

# Targeted marine cloud brightening can dampen El Niño

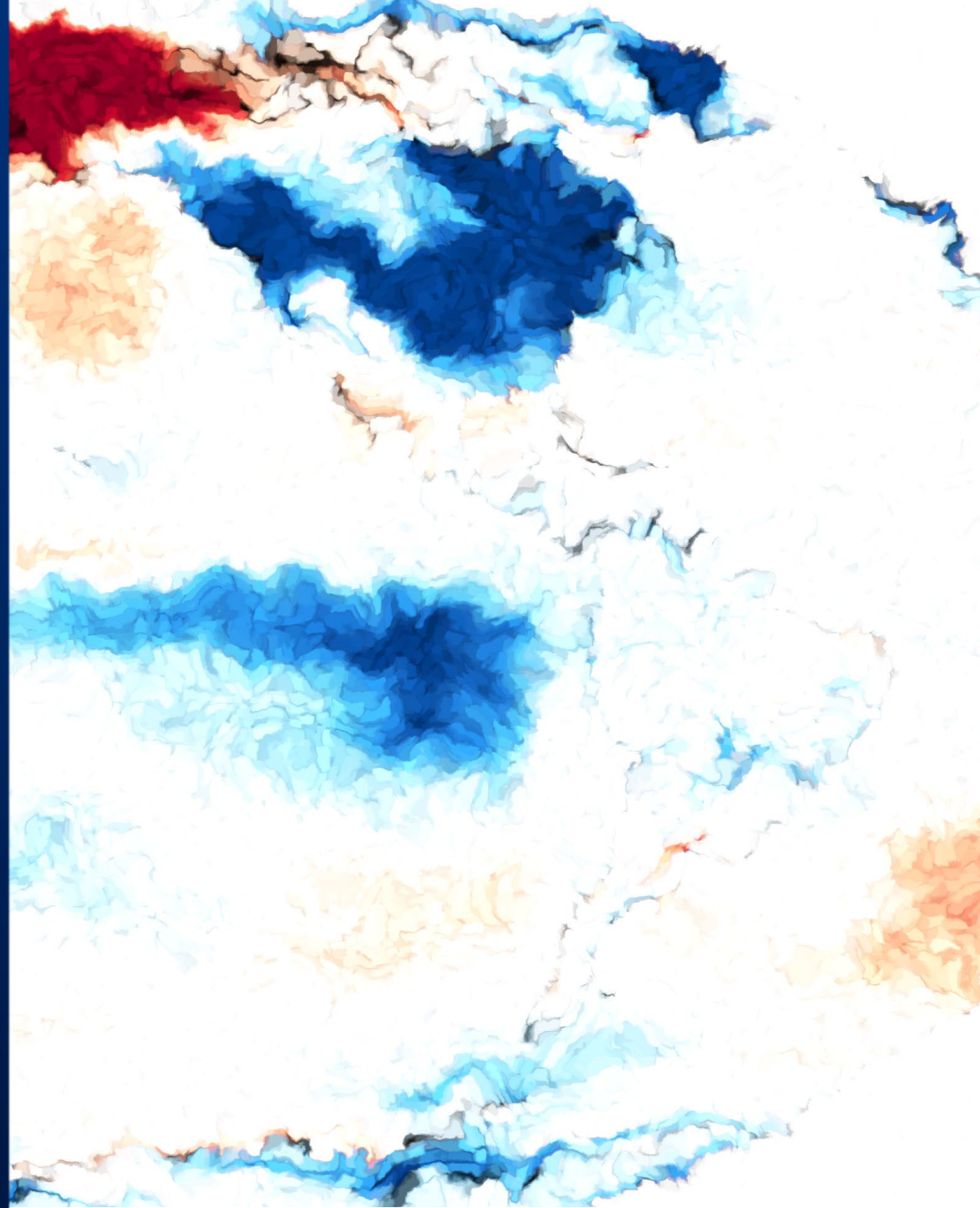
Jessica Wan

Scripps Institution of Oceanography, UC San Diego

with John Fasullo, Nan Rosenbloom, Chih-Chieh Jack Chen, Katharine Ricke

2024 CESM Workshop

12 June 2024



# We are currently experiencing compounding effects of anthropogenic warming and the 2023-24 El Niño

The Washington Post  
*Democracy Dies in Darkness*

## Record California storm fueled by bomb cyclone, El Niño, climate change

The storm directed an intense atmospheric river — or a moisture stream thousands of miles long — directly into Southern California

