

# 2026 Solar Climate Intervention Impacts on Extremes (SCI-EX) Abstracts

*Abstracts are listed alphabetically by last name*

## **Comparing future projections of warm spells and their characteristics under climate change and stratospheric aerosol injection in CESM2 and UKESM1**

*Ivy Glade (Colorado State University)*

The frequency and intensity of extreme heat events has increased over the last several decades, and are projected to continue to do so as global temperatures continue to rise. Warm spells are an extreme heat event characterized by the prolonged occurrence of anomalously high temperatures at any time of the year. These events impact a variety of human and natural systems, including human mortality and morbidity, crop and livestock yields, and energy demand in the warm season, as well as snowpack mass loss and permafrost extent in the cool season. The risks posed by continued temperature rise have prompted research into climate intervention approaches to reduce future rates of temperature increase. Stratospheric aerosol injection (SAI) is one method of climate intervention that would operate by injecting reflective aerosols, or the gases that lead to their formation, into the stratosphere to reflect a small amount of incoming solar radiation away from Earth. A limited amount of research has assessed the potential for SAI to mitigate future increases in the frequency and intensity of extreme heat events, but this work has been regionally specific, or has considered only high-end emissions scenarios that are no longer considered to be policy-relevant and SAI deployment scenarios that are unrealistic. Here, two sets of simulations that were conducted using well understood global Earth system models - namely CESM2 and UKESM1 - are used to compare future projections of warm spells under the moderate and policy-relevant SSP2-4.5 emissions scenario and an SAI deployment scenario that would begin in 2035 with the goal to maintain global mean temperature at 1.5C above pre-industrial. Although SAI deployment is able to mitigate future increases in warm spell event frequency and intensity that are expected under SSP2-4.5 in both CESM2 and UKESM1, there are distinct differences in how these models simulate future projections of warm spells, regardless of whether SAI is deployed. The physical mechanisms driving these differences are assessed and explained to address sources of intermodel uncertainty.



## **Future Seasonal Surface Temperature Predictability with and without ARISE-Stratospheric Aerosol Injection-1.5**

*Kirsten Mayer (NSF NCAR)*

To help reduce anthropogenic climate change impacts, various forms of solar radiation modification have been proposed to reduce the rate of warming. One method to intentionally reflect sunlight into space is through the introduction of reflective particles into the stratosphere, known as stratospheric aerosol injection (SAI). Previous research has shown that SAI implementation could lead to future climate impacts beyond surface temperature, including changes in El Niño Southern Oscillation (ENSO) variability. This response has the potential to modulate midlatitude variability and predictability through atmospheric teleconnections. Here, we explore possible differences in seasonal surface temperature predictability under a future with and without SAI implementation, using neural networks and the ARISE-SAI-1.5 simulations.

## **Evaluating the Impact of Solar Climate Intervention on Tropical Weather Extremes Using a Convection-Permitting Model for Prediction Across Scales-Atmosphere**

*Kelly Núñez Ocasio (Texas A&M University)*

This talk will focus on a recently submitted NSF proposal that proposes to investigate how stratospheric aerosol injection (SAI) geoengineering interacts with anthropogenic climate change to influence high-impact weather systems over Africa and the tropical Atlantic. Using a novel 15–3 km regionally refined, convection-permitting configuration of the Model for Prediction Across Scales–Atmosphere (MPAS-A), we will simulate the historically active 2020 Atlantic hurricane season under present-day conditions, a future warming scenario (SSP2-4.5), and three SAI scenarios from the ARISE ensemble (ARISE-SAI-1.5, ARISE-SAI-1.0, and ARISE-SAI-1.5-2045). The research will systematically examine how SAI and climate change jointly modulate the African Easterly Jet–West African Monsoon (AEJ–WAM) system, mesoscale convective systems (MCSs), African easterly waves (AEWs), and tropical cyclone (TC) genesis. Specifically, this work addresses three core science questions: (1) What are the impacts of SAI on the AEJ–WAM system? (2) How does SAI affect MCS frequency, intensity, and extreme rainfall? (3) What are the combined effects of SAI and warming on AEW dynamics and TC genesis? The 2020 season is particularly well suited for this analysis given its exceptional TC activity and the availability of a comprehensive ARISE ensemble. We will employ objective tracking algorithms—TAMS for MCSs, QTrack for AEWs, and TempestExtremes for TCs—to quantify changes in storm characteristics, including frequency, intensity, duration, propagation speed, and rainfall extremes. The talk will also provide motivation and background on the Atlantic–Africa regional climate system and summarize current knowledge gaps regarding how both SAI and projected global warming influence high-impact weather in this region. Finally, I will outline methodological developments within MPAS-A to represent SAI-related aerosol perturbations in the pseudo-SAI experiments, and highlight the advantages of the regionally refined MPAS framework relative to traditional global climate model configurations.



