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Second Atmospheric River Tracking Method Intercomparison Project (ARTMIP) Workshop

L. Ruby Leung

Atmospheric Sciences and Global Change Division
Pacific Northwest National Laboratory

Workshop organizing Committee:
- Christine Shields (NCAR), co-chair
- Jonathan Rutz (NOAA), co-chair
- Ruby Leung (PNNL)
- Michael Wehner (LBNL)
- Marty Ralph (SIO)

U.S. DEPARTMENT OF ENERGY

Workshop overview

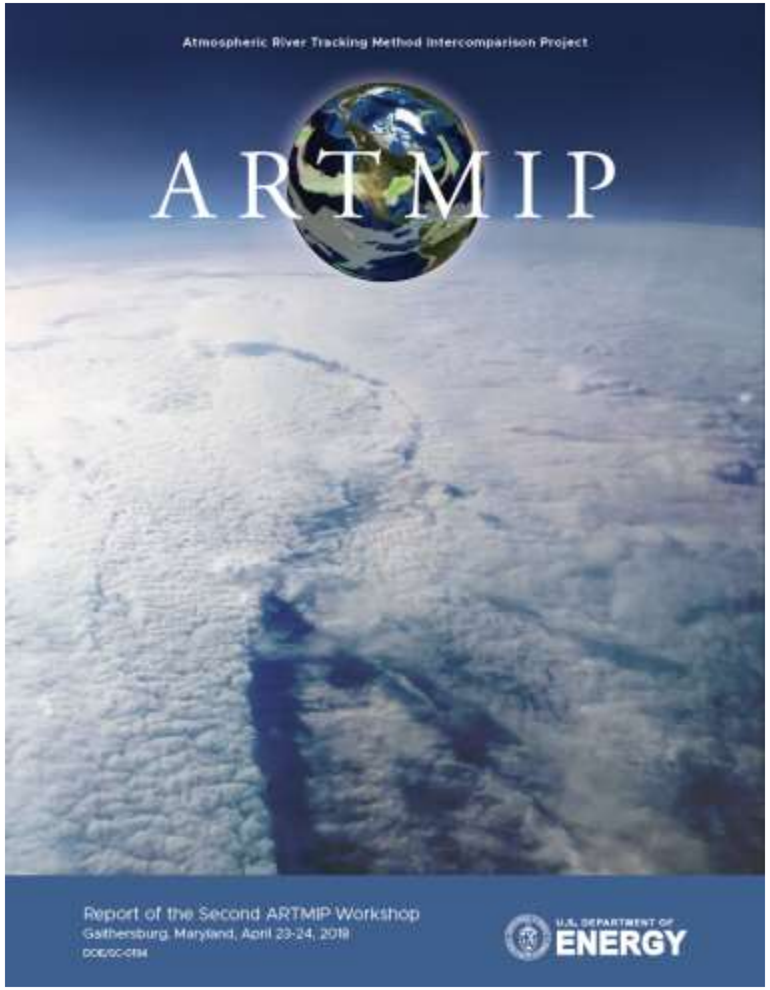
What: Second ARTMIP Workshop

When: 23-24 April 2018

Where: Gaithersburg, MD

Sponsor: DOE BER Regional and Global Model Analysis (RGMA) program – Renu Joseph

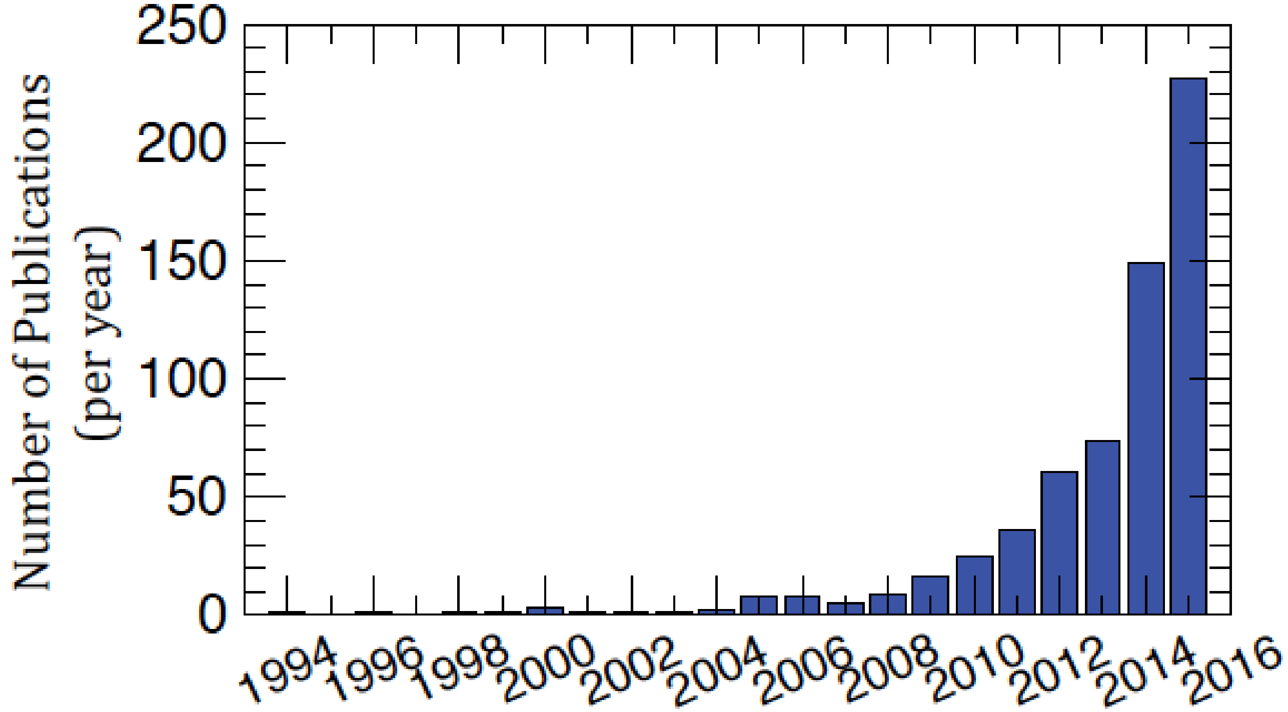
Participants: 36 from US federal agencies/programs, national laboratories, and US and international universities