By Diana Leonard

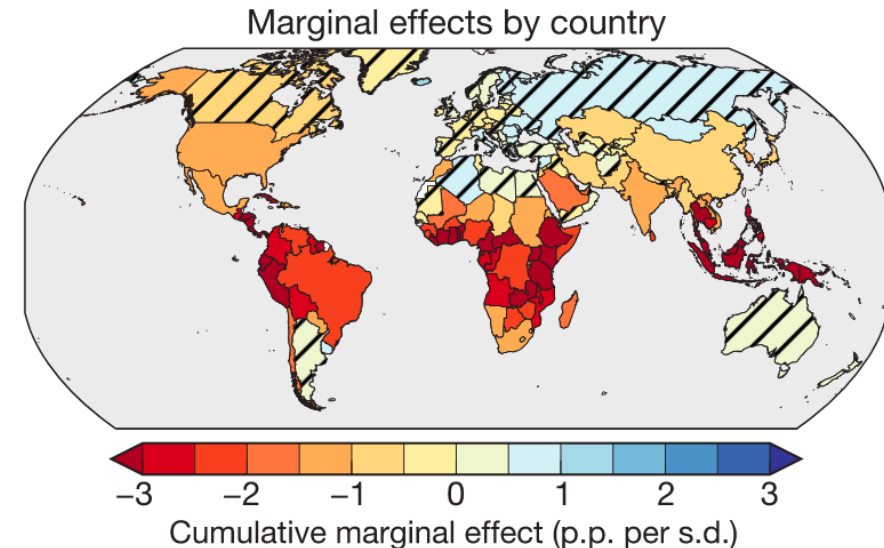
Updated February 6, 2024 at 4:44 p.m. EST | Published February 6, 2024 at 9:24 a.m. EST

World / Climate

## Planet endures record-hot April, as scientists warn 2024 could beat heat records for second year in a row

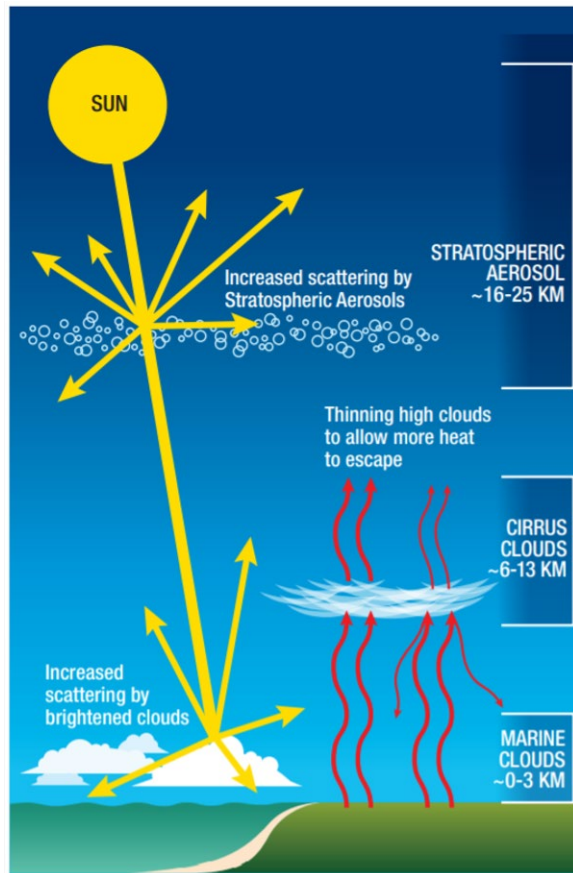
By Laura Paddison, CNN

© 3 minute read · Published 10:00 PM EDT, Tue May 7, 2024



(Callahan & Mankin, 2023)

# Solar geoengineering was originally proposed as an approach to reduce long-term global warming



Stratospheric aerosol injection (SAI)

Cirrus cloud thinning (CCT)

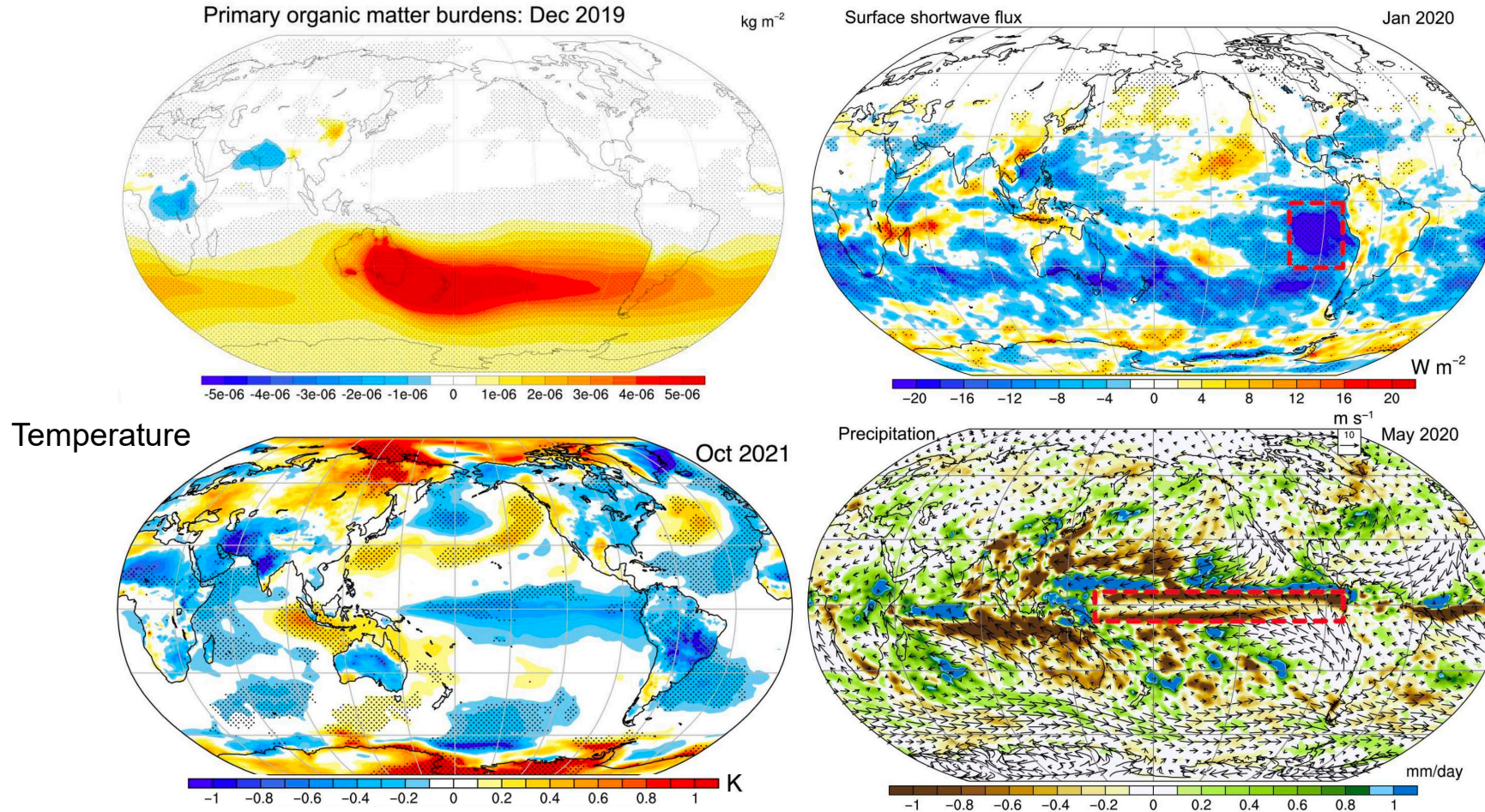
Marine cloud brightening (MCB)

