Understanding Atmospheric Rivers in a Future, Warmer Climate

Alexander Massa
Millersville University, NESSI

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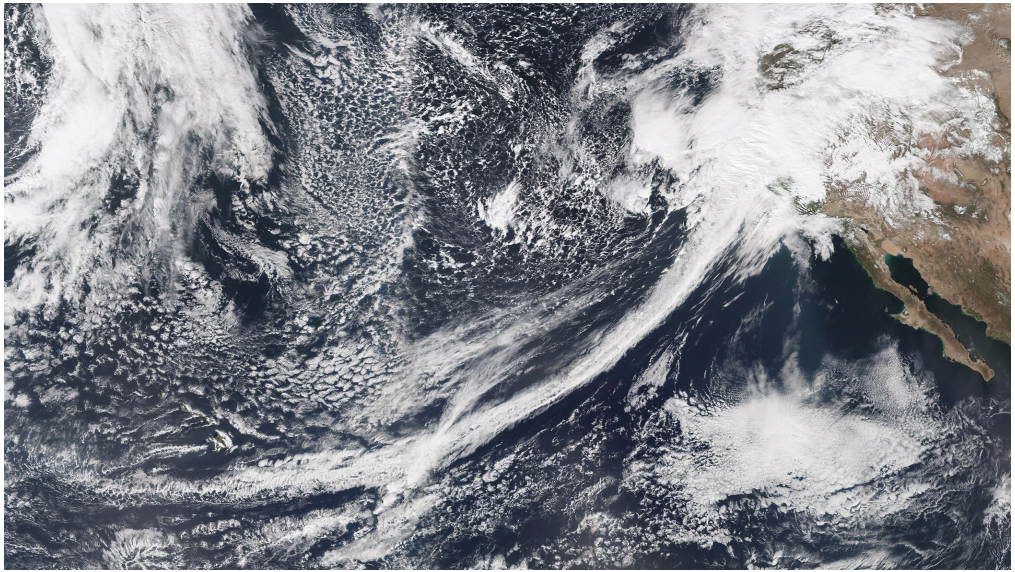
Outline

- **Background:** What is an atmospheric river (AR)?
- **Motivation:** How will climate change impact atmospheric rivers?
- **Plotting Atmospheric River Footprints:** Using data from the Atmospheric River Tracking Method Intercomparison Project and NCAR Command Language (NCL) scripts to produce plots of ARs
- **Atmospheric River Detection Tools (ARDTs):** Does the definition of an AR matter in order to understand ARs in a future climate?
- **Summary and Future Work**

What is an Atmospheric River?



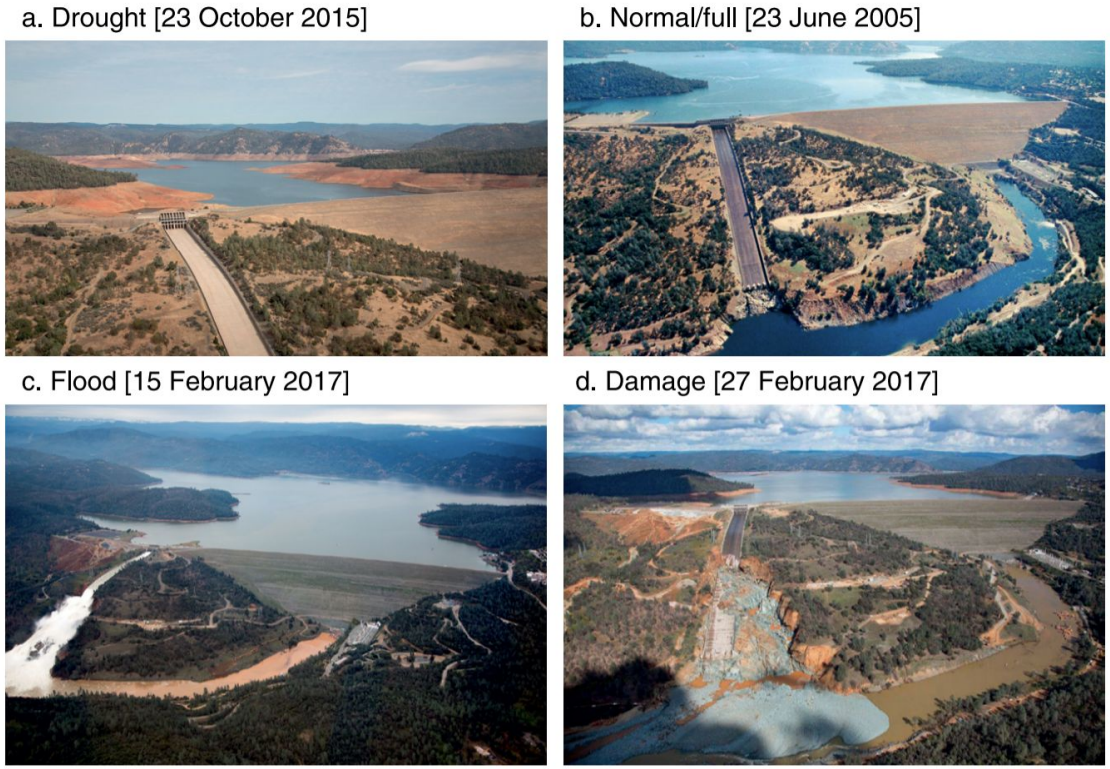
Credit: NASA; December 2017

"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" (Glossary of Meteorology).

What is an Atmospheric River?

- ARs provide around 30-50% of annual precipitation supply to areas along the West Coast (eg. Payne et al. and Dettinger)

- ARs serve as ‘drought busters’. Can also cause devastating environmental impacts (eg. Dettinger and Ralph et al.)