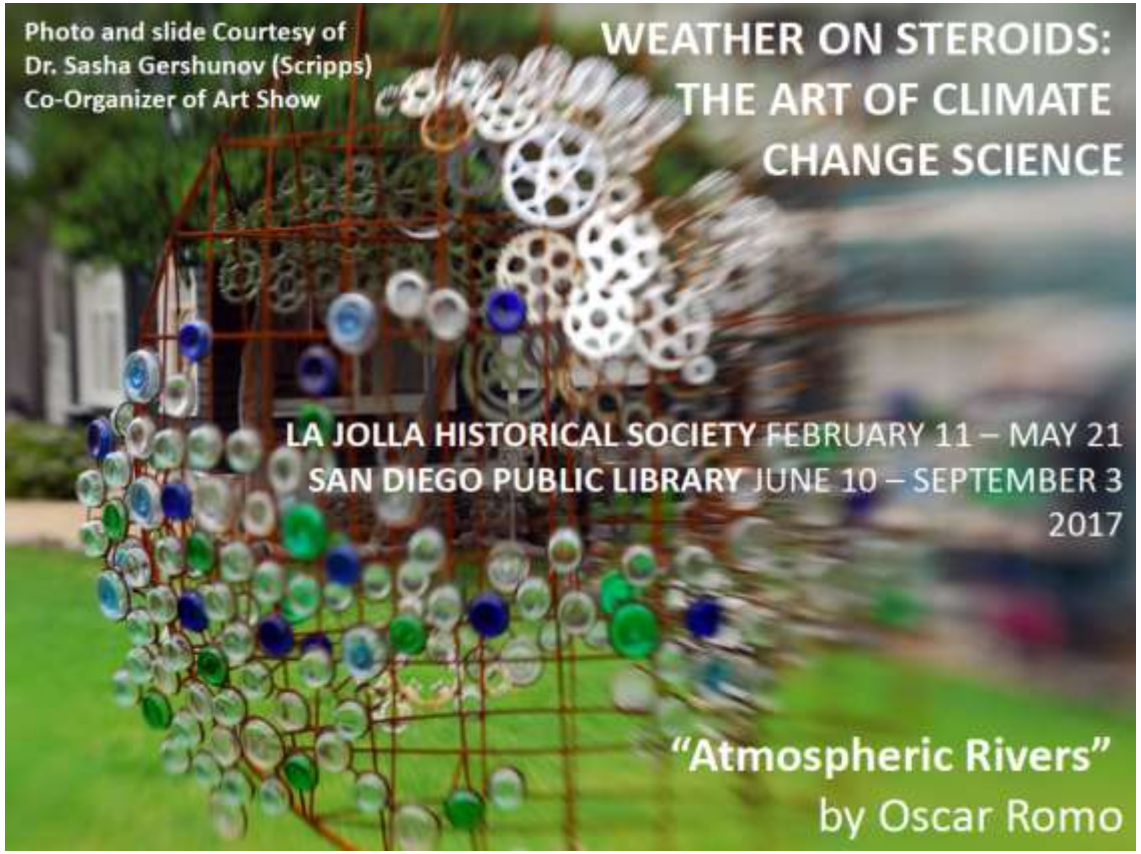
A history of AR research

- The concept of ARs emerged in the 1990s (Zhu and Newell 1998): ~90% of poleward vapor transport is accomplished by long, narrow filamentary structures that occupy less than 10% of the longitudes