“attempts to moderate warming by **increasing** the amount of **sunlight** that the atmosphere **reflects back to space** or by **reducing the trapping of outgoing thermal radiation**”

(National Academies, 2021)

...could regional marine cloud brightening instead target *seasonal* phenomena such as ENSO?

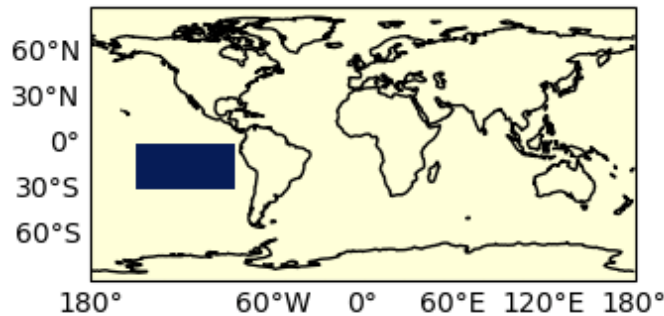
# “Natural” cloud brightening during 2019-20 Australian wildfires in CESM2 suggests regional MCB could enhance La Niña conditions



(Fasullo et al., 2023)

# Simulating ENSO response to MCB with the Seasonal-to-Multiyear Large Ensemble (SMYLE) using CESM2

1) Develop MCB masks nudging CDNC~500 #/cm<sup>3</sup> with varying initiation months and durations



Could MCB be deployed *after* the **spring predictability barrier** and still have an influence on the developing ENSO event?

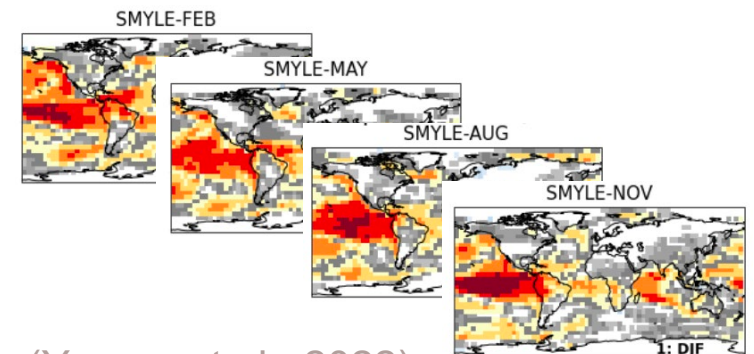
2) Select three historical events to test MCB's influence on ENSO

**2020-21**  
**La Niña:**  
Can we validate wildfire response in Fasullo et al. with MCB?

**2015-16**  
**El Niño:**  
How effective is MCB at weakening El Niño?

**1997-98**  
**El Niño:**  
Are the responses robust across different events?

3) Run 10-member SMYLE using CESM2 with MCB for illustrative ENSO events



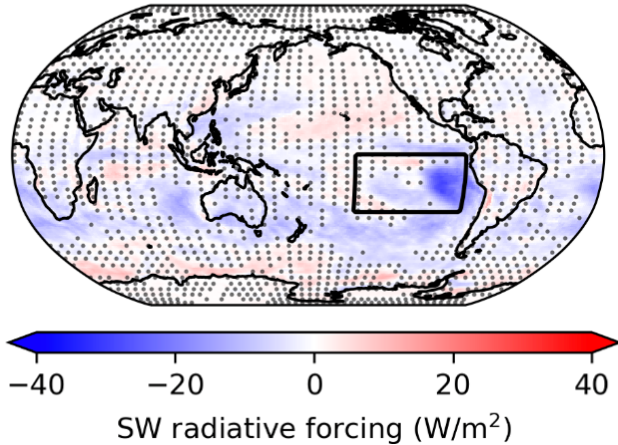
(Yeager et al., 2022)

**SMYLE** is a skilled **seasonal prediction tool** using **CESM2** for near-term prediction of multiyear phenomena including **ENSO**.