Oroville Dam

Credit: Fig. 1 from ‘A Scale to Characterize the Strength and Impacts of Atmospheric Rivers.’ Ralph et al. 2018

The Impacts of Climate Change

AR Climate change trends found in the literature :

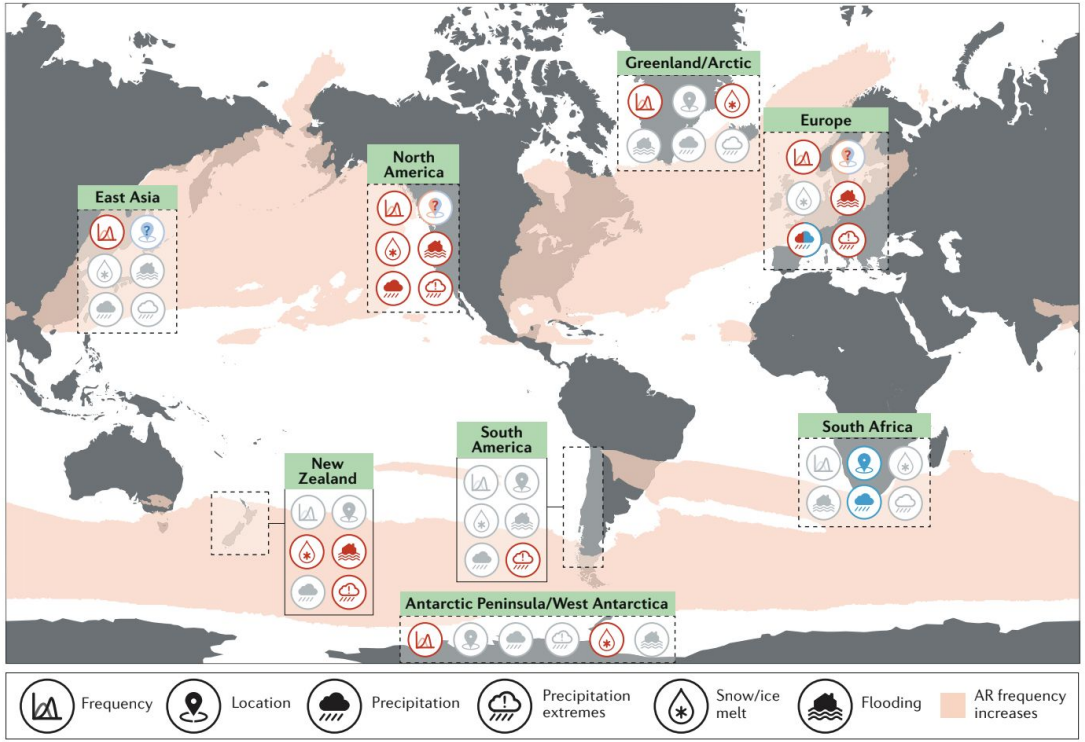
Regional summaries from NREE, Payne et al. 2020 based on all available literature.

Red icons = increases (Frequency poleward)

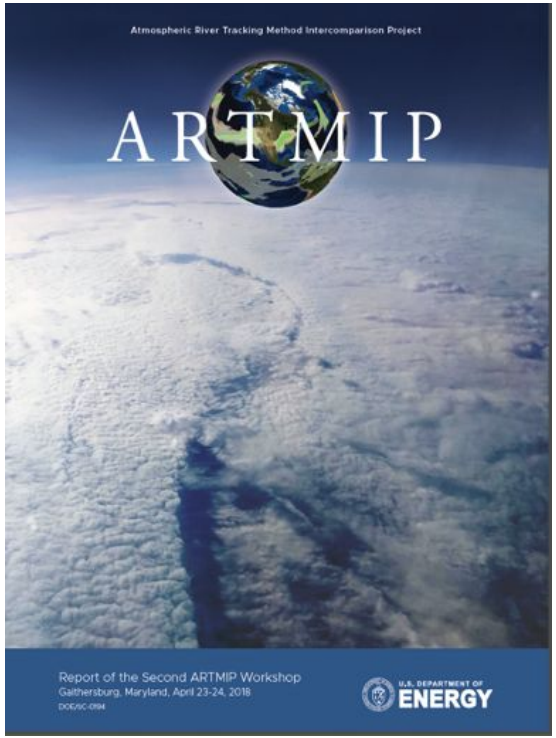
Blue icons = decreases (Frequency equatorward)

Pink shading based in Espinoza et al 2018 CMIP5 models with 1 algorithm.

Courtesy A. Payne



What is ARTMIP?



Picture credit: Jonathan Rutz
Report credit: U.S. Department of Energy

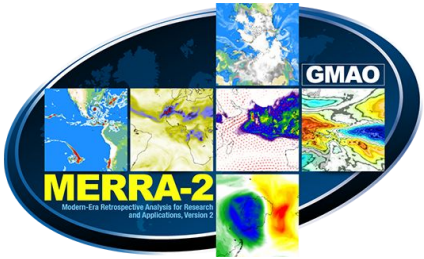
The goal of ARTMIP is to understand and quantify uncertainties in atmospheric river (AR) science based on choice of detection/tracking methodology.

https://www.cgd.ucar.edu/projects/artmip/

The Data Behind ARTMIP?

Tier 1:

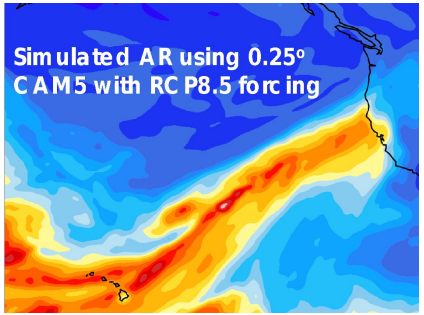
MERRA v2 Reanalysis Data



Source: https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/

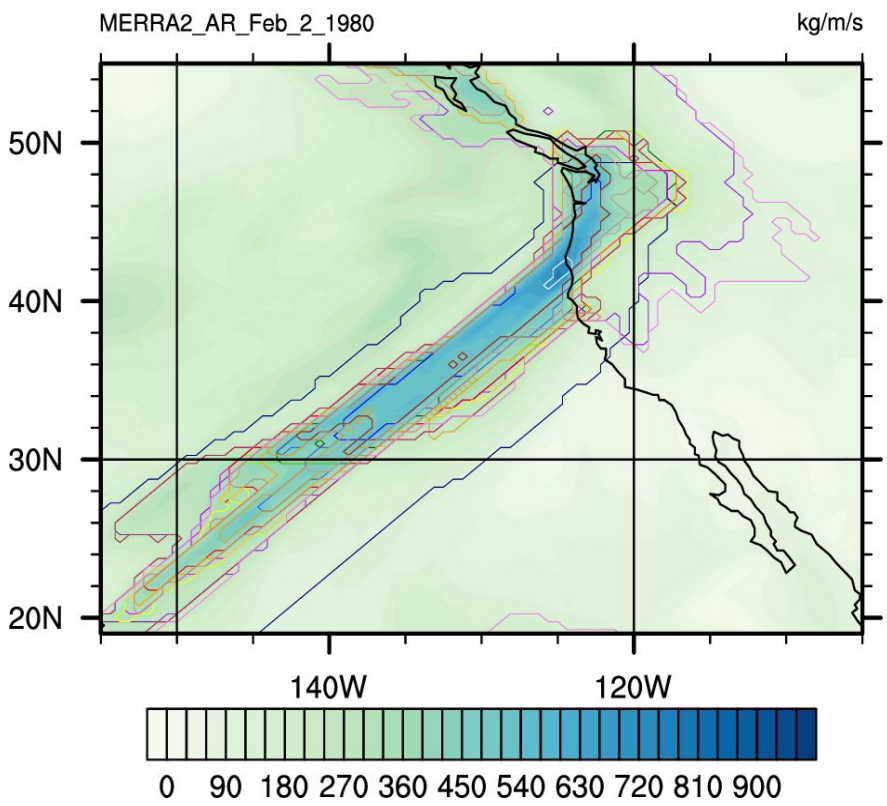
Tier 2:

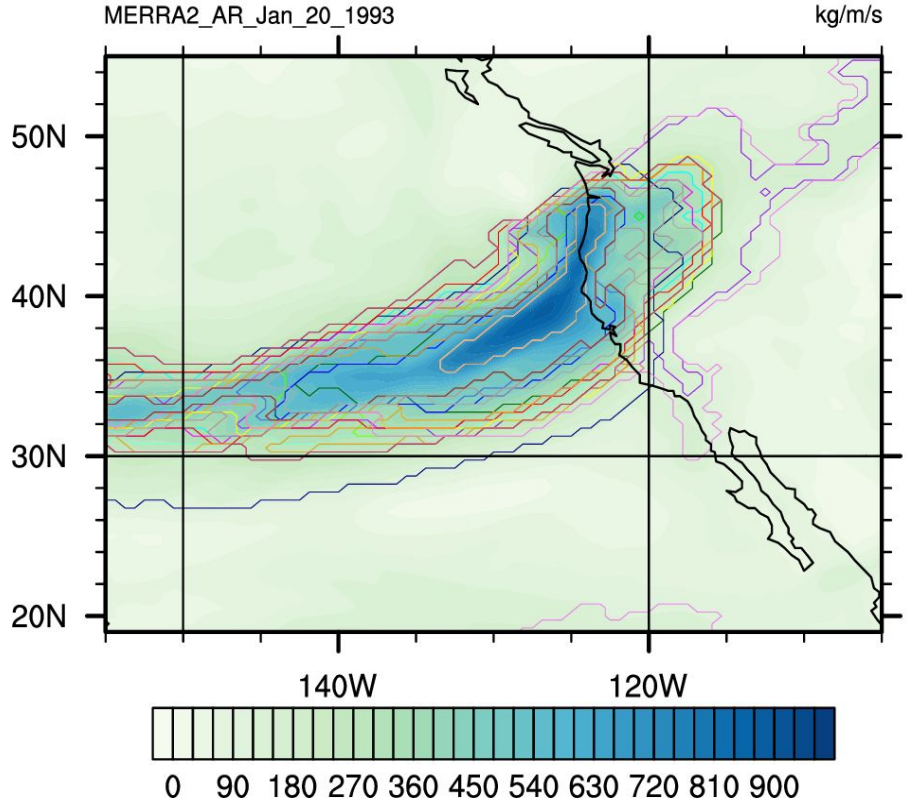
Community Atmosphere Model (CAM5) Data
[Historical & RCP8.5 Simulations]



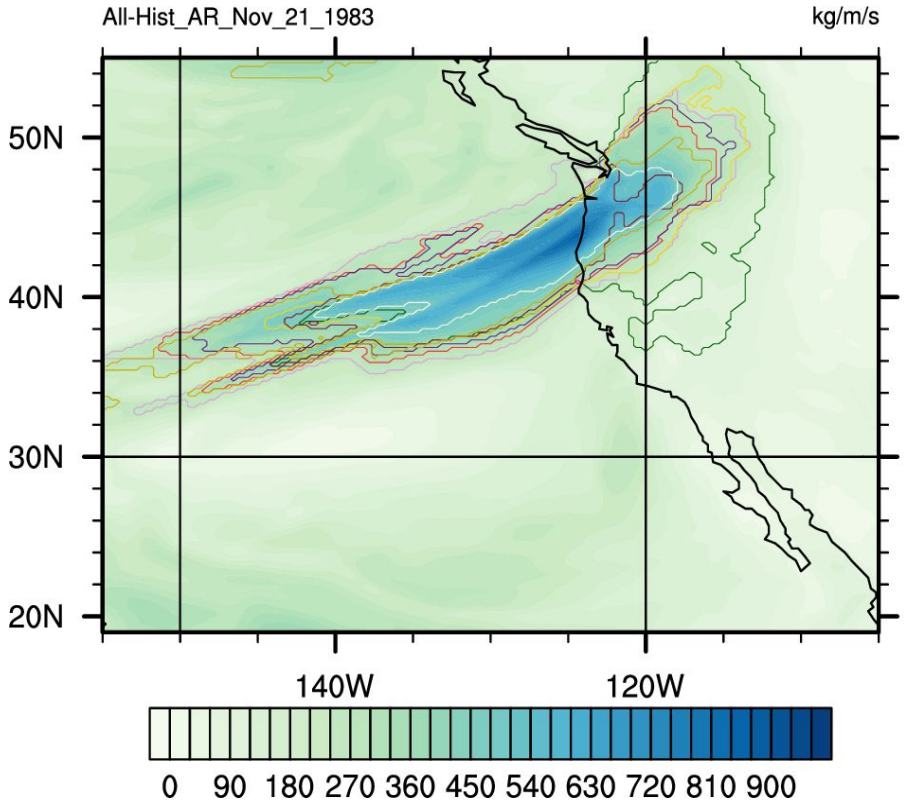
Source:
https://www.cgd.ucar.edu/projects/artmip/experimental-design.html