Scientific literature on ARs

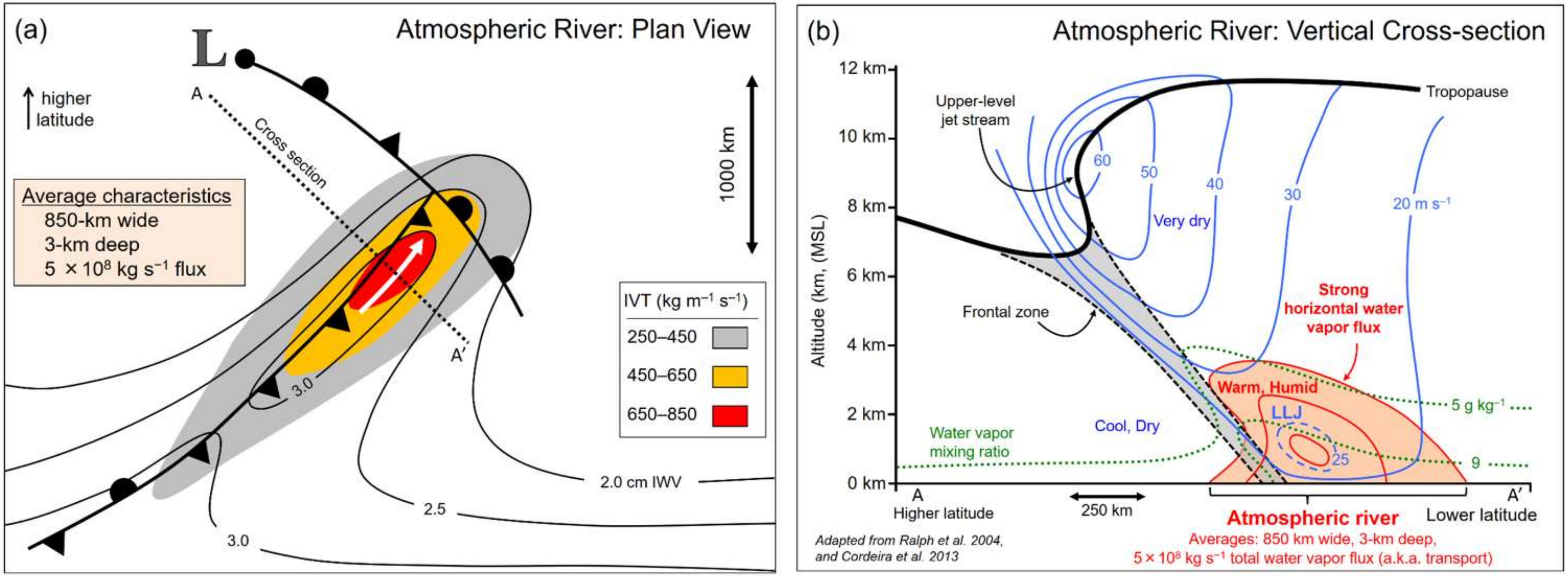


(Ralph et al. 2017 BAMS)



AR definition

- A qualitative definition of ARs was added to the AMS Glossary of Meteorology in 2017



(Ralph et al. 2018 BAMS)

AR definition

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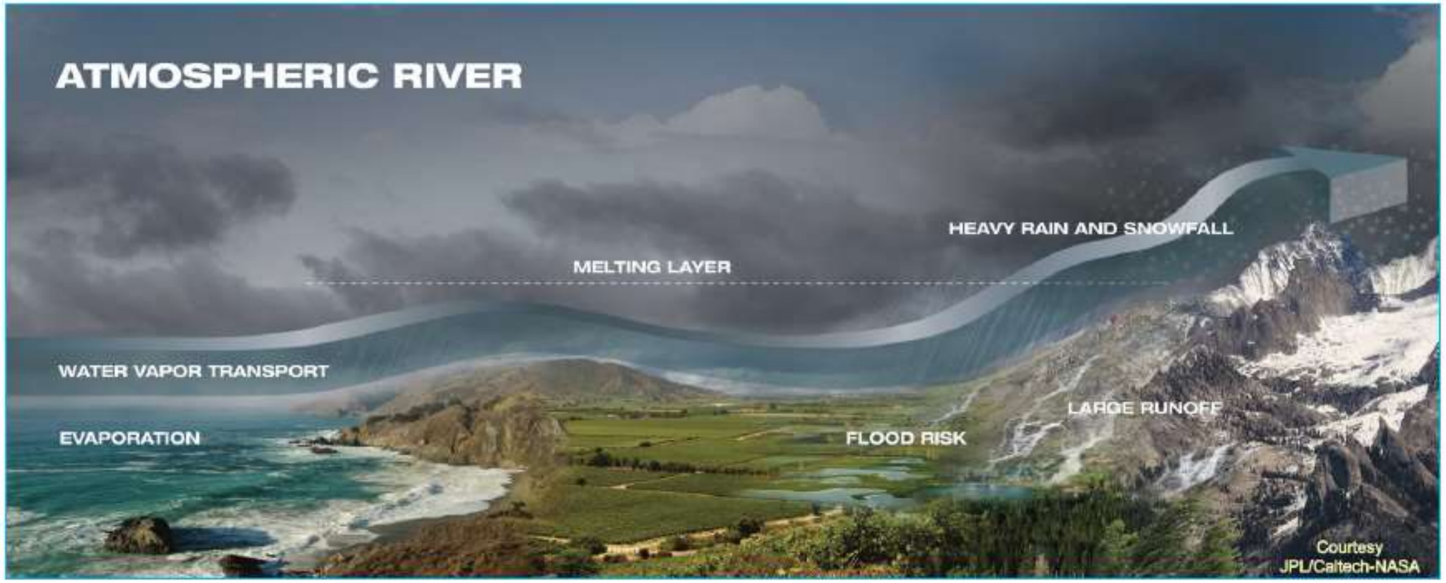
Glossary of Meteorology
AR definition added May 2017
Definition development described in BAMS (Ralph et al. 2018)