## Toward Reliable Regional Climate Intervention Information for Africa: Insights from Variable-Resolution CESM Experiments

*Kwesi A. Quagraine (NSF NCAR)*

Assessments of stratospheric aerosol injection (SAI) impacts over Africa depend on global climate models at horizontal resolutions ( $\sim 1^\circ$ ) too coarse to resolve the mesoscale circulations and convective organization governing regional precipitation. Whether the SAI precipitation response itself is resolution-dependent remains largely untested, introducing unquantified uncertainty into regional impact assessments for a continent where climate intervention consequences are of acute concern. We address this gap using variable-resolution CESM2-WACCM6 experiments that refine resolution from  $\sim 1^\circ$  ( $ne30$ ) to  $\sim 0.25^\circ$  ( $ne30 \times 4$ ) over Africa while maintaining a global domain with full stratospheric chemistry. Paired SAI and no-SAI atmosphere-only simulations with prescribed SST and sea ice boundary conditions from SSP5-8.5 runs isolate the atmospheric resolution effect across historical (2010-2030) and late-century (2080-2099) periods. Preliminary results reveal substantial resolution dependence in the SAI precipitation response. Over Central and West Africa, the coarse model produces strong SAI-induced drying largely absent at higher resolution, where enhanced dynamic moisture convergence offsets thermodynamic drying. Resolution-dependent differences in convective versus large-scale precipitation partitioning and diurnal cycle representation further shape these contrasting responses. These findings suggest that coarse-resolution SAI assessments may systematically misrepresent regional precipitation impacts over Africa, with implications for climate intervention governance and regional adaptation planning.

## How does SAI impact Atmospheric Rivers?

*Kwesi T. Quagraine (Texas A&M)*

In a warming climate, where climate adaptation and mitigation strategies are increasingly critical, understanding changes in major global atmospheric moisture transport mechanisms, such as atmospheric rivers (ARs), is essential for assessing shifts in the hydrological cycle. This study examines the frequency and impacts of ARs under the shared socioeconomic pathway (SSP2-4.5) warming scenario and the stratospheric aerosol injection (SAI) scenario (ARISE-SAI-1.5). Our findings indicate that under SAI-1.5, ARs retreat from inland regions, and the occurrence of high-impact ARs (Category 3 and above) decreases, although some uncertainty remains regarding the response time of ARs to SAI. However, under future climate without SAI (SSP2-4.5), ARs penetrate further inland, and there are higher numbers of high-impact ARs (Category 3 ARs). In the northern hemisphere oceans, SAI-1.5 leads to a gradual increase in AR frequency compared to SSP2-4.5, whereas the southern hemisphere oceans exhibit the opposite trend. Also, extreme AR-associated precipitation is reduced under SAI-1.5 relative to SSP2-4.5, whereas beneficial precipitation is projected to increase under SAI-1.5. The contrasting responses associated with AR location and intensity highlights the need for further research to better understand the underlying drivers of AR changes before SAI can be considered in policy decisions affecting global moisture transport mechanisms.



## From Roadmap to Research: Assessing Approaches to Slow Arctic Sea Ice Loss

*Ginny (Virginia) Selz (Ocean Visions)*

The Arctic has warmed three to four times faster than the global average alongside a roughly 50 percent decline in summer sea ice over the last forty years. Arctic sea ice changes influence global climate by accelerating regional warming, increasing ice-sheet melting, contributing to permafrost-driven methane emissions, disrupting ecosystems, and altering weather patterns and ocean circulation far beyond the polar region. While carbon mitigation and removal are necessary and non-negotiable to stabilize climate, scenarios inclusive of decarbonization targets suggest an intermittent ice-free Arctic by 2050, with cascading global impacts. In response, a number of emerging approaches have been proposed to slow the loss of Arctic Sea Ice. Ocean Visions led a collaborative assessment that evaluated 21 of these proposed approaches, including several types of solar climate intervention, examining their scientific basis, feasibility, and risks. The resulting Roadmaps identified priority research needs at global and Arctic scales. Roadmaps serve as the basis and guide the Arctic Sea Ice Restoration Research Fund and its initial portfolio that includes work on both Marine Cloud Brightening and Mixed Phase Cloud Thinning. Future work will build on early findings and the Roadmaps to advance responsible research.

### **KEYNOTE: Governance and ethics considerations in SRM research**

Solar radiation modification (SRM) has moved from the margins of climate discourse into a rapidly evolving field with growing attention. SRM could potentially limit some harms from climate change, but there is still considerable uncertainty surrounding its physical and social impacts, and the political context of the field remains fraught. The global nature of SRM, including the ethical and justice implications of such approaches demand thoughtful and inclusive governance - including for research. This talk will explore why governance matters: without transparent norms, accountability, and meaningful public participation, SRM research risks proceeding in ways that reinforce power imbalances, erode public trust, and ultimately harm the research itself. This talk will also describe the growing landscape of activity, including ethical frameworks, intergovernmental perspectives, and national government actions. By contextualizing SRM research governance within its historical trajectory and current ethical debates, it will highlight both the challenges and opportunities of building governance regimes that are just, inclusive, and robust enough to guide decisions in a challenging political era.