# MCB enhances La Niña conditions, reproducing the observed cloud responses from the 2019-20 Australian wildfires as a natural analog for MCB

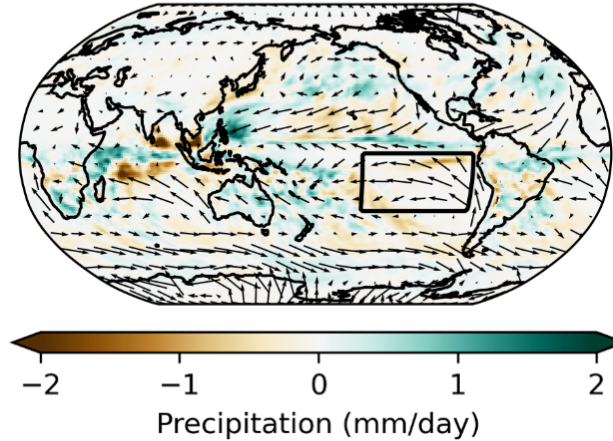
Clouds brighten in the SESP region leading to negative surface SW flux

**a** 2020-2021 La Niña + wildfires



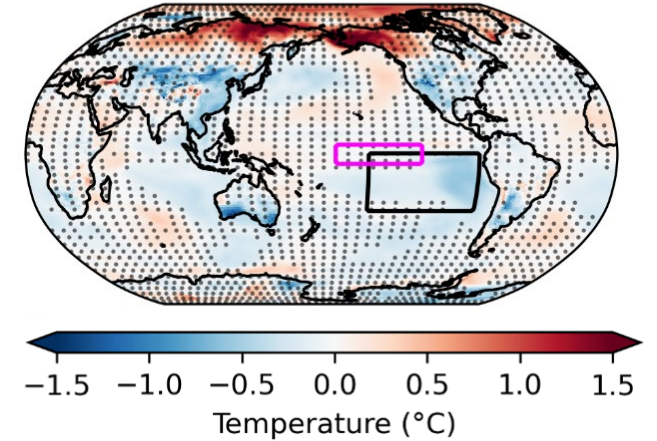
Intertropical convergence zone shifts northward

**b**



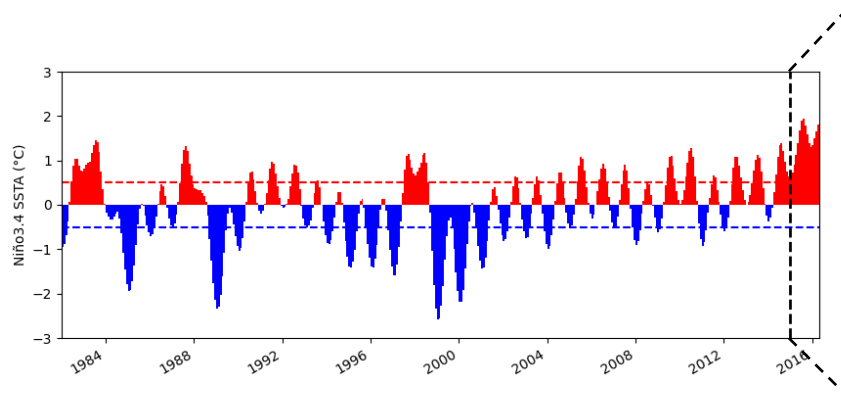
Niño3.4 region cools and La Niña-like pattern develops

**c**

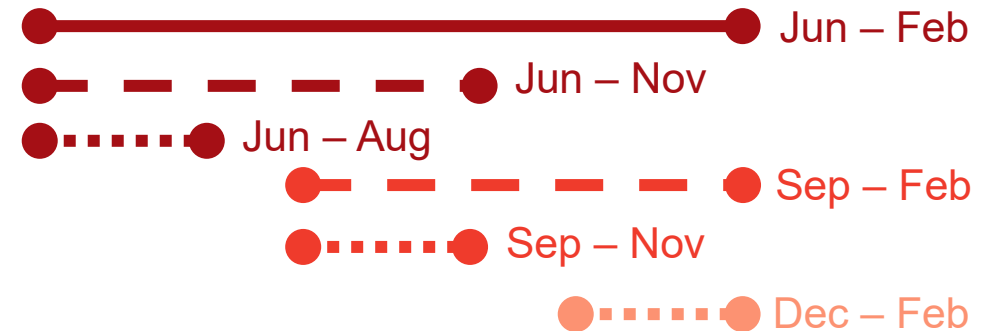


(Wan et al., submitted)