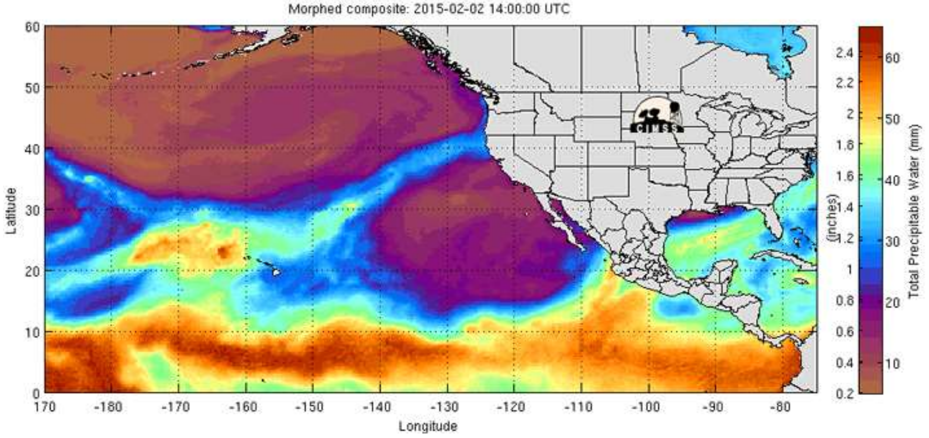
ATMOSPHERIC RIVER

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. The water vapor in atmospheric rivers is supplied by tropical and/or extratropical moisture sources. Atmospheric rivers frequently lead to heavy precipitation where they are forced upward, e.g., by mountains or by ascent in the warm-conveyor-belt. Horizontal water vapor transport in the mid-latitudes occurs primarily in atmospheric rivers and is focused in the lower troposphere.

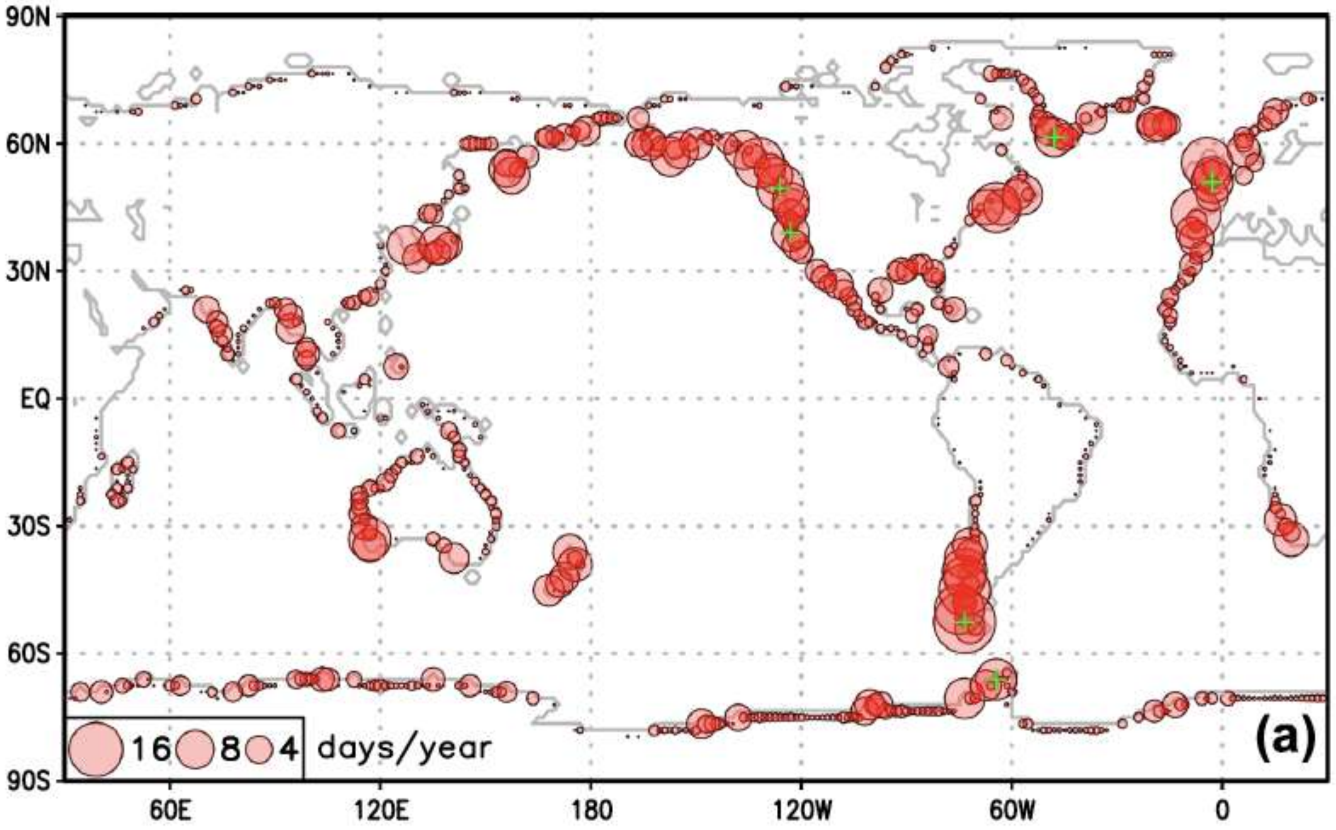


Many approaches developed to detect and track ARs are consistent with the AR definition