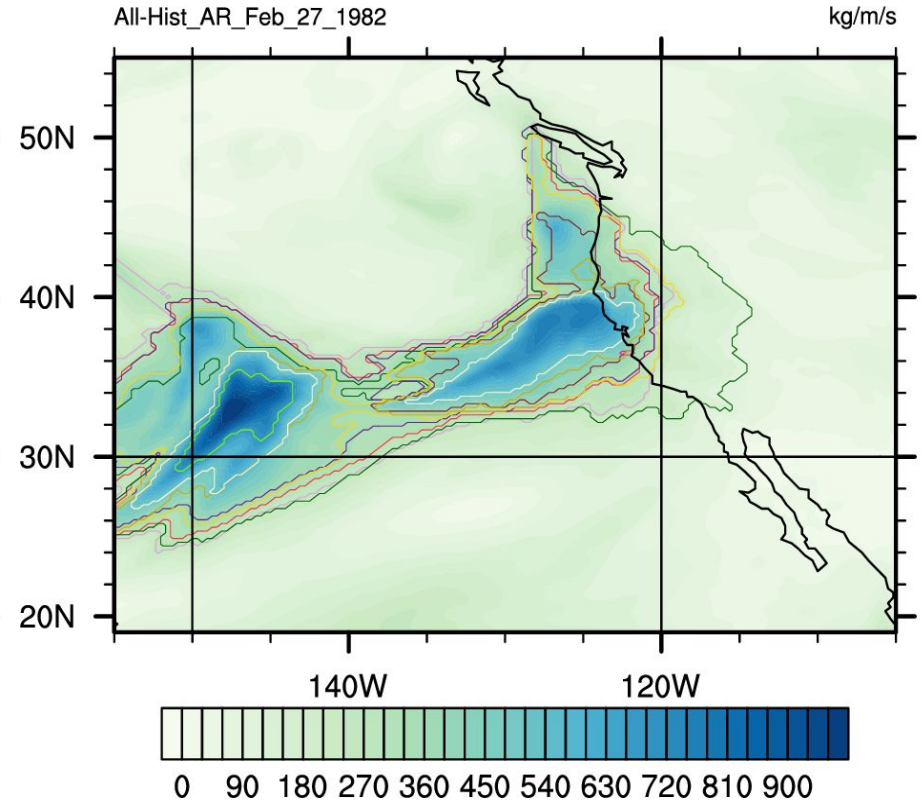
Plotting Atmospheric River Footprints Using NCL Scripts



