Not All 1.5°C Worlds Are Equal: Mitigation versus Solar Radiation Modification

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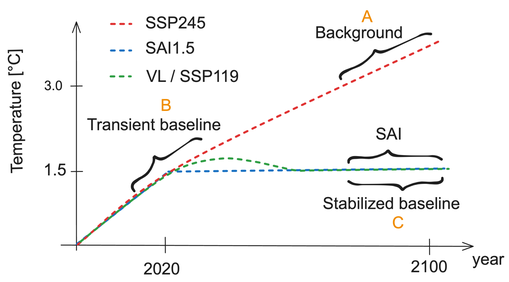
1. "World-World" vs. "Risk-Risk" Framing



A vs. SAI:
"Risk-Risk" framing

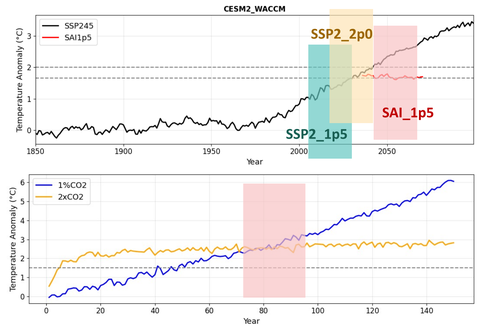
C vs. SAI:
"World-World" framing

RQ: What are the trade-offs of choosing SAI over mitigation to achieve 1.5°C?

2. Methods

- CESM2-WACCM
- ARISE simulations[1]
  - SSP2-4.5 baseline
  - SAI: 2035-2070
  - 15°N, 15°S, 30°N, 30°S
  - T stabilization at 1.5°C
- Additional analysis: Machine learning classification (SAI_1.5 vs. Mitigation_1.5)

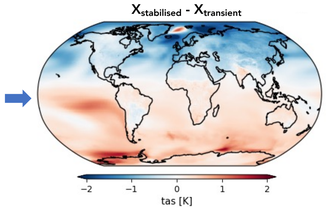
3. Pseudo-Stabilized Baseline



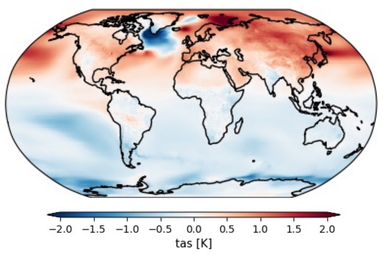
Correction factor to account for impact of warming rate on baseline[2]

$$x_{\text{stabilised}} = x_{\text{transient}} - \frac{R_{\text{transient}}}{R_{1\%CO_2} - R_{2xCO_2}} \left(x_{1\%CO_2} - x_{2xCO_2}\right).$$

Additional warming of southern oceans; cooler northern atlantic (AMOC weakning)

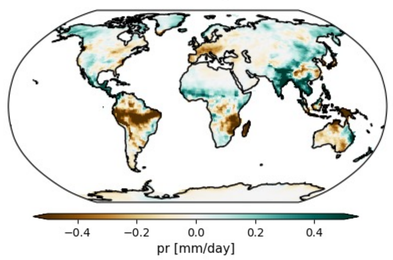


4. SAI vs. Mitigation: Temperature



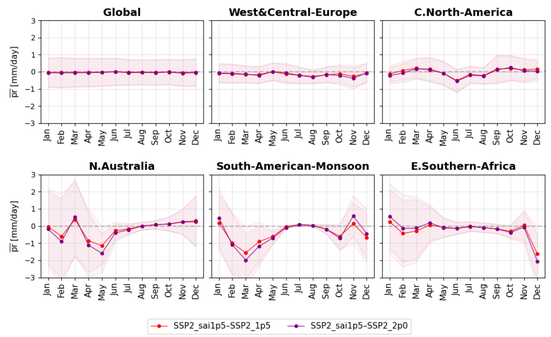
Increased cooling of the southern hemisphere when compared against the (warmer) pseudo-stabilized baseline