AR global distribution



Frequency of AR landfall (1997-2014)



(Guan and Waliser 2015 JGR)

Why ARTMIP

- There are many heuristic AR tracking algorithms employed in the literature
- Our quantitative—and possibly qualitative—understanding of ARs and their impacts may depend on the details of the algorithm used
- No dataset yet exists to systematically explore the impact of AR tracking algorithm choice on scientific results
- The broader scientific community therefore lacks any formal guidance on the advantages and disadvantages of different AR tracking methods

ARTMIP workshops

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- The 1st ARTMIP workshop defined and launched a multi-tiered intercomparison experiment designed to fill the above community need:
  - Tier 1 aims at understanding the impact of AR algorithm on quantitative baseline statistics and characteristics of ARs
  - Tier 2 includes sensitivity studies designed around specific science questions, such as reanalysis uncertainty and influences associated with climate change
- The 2nd ARTMIP workshop provided a forum to:
  - discuss gaps and emerging opportunities for advancing the science and tracking of ARs
  - discuss analyses of the Tier 1 dataset
  - synthesize the results and implications of the Tier 1 analyses
  - use this information to define the experimental designs for the various Tier 2 experiments
  - work towards developing systematic analyses and evaluation of the advantages and disadvantages of different AR algorithms for various scientific questions

ARTMIP: Science questions

- How do metrics such as frequency, duration, intensity, and precipitation associated with ARs change from one algorithm to the next?
- Which algorithms are best suited for addressing AR impacts?
- Are there major differences between global versus regional tracking?
- Can AR tracking methods be equally useful for forecasts vs. climate projections?
- How do algorithmic choices impact the representation of AR dynamics?
- How and why do different algorithm choices change our understanding of ARs now and into the future?
- Do global models represent AR characteristics and processes accurately, and how do AR tracking methods influence this assessment?
- What are the drivers for AR genesis based on ARs tracked using different methods?
- What forecast variables and forecast skill are most useful for stakeholders?
- Do AR tracking methods affect assessment of forecast skill and hence communication of the usefulness of AR forecasts to stakeholders?

Diverse algorithmic choices

Parameter Type →

Parameters Choices ↓

Computation Type	Geometry Requirements	Threshold Requirements	Temporal Requirements	Regions (Examples)
Condition If conditions are met, then AR exists for each time instance at each grid point. This counts time slices at a specific grid point.	Length	Absolute Value is explicitly defined.	Time slice Consecutive time slices can be counted to compute AR duration, but it is not required to identify an AR.	Global
Tracking Lagrangian approach: if conditions are met, AR object is defined and followed across time and space.	Width	Relative Value is computed based on anomaly or statistic.	Time stitching Coherent AR object is followed through time as a part of the algorithm.	North Pacific Landfalling
	Shape	No thresholds (object only)		North Atlantic Landfalling
	Axis or Orientation			Southeast U.S.
				South America
				Polar