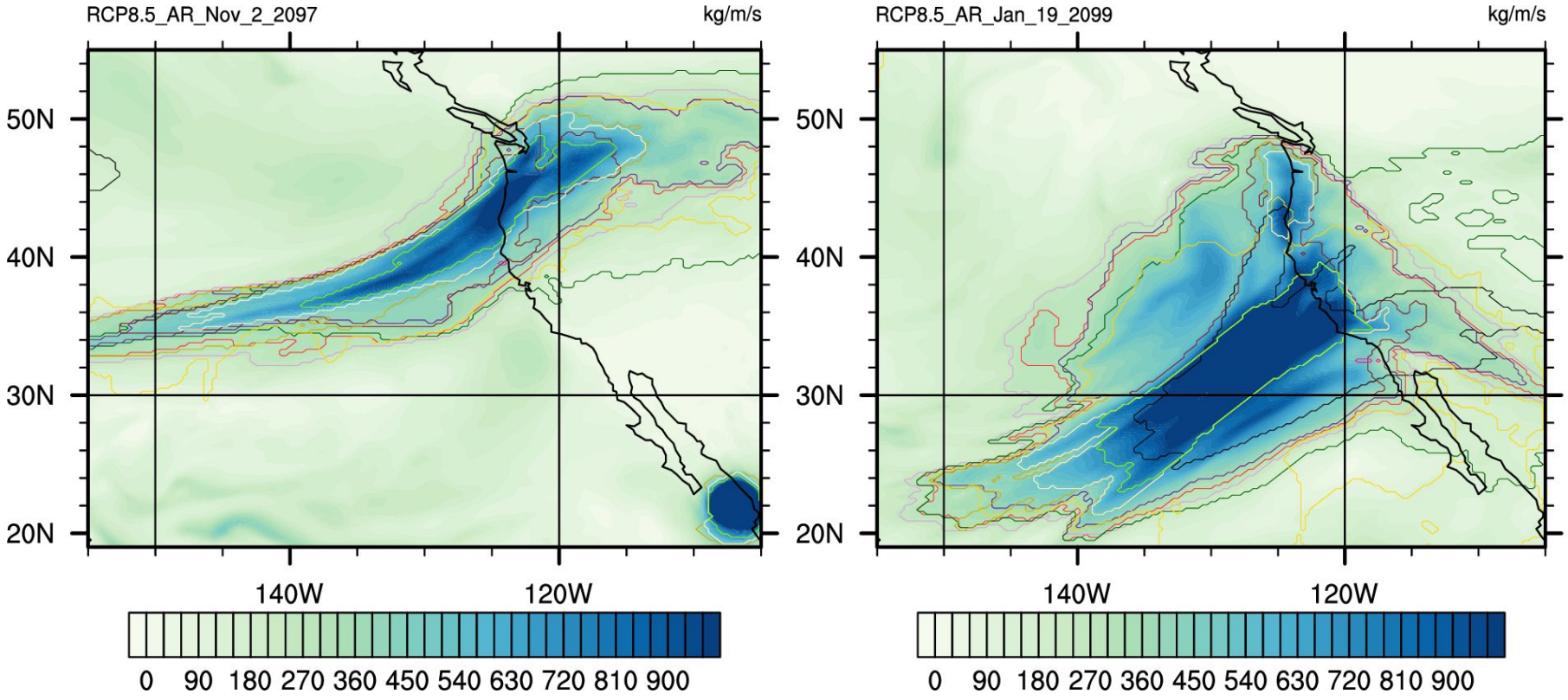


Plotting Atmospheric River Footprints Using NCL Scripts



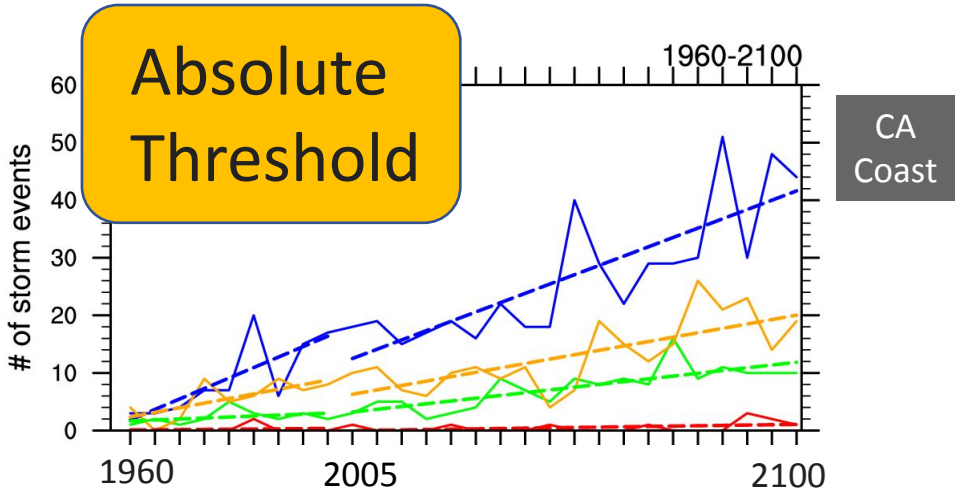


Plotting Atmospheric River Footprints Using NCL Scripts



Does ARDT Definition Matter?

➔ Changes in future AR frequency, intensity, and size depends on the methods or algorithms being used



CA Coast

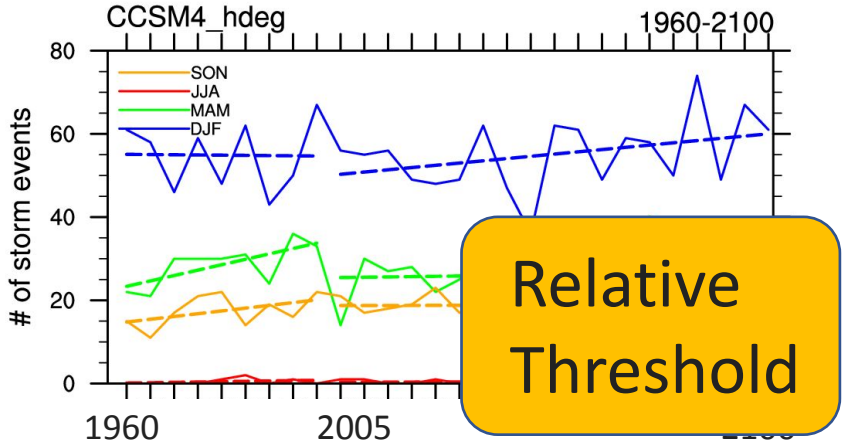


Image Courtesy of Shields and Kiehl 2016

Caveats

- Plots provided are case studies
- Case studies are only moments in time, might not accurately represent all ARs of the future
- Further analysis of entire ARTMIP data sets is needed in order to paint an accurate picture of future ARs

Conclusions

- ARs play an important role in transporting large amounts of water vapor to regions across the globe

- In the future, ARs will have the ability to potentially transport more water vapor as a result of changes in the Clausius Clapeyron relationship

- Changes in future AR frequency, intensity, and size depends on the method or algorithm being used

Future Considerations

- Utilize entire ARTMIP datasets to better identify future changes in ARs
- Move away from case studies, and begin to analyze the differences between historical climatological data and projected future climatological data associated with ARs

Acknowledgements

A Special Thank You to….

