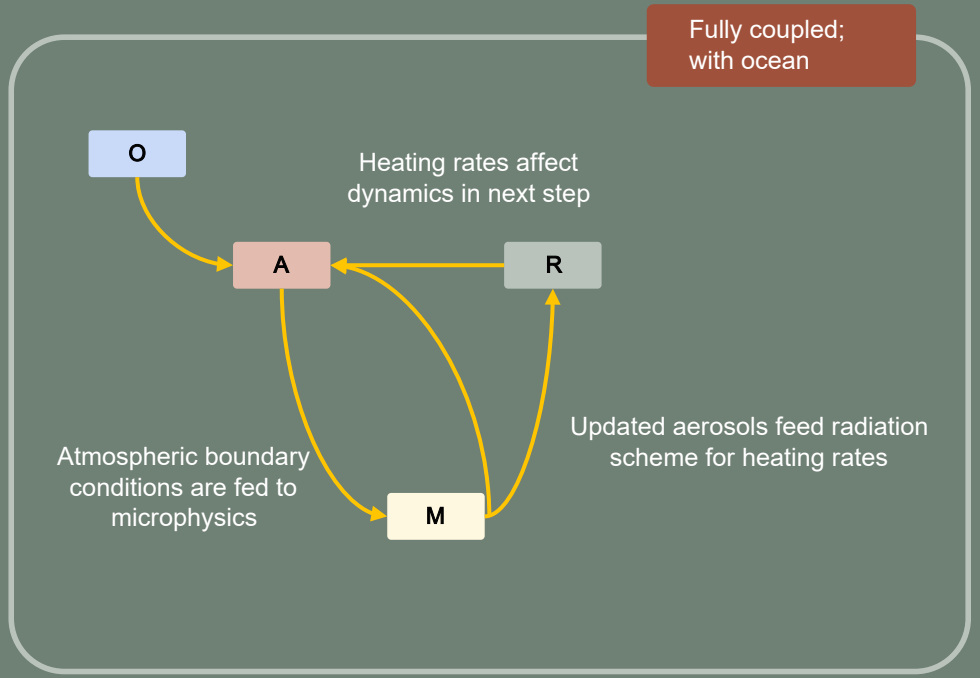
Coupling - how to couple?