ARTMIP: Tier 1 results

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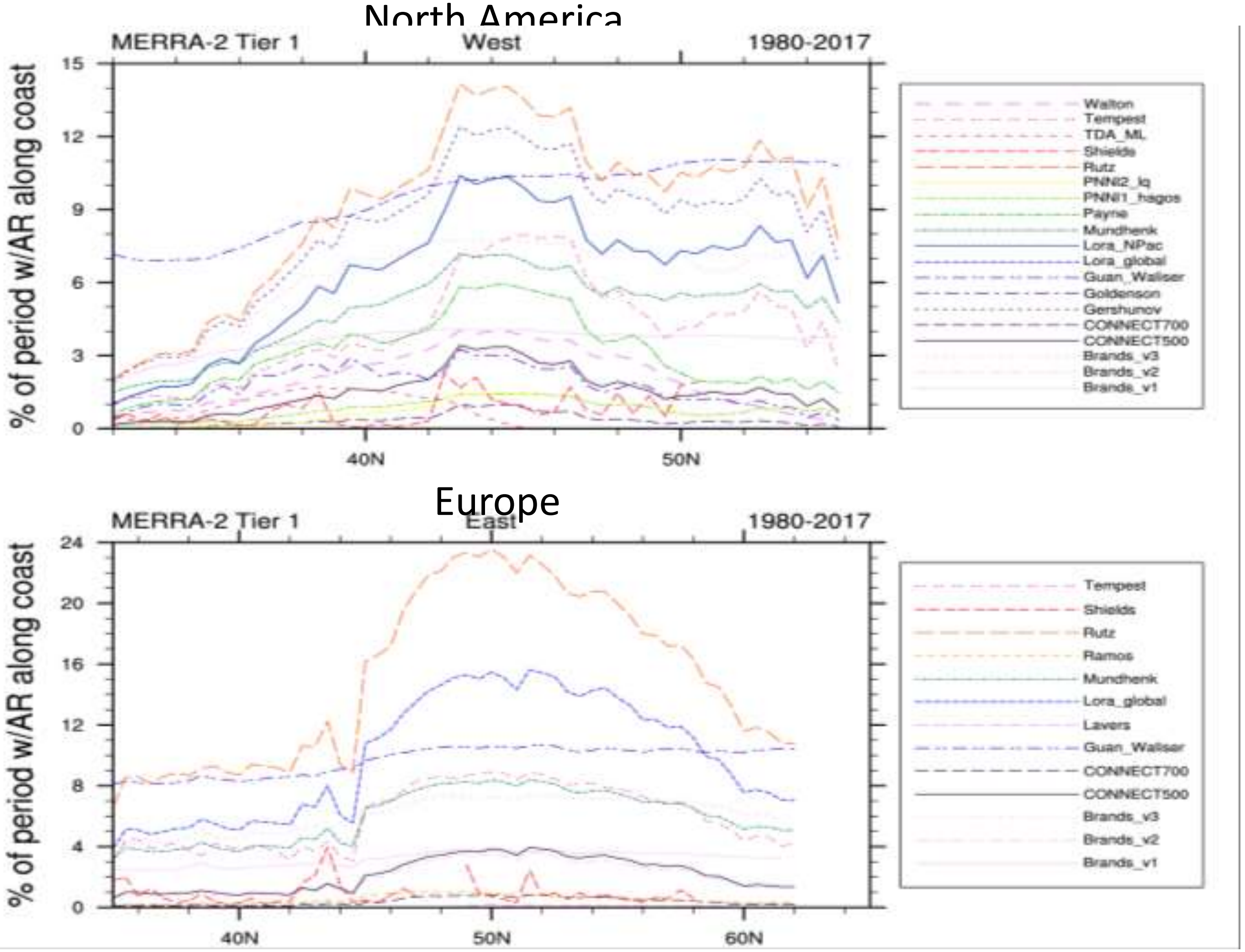
- All algorithms applied to the same global reanalysis data (MERRA)
- Full period, all months
- Large frequency diversity
- Shape of latitudinal distribution generally holds, with some exceptions

Tier 1 Analysis: Frequency



ARTMIP: Tier 1 results

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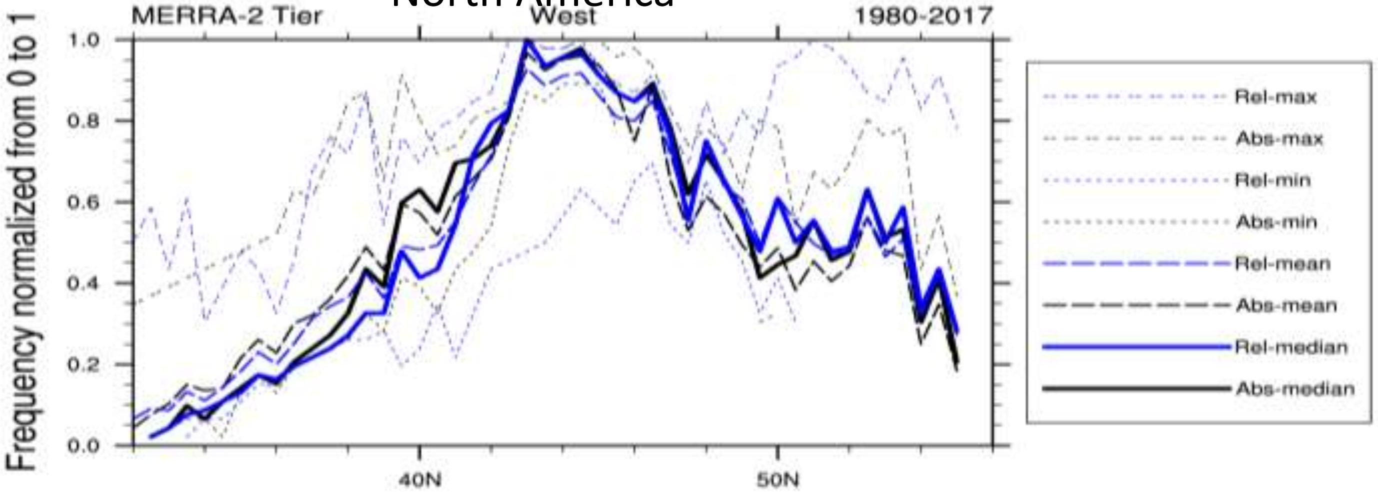
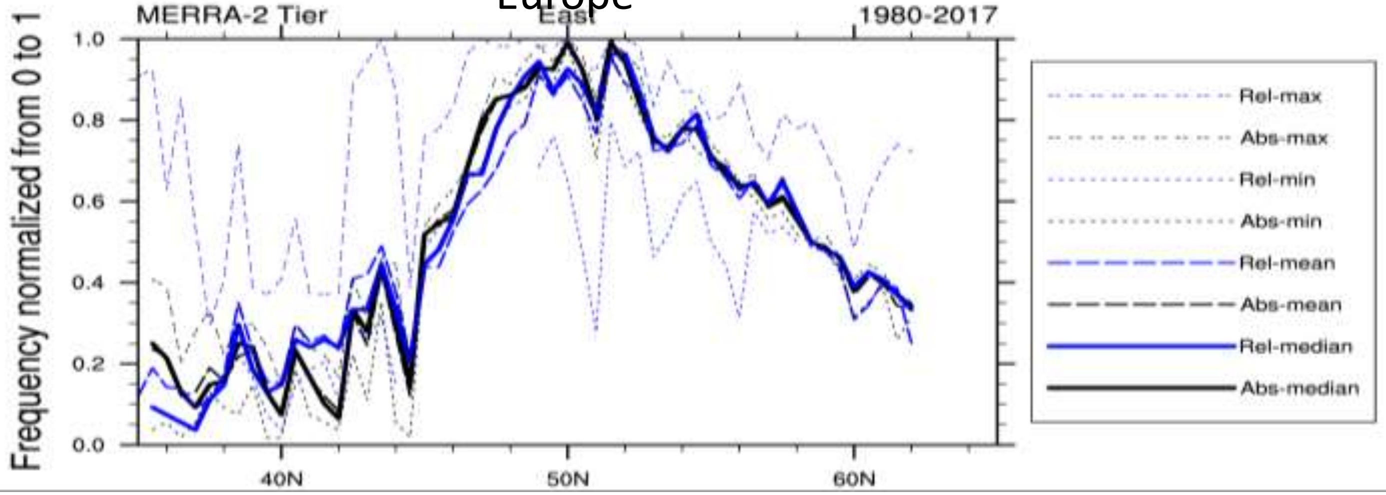
- Normalized and broken up into “clusters” – i.e., grouped by algorithm parameters
- Moisture threshold parameter – “absolute” vs. “relative”