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Maria Molina

NCAR

Everyone on the NESSI and SIParCS Team

Extra Slides

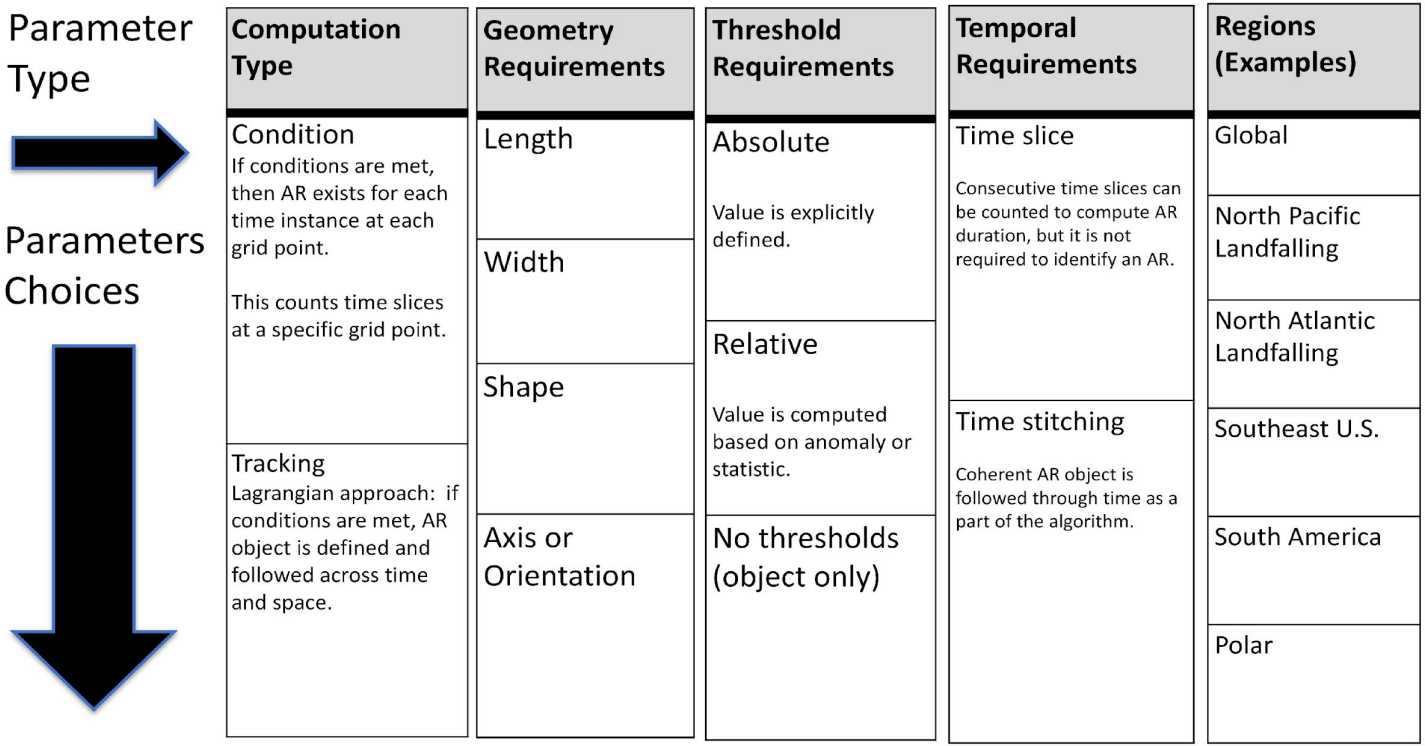
What I Learned This Summer

- ★ Developed an understanding of and appreciation for ARs and climate change

- ★ Learned these tools
  - NCL
  - Unix Commands
  - C Shell
  - Ncview
  - HPC

- ★ Learned the basics of data management, proposal writing, giving a scientific presentation, and much much more!

Breaking Down ARDT Parameters



Credit: Figure 1 from 'Atmospheric River Tracking Method Intercomparison Project (ARTMIP): project goals and experimental design' Shields et al. 2018

Categorizing ARs

Table 2. (top) An AR intensity scale based on maximum instantaneous IVT magnitude and duration of AR conditions (i.e., IVT > 250 kg m^{-1} s^{-1}), and (bottom) a subjective assessment of the potential for beneficial or hazardous impacts.

Max IVT (kg m^{-1} s^{-1})	Duration of AR conditions (h)		
	≤24	≥24–48	≥48
≤250	Not an AR	Not an AR	Not an AR
≥250–500	Weak AR	AR Cat 1	AR Cat 2
≥500–750	AR Cat 1	AR Cat 2	AR Cat 3
≥750–1,000	AR Cat 2	AR Cat 3	AR Cat 4
≥1,000–1,250	AR Cat 3	AR Cat 4	AR Cat 5
≥1,250	AR Cat 4	AR Cat 5	AR Cat 5

AR category scale	Assessment of beneficial vs hazardous impacts
AR Cat 1	Primarily beneficial
AR Cat 2	Mostly beneficial, but also hazardous
AR Cat 3	Balance of beneficial and hazardous
AR Cat 4	Mostly hazardous, but also beneficial
AR Cat 5	Primarily hazardous

Credit: Table 2 from 'A Scale to Characterize the Strength and Impacts of Atmospheric Rivers.' Ralph et al. 2018

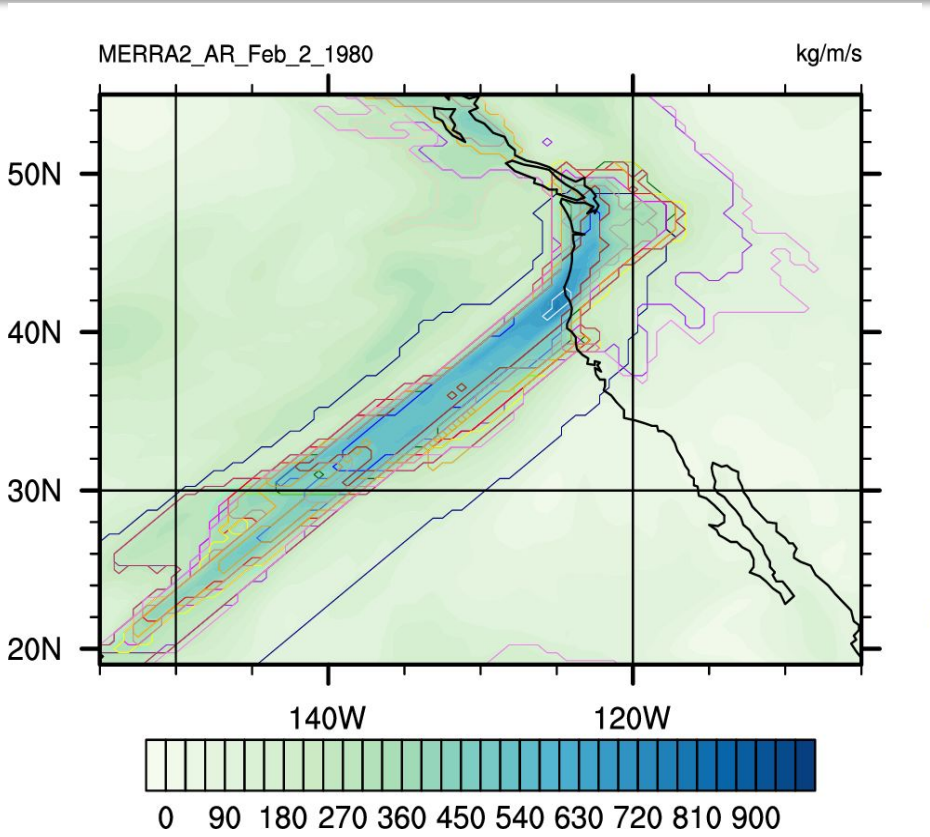
Definitions

- **Atmospheric River (AR) -** “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” (Glossary of Meteorology).

