Assessing Changes in Atmospheric Rivers under Stratospheric Aerosol Injection (SAI) using ARISE-SAI-1.5 (Reproduced from Quagraine et al., 2025, revised)

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What are Atmospheric Rivers (ARs)?

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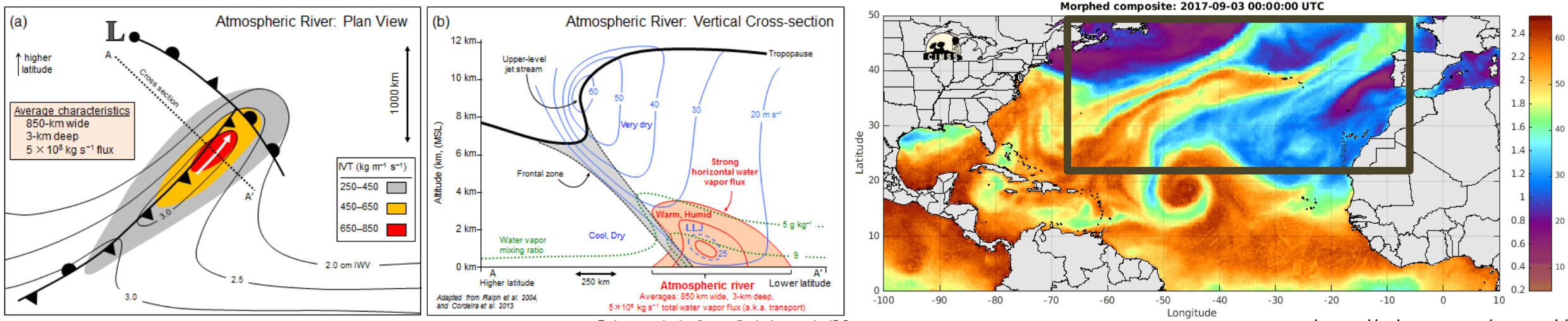
Atmospheric Rivers are a long, narrow, and transient corridor of strong horizontal water vapor transport that is typically associated with a low-level jet stream ahead of the cold front of an extratropical cyclone.

Horizontal water vapor transport in the midlatitudes occurs primarily in atmospheric rivers and is focused in the lower troposphere. Atmospheric rivers are the largest "rivers" of fresh water on Earth, transporting on average more than double the flow of the Amazon River.



Schematic is from Ralph et al. (2017).

https://psl.noaa.gov/arportal/

Why do we care?

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1. Weak ARs produce beneficial rain and snow for water stressed areas and drought relief *(Guan et al., 2010, M. Dettinger, 2011; Rutz & Steenburgh, 2012, Kunkel & Champion, 2019)*.

2. Contributes to high precipitation events globally *(Dhana Laskhmi & Satyanarayana, 2020, Blamey et al., 2018).*

3. Leads to flooding, landslides and more recently, enhance heatwaves *(Lamjiri et al., 2017, Barth et al., 2017, Mo et al., 2022, Scholz et al., 2024).*

AIM

THE PROBLEM

Due to climate change, the number of extreme precipitation events are projected to either increase in frequency and or intensify. In the present climate, ARs can be associated with both extreme and beneficial precipitation. However, **we do not know how these would be affected by SAI**