Tier 1 Analysis: Normalized Frequency

North America



Europe



ARTMIP: Tier 2 plan

- Two subtopics: climate change and reanalysis sensitivity
- Each group applies its algorithm to provide an archive of ARs for analysis delving into topical science questions important to research groups and stakeholders
- Climate change:
  - LBNL (Michael Wehner) to provide high resolution fvCAM5 simulations of a recent historical period and the end of century under RCP8.5 – led by Ashley Payne, U. Michigan
  - Multi-model ensembles of CMIP5 lower resolution simulations (8 – 14 models) – led by Travis O'Brien, LBNL
  - AMIP vs. CMIP simulations – led by Aneesh Subramanian, SIO
  - Simulations at multiple resolution (2^{o}, 1^{o}, and 0.25^{o}) fvCAM5
- Reanalysis sensitivity: algorithms applied to multiple reanalysis products

Research needs

- Understand the apparent spread in the statistics and characteristics of ARs among AR algorithms
- Investigate whether our quantitative, and possibly qualitative, understanding of how ARs may change in the future depends on the details of the algorithm used
- Communicate to stakeholders how the choice of the algorithms affect the impacts associated with ARs identified by different methods
- Provide guidance to stakeholders to help discern which algorithm metrics are most appropriate for them
- Systematic analysis and quantification of uncertainties and their implications – ARTMIP catalogues should be made available to the scientific community

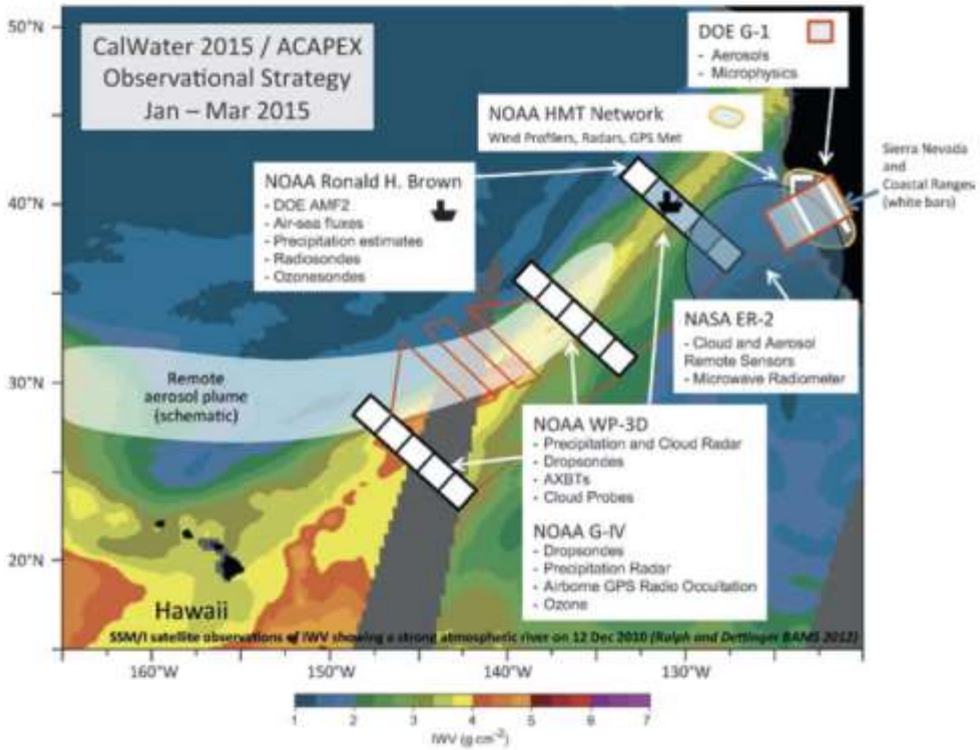
Beyond ARTMIP

- More research is needed to:
  - improve modeling and forecasting
  - improve observations and high resolution data
  - develop metrics and diagnostics to understand and quantify modeling skill
  - use a modeling hierarchy to understand AR predictability, AR impacts, and ARs in paleoclimate records