5. SAI vs. Mitigation: Precipitation

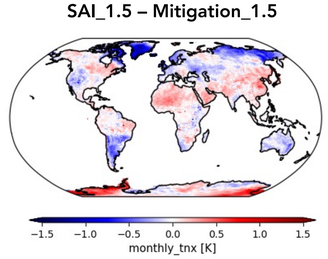


SAI 1.5°C world is drier than mitigation 1.5°C world (–0.03 mm/d)

Large regional disparity (winners vs. losers): increased drying in important agricultural regions

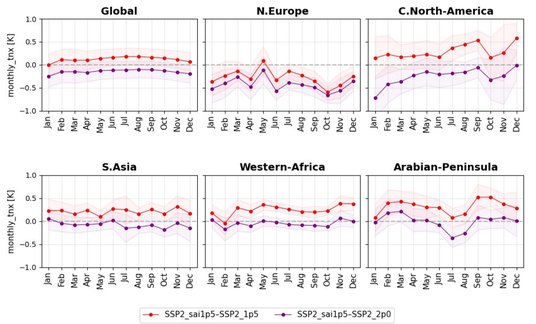


6. SAI vs. Mitigation: Warm Nights



Increased night-time heat in an SAI 1.5°C world compared to a mitigation 1.5°C world

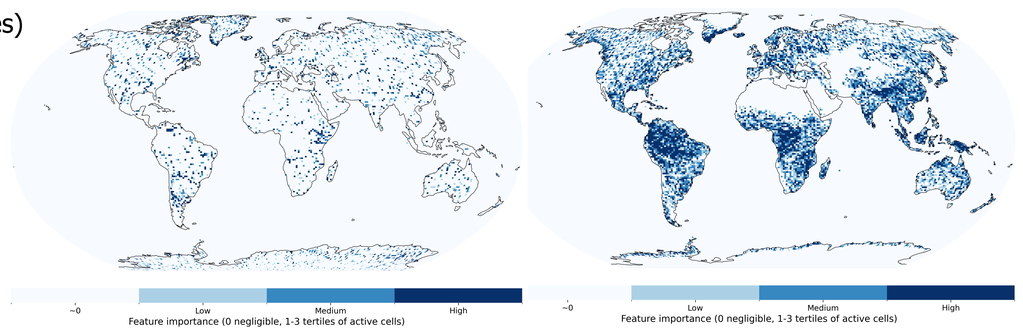
Warmer nights for many tropical regions in an SAI 1.5°C world, can have important health consequences



7. Machine Learning: Classifying SAI vs. Mitigation Worlds

- Machine learning classifier (gradient-boosting machines) to distinguish between SAI & mitigation 1.5°C worlds
  - pair years with similar GMT
  - across 10 ensemble members
  - features: grid*12 months; *tas* and *pr* separately
  - Leave-one-out validation (no data leakage)
- Explainability analyses to identify the regions driving the separation

Although GMTs are similar, regional differences are sufficiently large that an SAI-driven and mitigation-driven 1.5°C worlds are fundamentally different



Temperature: classification accuracy >90%; no single dominant region (feature importance)

Precip.: classification accuracy 86%; strongest signal in tropical monsoon regions

8. Summary

- A climate-engineered future with SAI differs from a GHG mitigation world
- Nobody experiences the global mean. SAI introduces pronounced regional & seasonal differences, particularly in hydrological variables
- In some regions, changes in an SAI 1.5C world may be more pronounced than a mitigation 1.5°C world (e.g., more severe night time heat events)
- Limitations: (1) single model, (2) pseudo-stabilized rather than truly stabilized baseline

References

[1] Richter, J. H., et al. (2022). Assessing Responses and Impacts of Solar climate intervention on the Earth system with stratospheric aerosol injection (ARISE-SAI): protocol and initial results from the first simulations. *GMD*, 15(22), 8221-8243.

[2] Duffey, A., & Irvine, P. J. (2024). Accounting for transience in the baseline climate state changes the surface climate response attributed to stratospheric aerosol injection. *Env. Res. Clim.* , 3(4), 041008.

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