THE CLUE

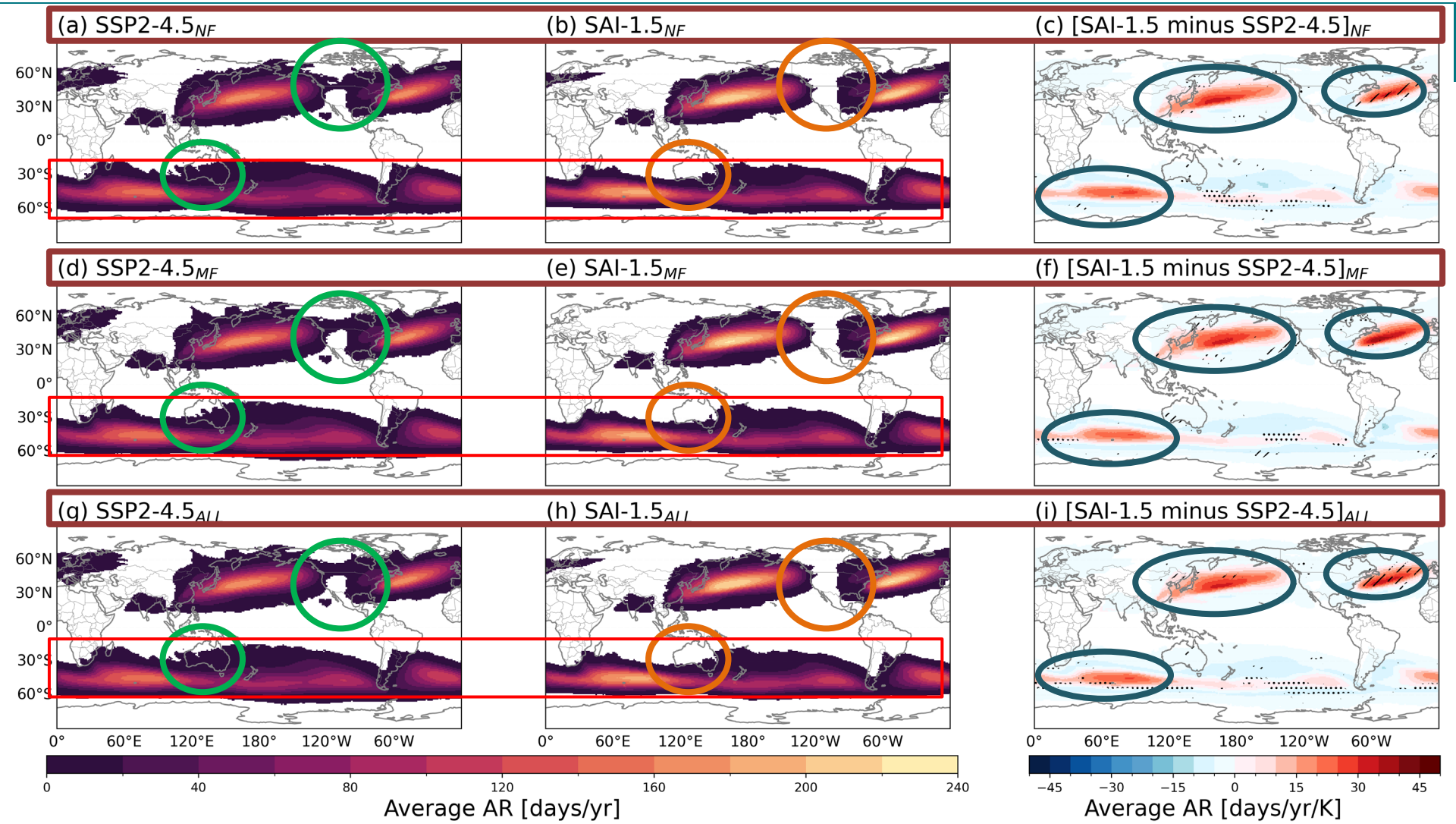
SAI is expected to cool the Earth's atmosphere temporarily as we look for long-term solutions. Therefore, **we expect SAI to reduce extreme precipitation associated with ARs**.

Data and Methods

DATASET	DETAILS
Whole Atmosphere Community Climate Model version 6 (WACCM6)	CESM2 with WACCM6 atmospheric component
SSP 2- 4.5 Scenario (WACCM6)	~2.7-3.4 C increase in temperature by end of century
Assessing Responses and Impacts of Solar Climate Intervention on the Earth with Stratospheric Aerosol Injection (ARISE-SAI-1.5)	Maintain 1.5 C increase above pre-industrial

- We split analyses into near-future (2035-2054, NF) and mid-future (2050-2069, MF)
- We detect ARs using the Toolkit for Extreme Climate Analysis Bayesian AR Detector (TECA BARD v1.0.1).
- We categorize ARs using the Ralph et al, 2019 AR categorization scale.

Results: How many AR days are projected under SAI and SSP?