# Could we deploy MCB after the spring predictability barrier to deliberately weaken El Niño?



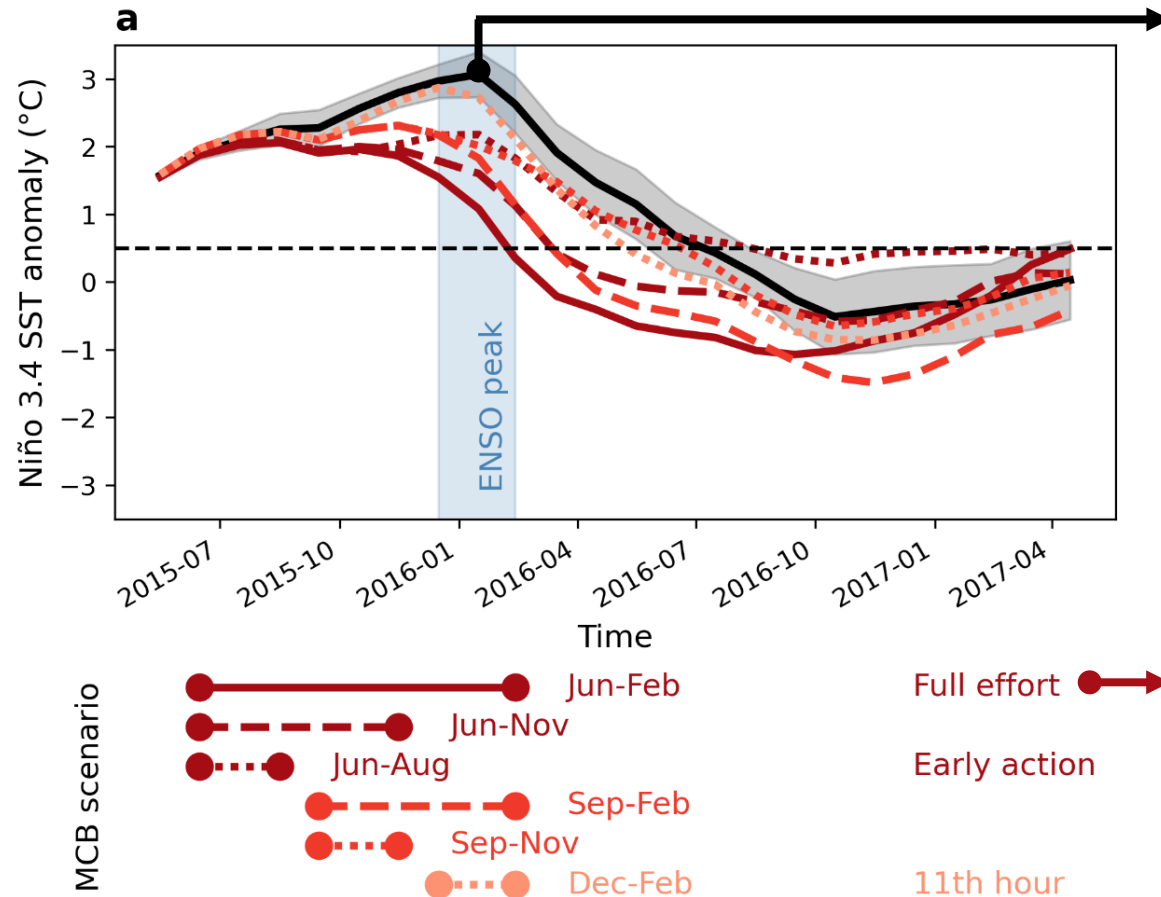
MCB scenario



(Wan et al., submitted)