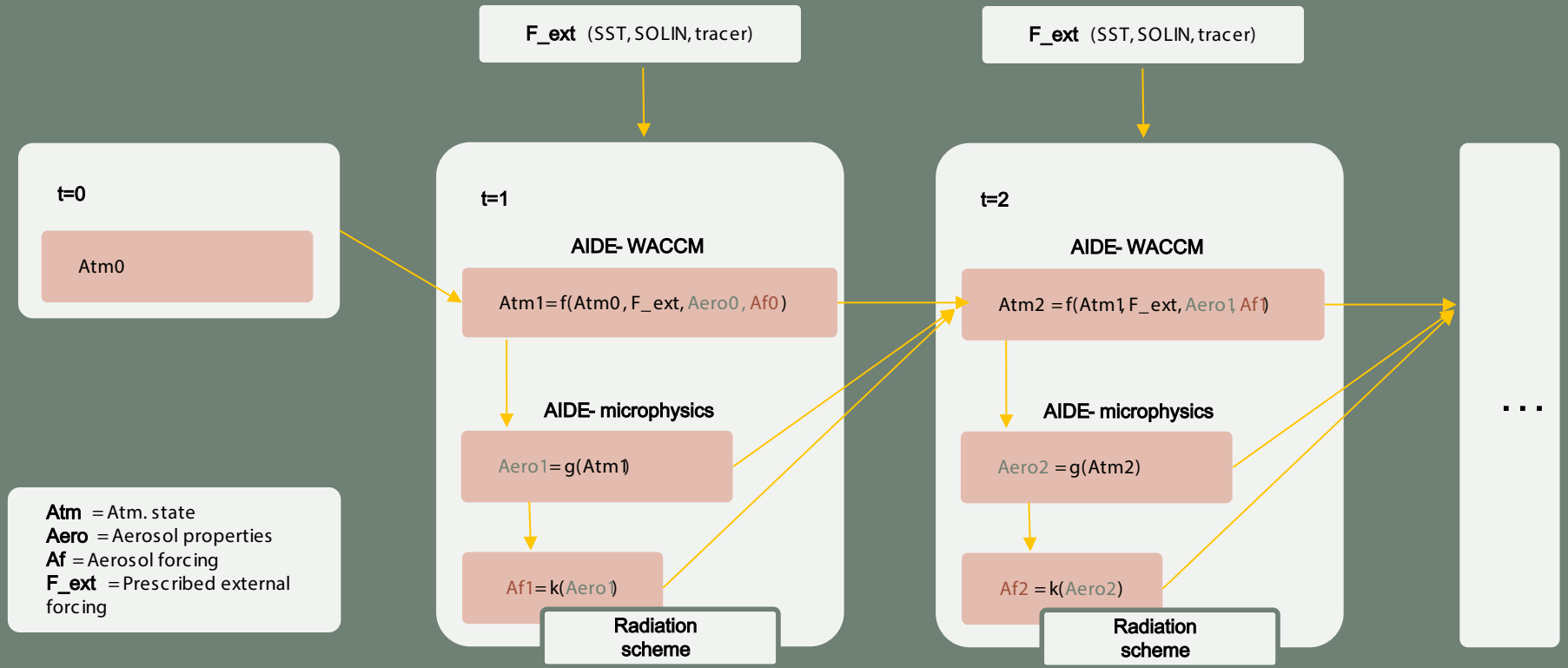


Coupling - how to couple?

M	AIDE microphysics
A	AIDE WACCM
R	Radiative scheme
O	Ocean model



Coupling



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Model setups needed for uncertainty analysis

Uncertainty	First pass	Second pass
Aerosol spatial distribution	A	A → M ← R
Strat. water vapor		A + M
Volc. eruptions during deployment	A	A ← M
Strat. ozone	A → M	A + M
Strat. transport feedback		A → M ← R
Ice sheets and glaciers	A	O → A → M ← R
AMOC		
Ocean carbon cycle		

Pinatubo Perturbed Parameter Ensemble (PPE) to validate CESM-WACCM microphysical response

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Identify those parameters that lead to the best agreement with observations regarding **lifetime and climate impact of Mt. Pinatubo**

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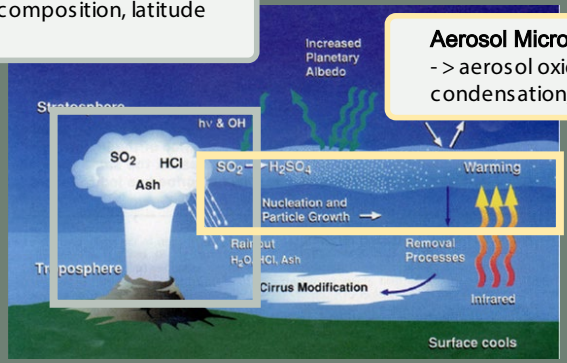
Vary **16 parameters across 160 ensemble members**

Pinatubo Perturbed Parameter Ensemble (PPE) to validate CESM-WACCM microphysical response

Identify those parameters that lead to the best agreement with observations regarding **lifetime and climate impact of Mt. Pinatubo**

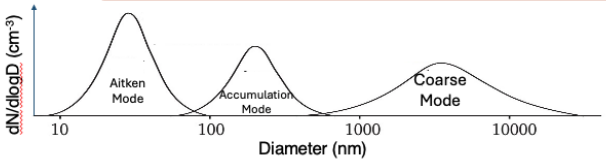
Vary **16 parameters across 160 ensemble members**

Injection Parameters (5)
- > injection height, composition, latitude spread, mass



Aerosol Microphysics (4)
- > aerosol oxidation, nucleation, condensation, sedimentation

Modal Aerosol Structure in MAM4 (7)
- > Aitken, accumulation and coarse mode, upper/lower Dg, sigma



Timmreck et al. 2018; McCormick et al., 1995 (volc. figure)

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Facilitate Stratospheric Aerosol Injection (SAI) research

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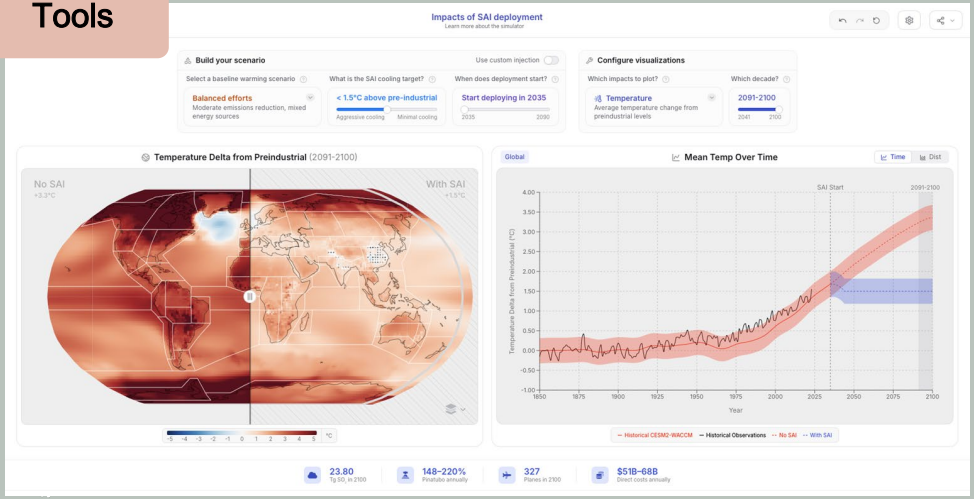
Tools