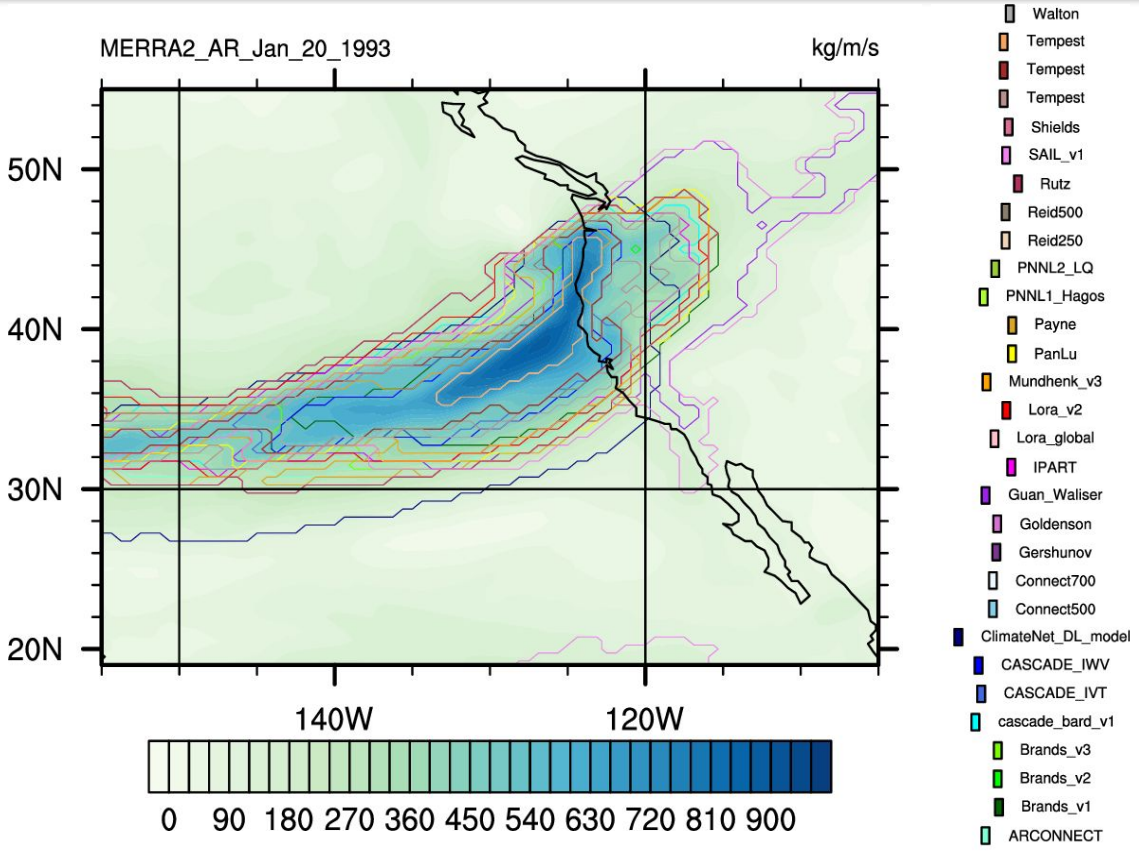
- **Climate Change -** changes in atmospheric characteristics that deviate from climatological norms

- **Atmospheric River Detection Tool (ARDT) -** Methods used to identify and track atmospheric rivers

AR Plots With Method Labels



AR Plots With Method Labels



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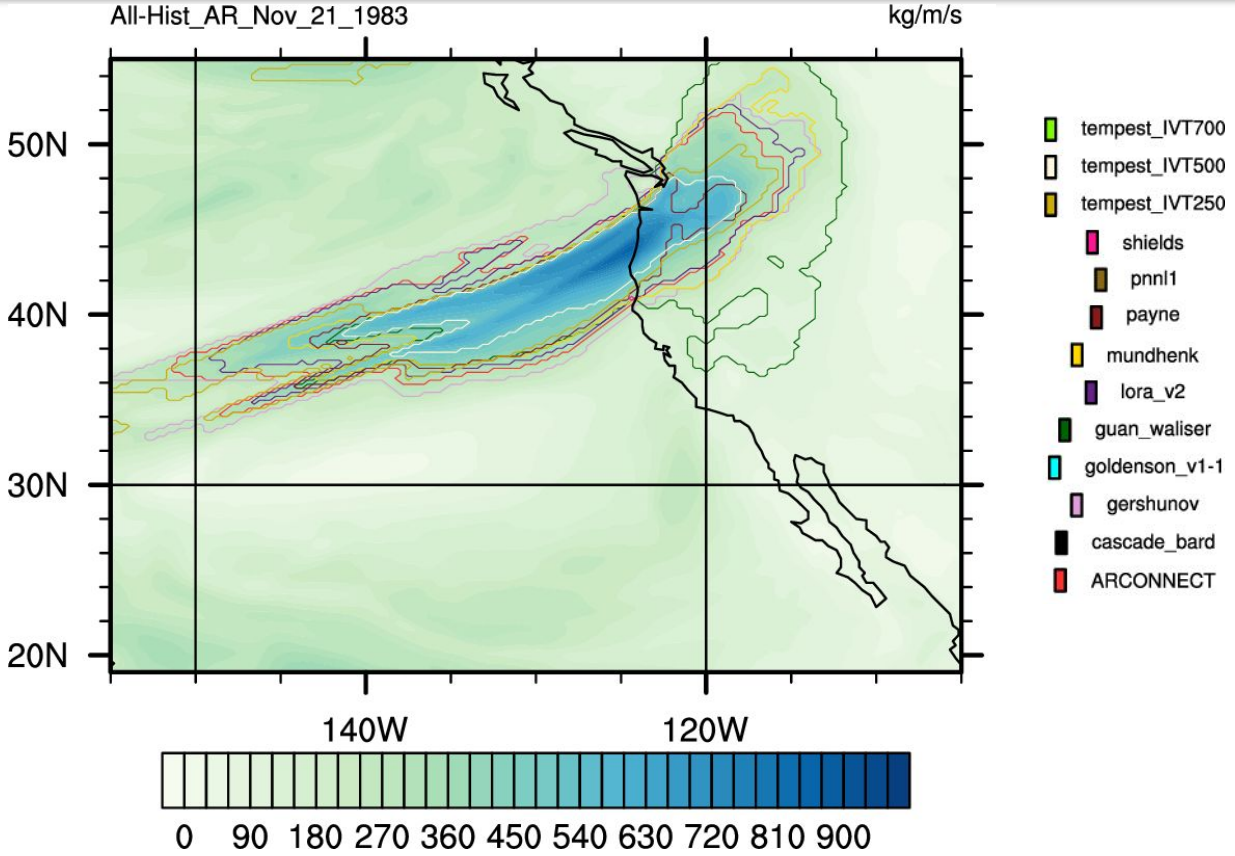