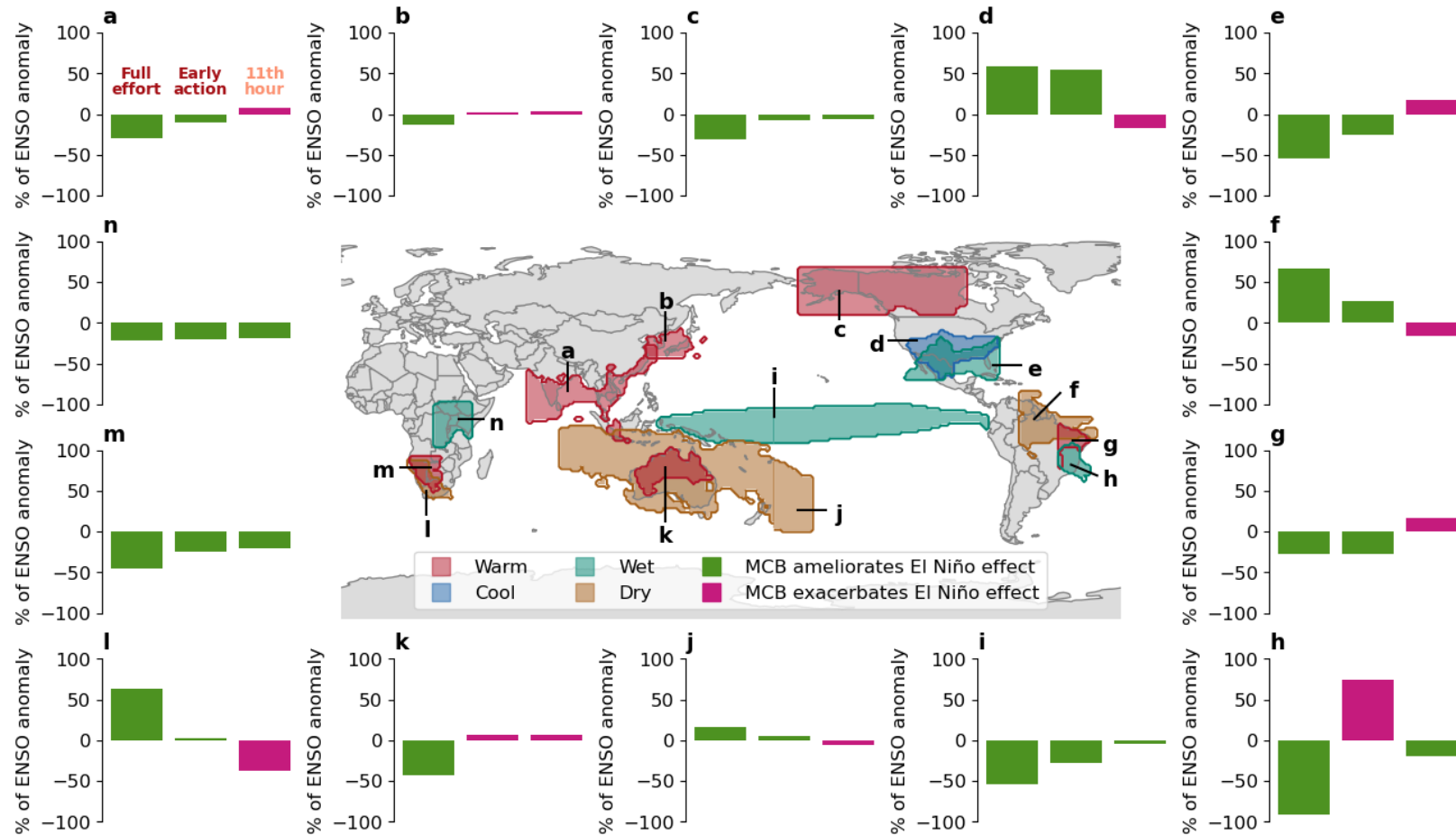


# MCB dampens El Niño, and the responses depend on the timing of intervention



(Wan et al., submitted)

# Timely strategic MCB deployment could ameliorate remote teleconnections caused by El Niño



(Wan et al., submitted)

1. We exploit an experiment-of-opportunity for model validation.

The 2019-20 Australian wildfire event contributing to La Niña is a good natural analog for regional MCB.

2. We establish a link between our observational analogue and a welfare-relevant climate risk.

The responses are similar if cloud brightening had occurred prior to an El Niño instead.

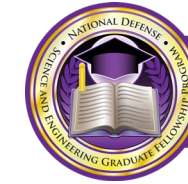
3. We demonstrate physical feasibility within the constraints of ENSO predictive capabilities.

MCB deployed after the spring predictability barrier could deliberately dampen El Niño.

# References

- Leonard, D. (2024). Record California storm fueled by bomb cyclone, El Niño, climate change. The Washington Post. <https://www.washingtonpost.com/weather/2024/02/06/california-storm-atmospheric-river-explained/>
- Paddison, L. (2024). Planet endures record-hot April, as scientists warn 2024 could beat heat records for second year in a row. <https://www.cnn.com/2024/05/07/climate/record-hot-april/index.html>
- Callahan, C. W. & Mankin, J. S. (2023). Persistent effect of El Niño on global economic growth. *Science* 380, 1064–1069.
- Feingold, G., et al. (2024). Physical science research needed to evaluate the viability and risks of marine cloud brightening. *Sci. Adv.* 10, eadi8594(2024). DOI:10.1126/sciadv.adi8594
- Fasullo, J. T., et al. (2023). A multiyear tropical Pacific cooling response to recent Australian wildfires in CESM2. *Sci Adv*, 9(19), eadg1213.
- Yeager, S. G., et al. (2022). The Seasonal-to-Multiyear Large Ensemble (SMYLE) prediction system using the Community Earth System Model version 2. *GMD*, 15(16), 6451–6493.
- Lindsey, R. (2016). Global impacts of El Niño and La Niña. Climate.gov. <https://www.climate.gov/news-features/featured-images/global-impacts-el-ni%C3%B1o-and-la-ni%C3%B1a>

We thank the following funders of this work:



**NDSEG**



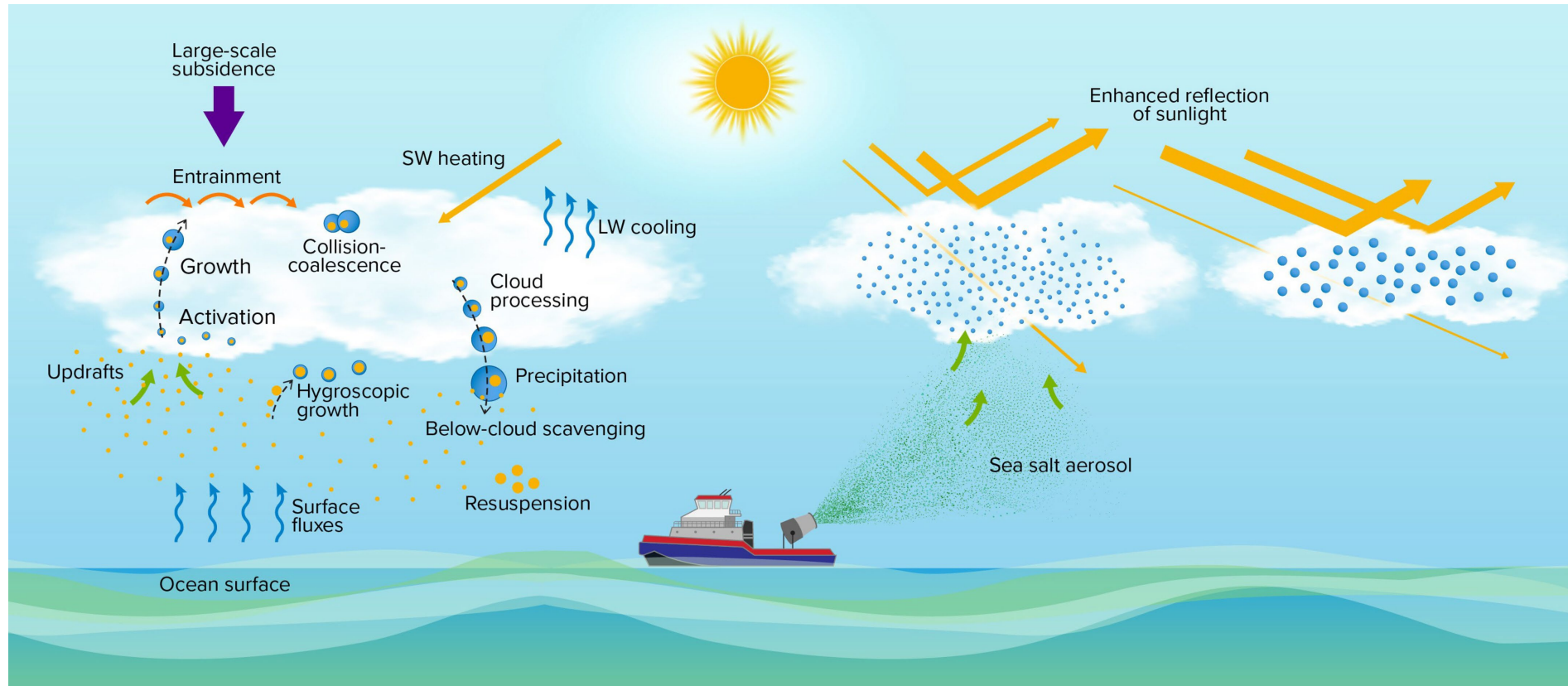
Thanks for listening!

**Jessica Wan**

✉ [j4wan@ucsd.edu](mailto:j4wan@ucsd.edu)  [jessicaswan.github.io](https://jessicaswan.github.io)