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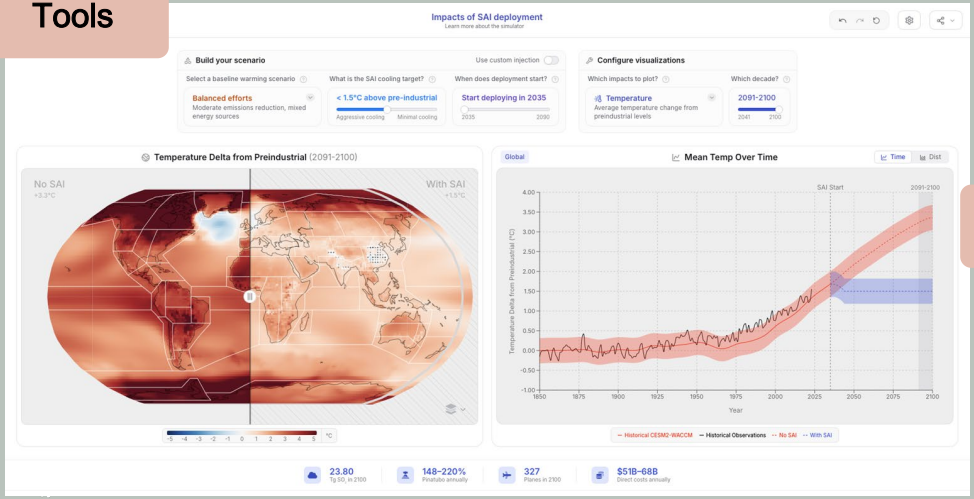
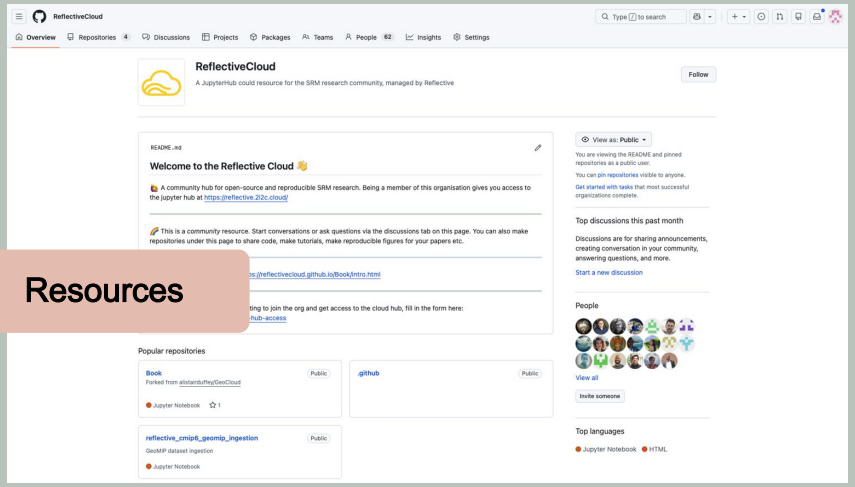


Resources



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AIDE- SAI → Tool to systematically analyse modeling uncertainties related to SAI

Susanne Baur [1], **Ali Akherati** [1], **Hunter Brown** [5], Dakota Gruener[1], Emily Kuhn[1], Marianna Linz[1,3], John Orcutt[1], **Daniele Visioni** [1,2], Duncan Watson-Parris[1,4]

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Hunter

Mt. Pinatubo PPE

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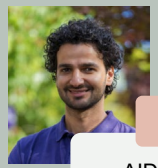

Ali

AIDE- microphysics

Hunter

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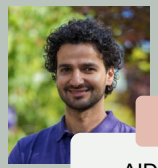

Ali

AIDE- microphysics

Hunter

Mt. Pinatubo PPE

AIDE- WACCM

Susanne

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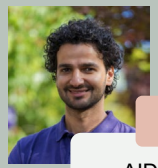

Ali

AIDE- microphysics

Hunter

Mt. Pinatubo PPE

AIDE- WACCM

Susanne

He's here too

Dan

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