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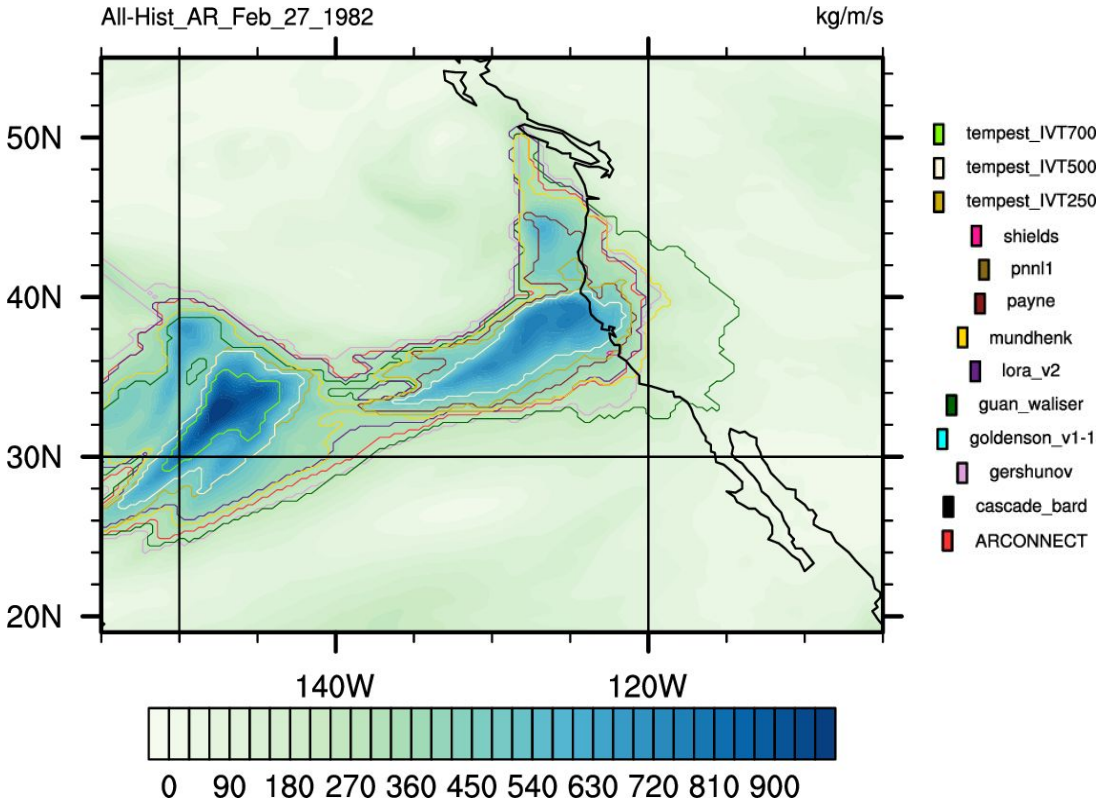

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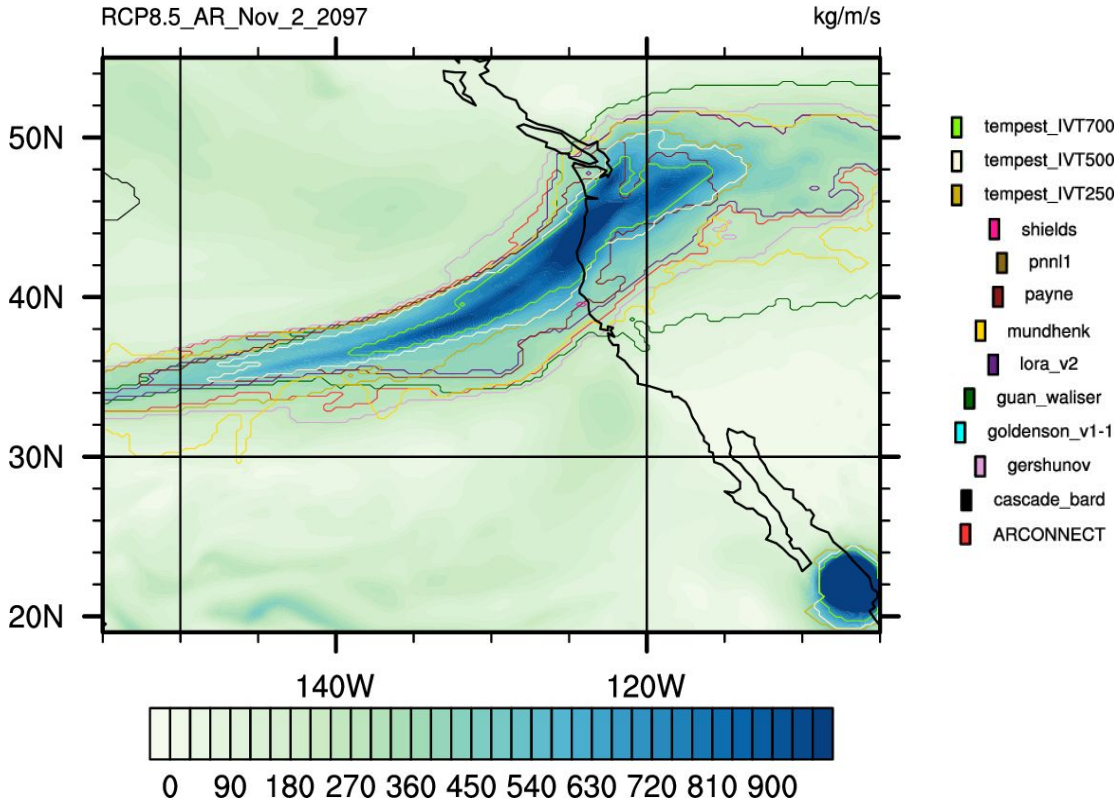

AR Plots With Method Labels