THINGS TO NOTE

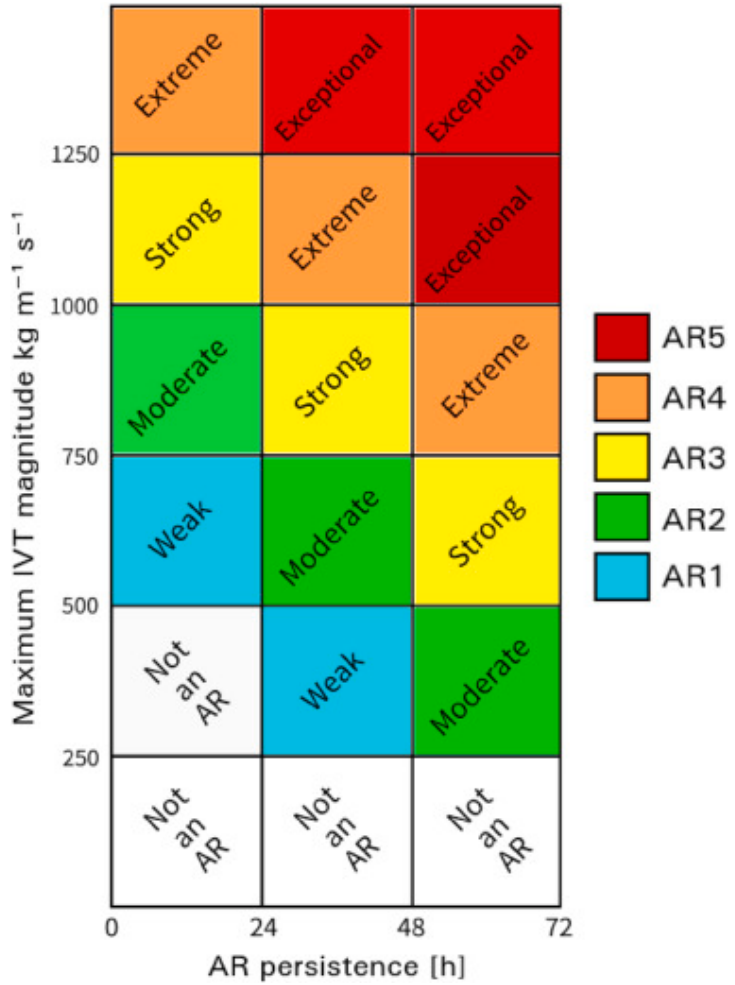
Compared to SSP, we observe

1. Fewer inland ARs days/year under SAI.

2. Higher number of ARs within the oceans under SAI.

3. ARs are restricted to mid-latitudes under SAI.

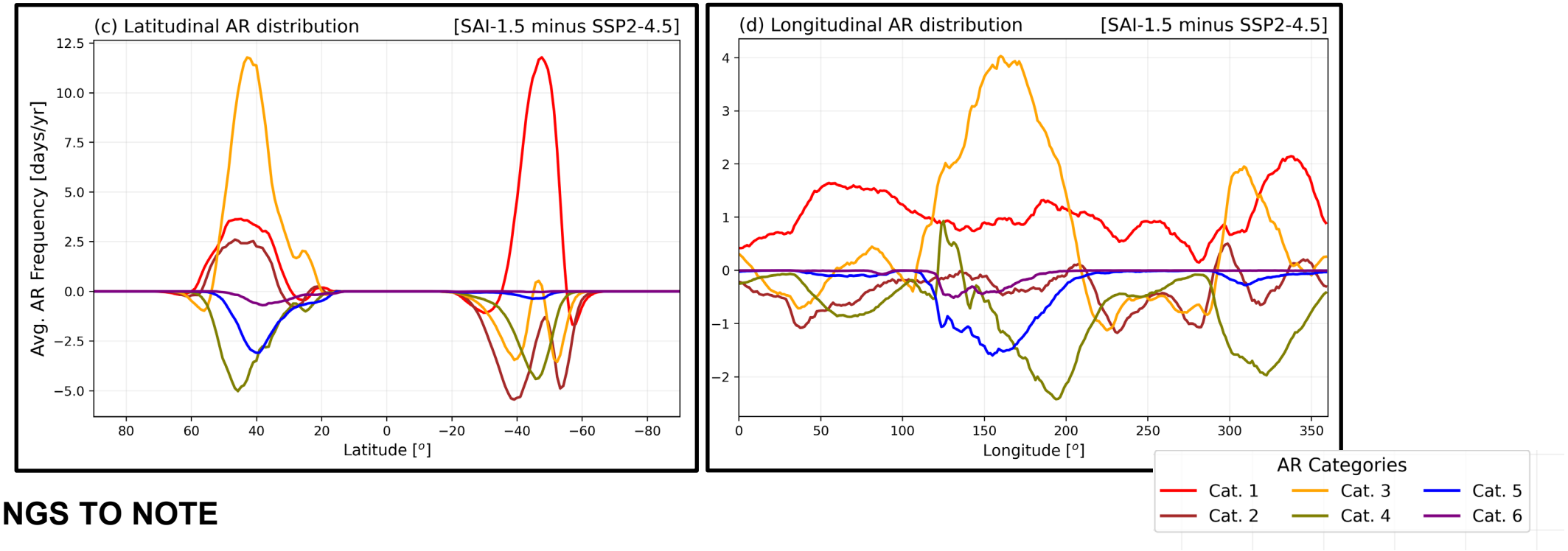
AR Categorization Scale (Ralph et al., 2019)



- weak is ≥ 250–500 kg m^{-1} s^{-1},
- moderate is ≥ 500–750 kg m^{-1} s^{-1} (transitional from mostly beneficial to hazardous),
- strong is ≥ 750 – 1,000 kg m^{-1} s^{-1},
- extreme is ≥ 1,000 – 1,250 kg m^{-1} s^{-1}, and
- exceptional is ≥ 1,250 kg m^{-1} s^{-1}.

Results: How does SAI affect AR categories compared to SSP?

Figure 2. Latitudinal and longitudinal distributions of Atmospheric River (AR) categories.