## **The impacts of stratospheric aerosol injection on extreme fire weather**

*Danielle Touma (University of Texas Institute for Geophysics)*

Stratospheric aerosol injection (SAI) would potentially be effective in limiting global warming and preserving large-scale temperature patterns; however, there are still gaps in understanding the impact of SAI on wildfire risk. In this study, extreme fire weather is assessed in an Earth system model experiment that deploys SAI beginning in 2035, targeting a global temperature increase of 1.5 degrees Celsius above pre-industrial levels under a moderate warming scenario. After SAI deployment, increases in extreme fire weather event frequency from climate change are dampened over much of the globe, including the Mediterranean, northeast Brazil, and eastern Europe. However, SAI has little impact over the western Amazon and northern Australia and causes larger increases in extreme fire weather frequency in west central Africa relative to the moderate emissions scenario. Variations in the impacts of warming and SAI on moisture conditions on different time scales determine the spatiotemporal differences in extreme fire weather frequency changes, and are plausibly linked to changes in synoptic-scale circulation. This study highlights that regional and spatial heterogeneities of SAI climate effects simulated in a model are amplified when assessing wildfire risk, and that these differences must be accounted for when quantifying the possible benefit of SAI.

## **An overview of SAI research efforts at NSF NCAR**

*Mari Tye (NSF NCAR)*

Using its Community Earth System Model (CESM), NSF NCAR has been contributing to the model ensembles of SAI simulations since the Geoengineering Large Ensemble (GLENS), in addition to targeted research using those simulations. Here I present an overview of the available data, and the different research activities that are ongoing.

## **KEYNOTE: Steps towards a more robust assessment of climate intervention strategies**

*Daniele Vioni (Cornell University)*

Past explosive volcanic eruptions have shown that large SO<sub>2</sub> injections in the stratosphere have a temporary cooling effect on our planet temperatures. This has led some to consider whether artificial injections of sulfate (Stratospheric Aerosols Injections, SAI), as well as other climate intervention strategies like Marine Cloud Brightening (MCB), could temporarily ameliorate some of the effects of climate change, as a supplement to emission reduction. Numerous climate models have analyzed the potential impacts of SAI and MCB: based on current international multi-model comparisons as part of the Geoengineering Model Intercomparison Project (GeoMIP), and large ensembles of simulations produced with the Community Earth System Model., I will describe broad areas of agreement but also highlight large inter-model differences and shortcomings from the simulation of aerosol clouds downstream to regional climate changes, as well as discuss the problems and some potential solutions with fully mapping the potential space of different climate intervention applications. Building on this, I will share some personal insights about areas where future research should be headed (with an eye towards the specific topics that will be discussed in this workshop) through my experiences in the World Climate Research Programme Lighthouse Activity on Climate Intervention Research and as part of Seventh Assessment Report for the Intergovernmental Panel on Climate Change (IPCC). As the topic of climate intervention gains relevance internationally, it is clear that the basis for any potential future agreement around this topic can't just include improved modeling tools and better observational capabilities, but also a wide range of collaborations across disciplines both in the natural and social realms and a strong commitment to international cooperation.

## **Subtropical Marine Cloud Brightening Suppresses the El Niño–Southern Oscillation**

*Chen Xing (University of Texas Institute for Geophysics)*

Stratospheric aerosol injection (SAI) and marine cloud brightening (MCB) are two proposed methods of compensating for greenhouse gas-induced warming by reflecting incoming solar radiation. However, their effects on the El Niño–Southern Oscillation (ENSO), a critical mode of climate variability, are poorly understood. Here we use ensembles of climate model simulations to show that deploying MCB in the subtropical eastern Pacific dramatically reduces ENSO amplitude by approximately 61%, while SAI has a negligible impact. MCB increases cloud albedo, which cools the subtropical eastern Pacific and triggers a loss of moist static energy. This cooling promotes atmospheric subsidence, dries the tropical Pacific, and intensifies the trade winds. The ultimate effect is a dramatic reduction in all air-sea feedback processes operating during ENSO, which we demonstrate using a mixed-layer heat budget. This contrast between the MCB and SAI impacts on ENSO shows that the choice of climate intervention strategy used to mitigate global warming has drastic regional implications.



## How Solar Climate Intervention May Shape Extreme Climate Events

*Leyuan “Lexie” Zhang (University of Texas Institute for Geophysics)*

This presentation introduces key concepts and physical mechanisms relevant to the Solar Climate Intervention Impacts on Extremes (SCI-EX) Workshop. It provides a common framework for the discussions that follow. Major solar climate intervention approaches, including stratospheric aerosol injection and marine cloud brightening, are briefly reviewed. The talk then examines how these strategies may influence extreme climate events by altering temperature, precipitation, and atmospheric circulation. Current modeling efforts and commonly used datasets in SCI research, including global and downscaled climate simulations, are also discussed. The focus is on hydroclimate and drought-related extremes, with additional attention to compound events and predictability.

*Organizing committee: Danielle Touma, Geeta Persad, and Leyuan (Lexie) Zhang at The University of Texas at Austin.*

*This workshop is supported in part by Linda Steen-Norris & Lee Norris. We are grateful for Dr. and Mrs. Norris’s generosity and commitment to advancing research in solar climate intervention.*