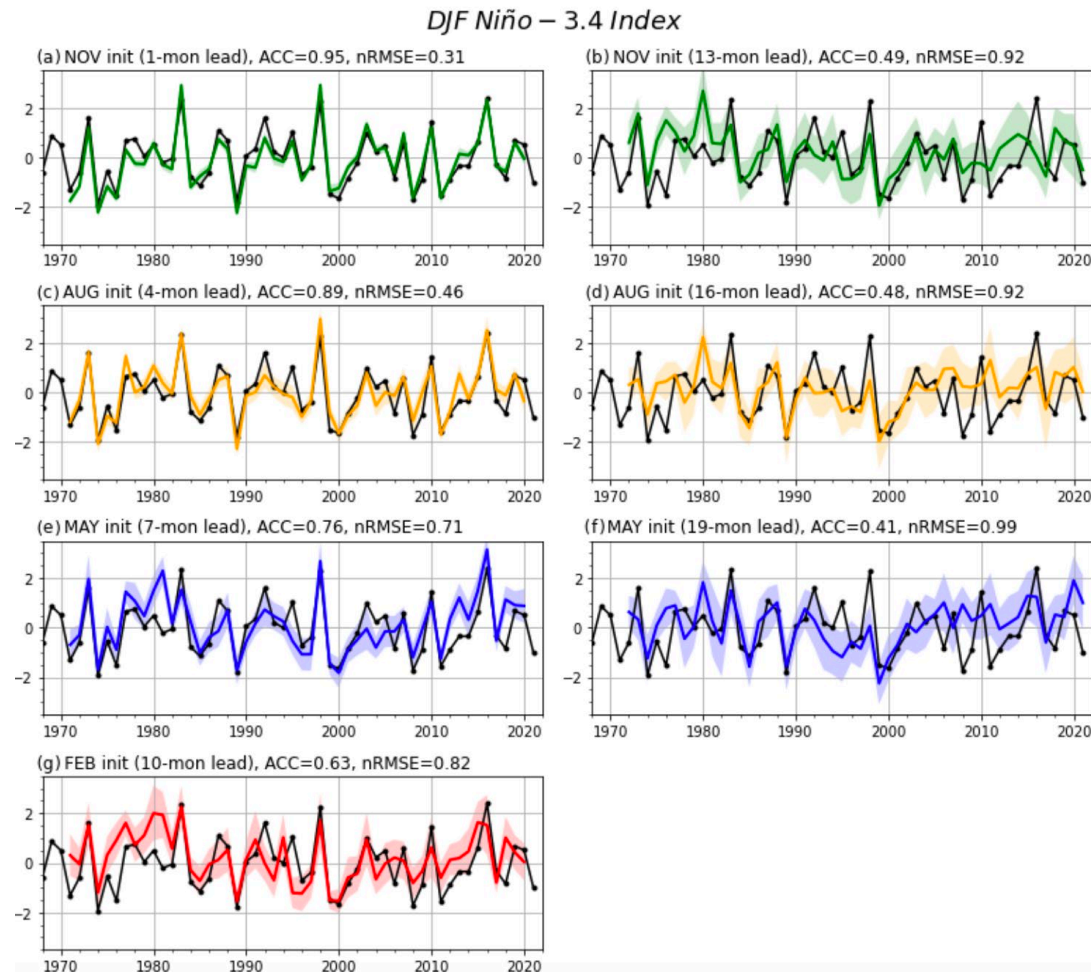
✂ @jesswan15

# How does marine cloud brightening (MCB) work?



(Feingold et al., 2024)

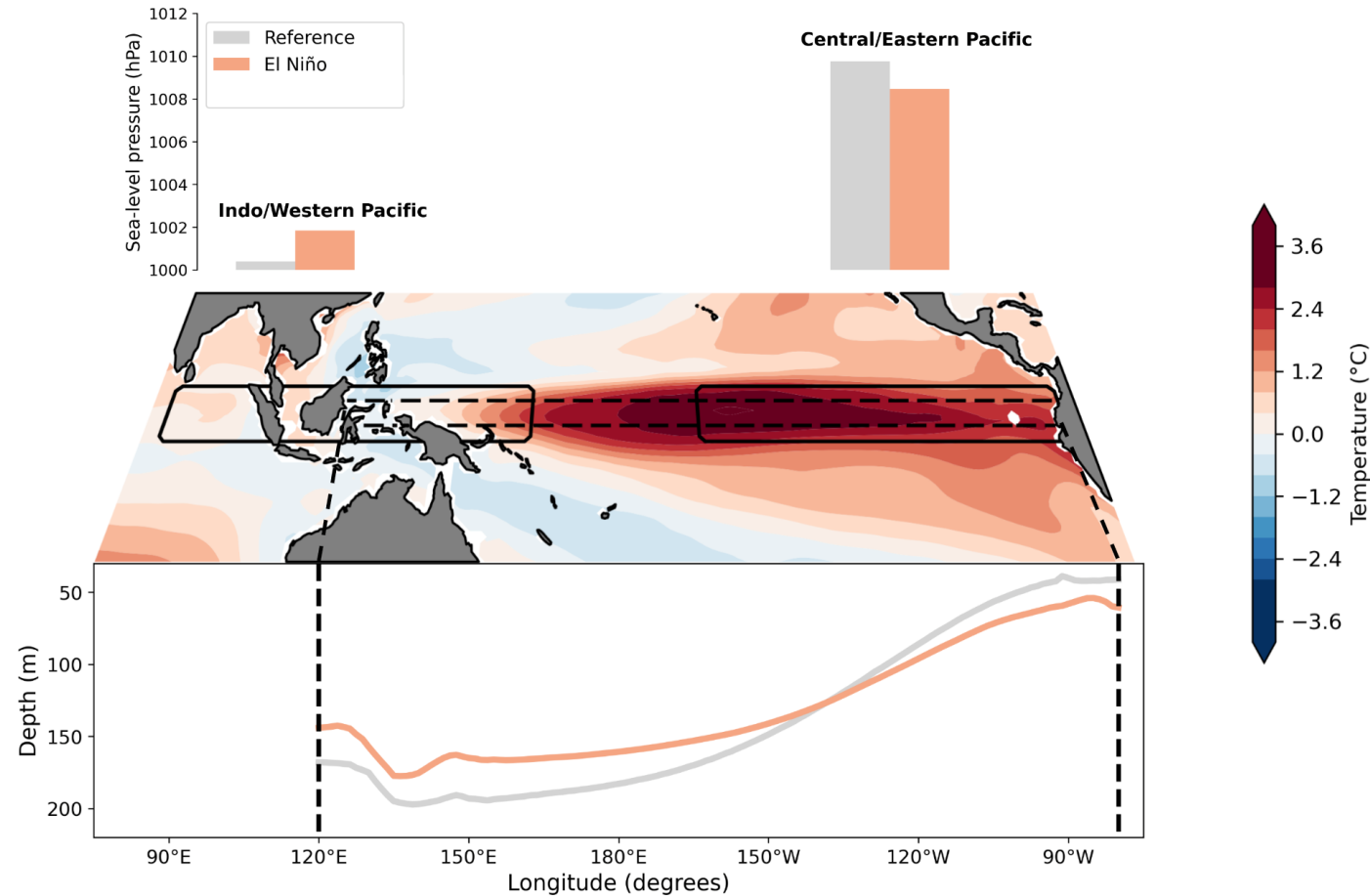
# How well does SMYLE reproduce ENSO?



SMYLE Niño3.4 prediction skill is comparable to other operational seasonal forecast systems with an anomaly correlation coefficient (ACC) of  $\sim 0.6$  at 12-month lead times.

(Yeager et al., 2022)

# Early MCB disrupts ENSO growth feedbacks, effectively restoring neutral conditions





# 1997-98 El Niño is also substantially weakened by MCB, but the magnitude and spatial response varies