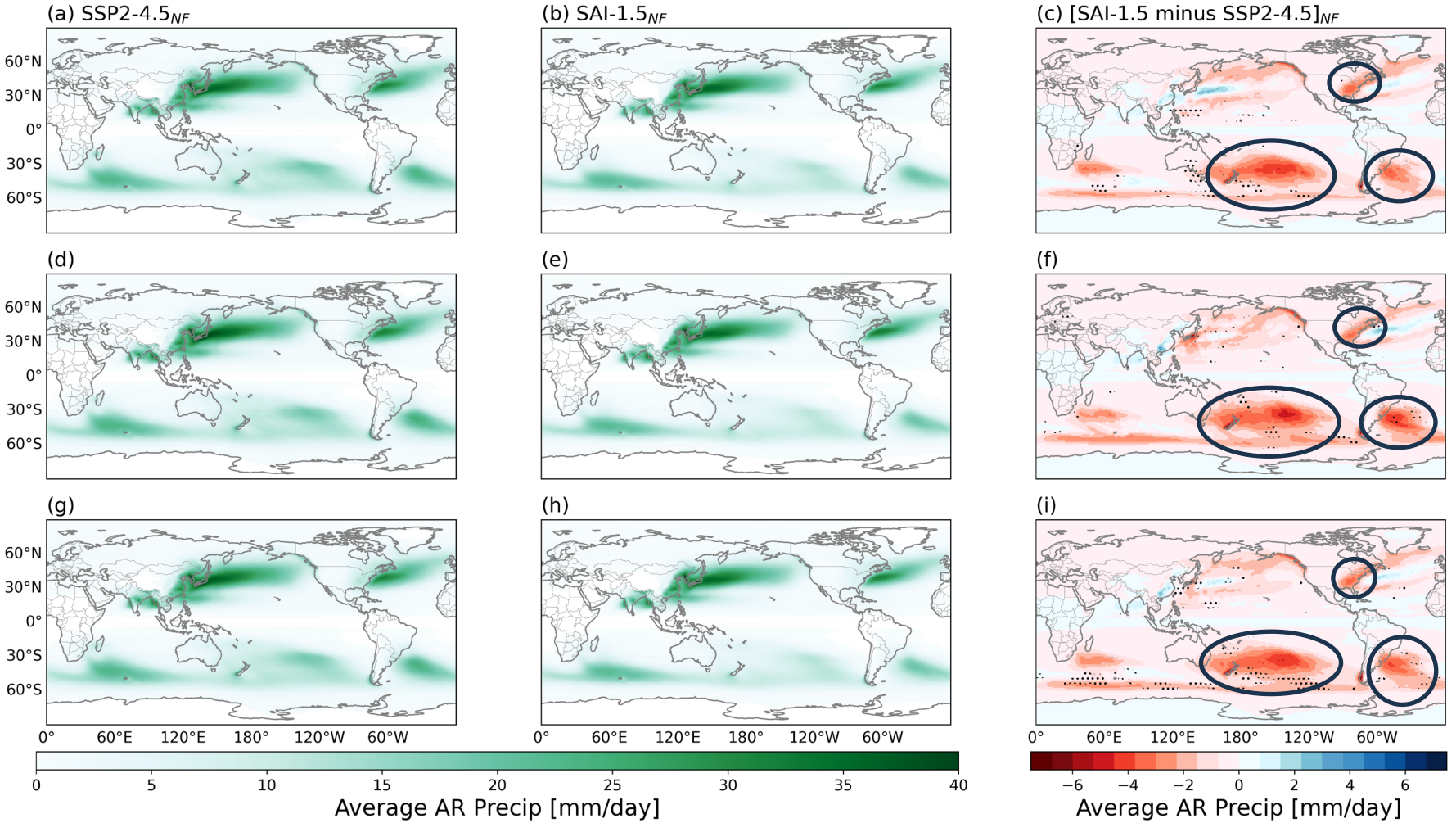
THINGS TO NOTE

1. Under SAI there is a decrease in the number of category 4 – 6 events compared to SSP in the Northern Hemisphere.
2. Number of category 1 events increase in the Southern Hemisphere.

All together, SAI reduces the number of extreme AR events but increases beneficial AR events in both Hemispheres.

Results: So why do we care?
AR – related precipitation

Figure 4. Figure shows spatial maps of AR – associated precipitation.



THINGS TO NOTE

SAI reduces AR-precipitation compared to SSP!

But most of these locations are within the oceans or closer to coastal areas.

SAI: Stratospheric Aerosol Injections
SSP: Shared Socio-economic Pathways

CONCLUSIONS

RESULTS ARE FOR ONE SAI SCENARIO (ARISE-SAI-1.5)

SAI reduces AR – associated precipitation.

SAI reduces number of catastrophic AR events per year

SAI increases beneficial AR events per year

Acknowledgements

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Thank you!

Questions