AR research need: observations

- Satellite and reanalysis products are the primary sources of data used to study ARs
- Field campaigns provide important data to validate satellite/reanalysis products and support process studies

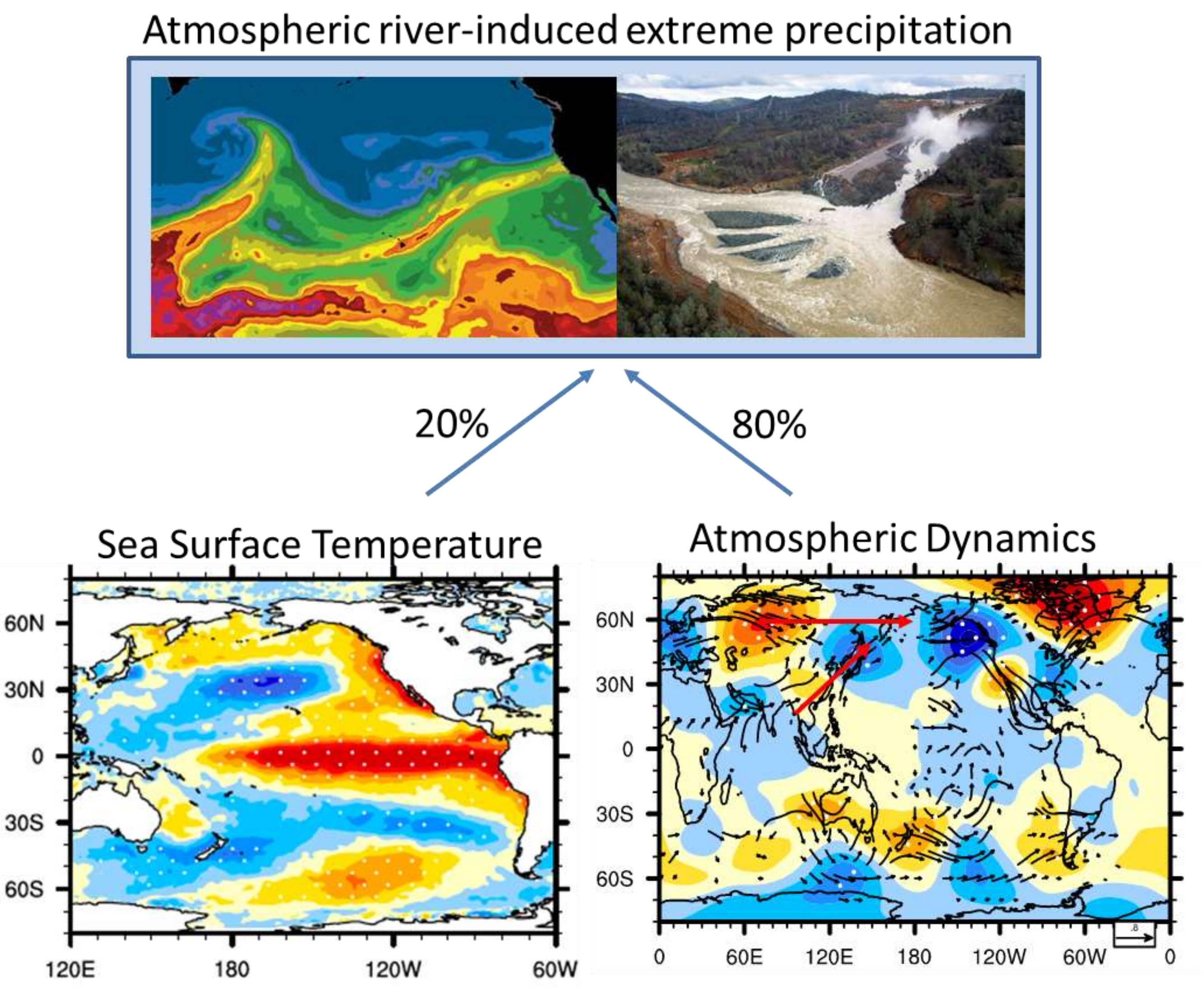
CalWater/ACAPEX 2015



Antarctica Circumnavigation Expedition (2016/12 – 2017/3)

AR research need: predictability

- Sea surface temperature, the more predictable element of the climate system, accounts for only 20 percent of extreme precipitation variability along the U.S. West Coast, with atmospheric dynamics explaining the remaining 80 percent
- The 2017 AR that damaged the Oroville spillway is associated with circumglobal wavetrain



(Dong et al. 2018 J Clim)

AR research need: communicating AR impacts

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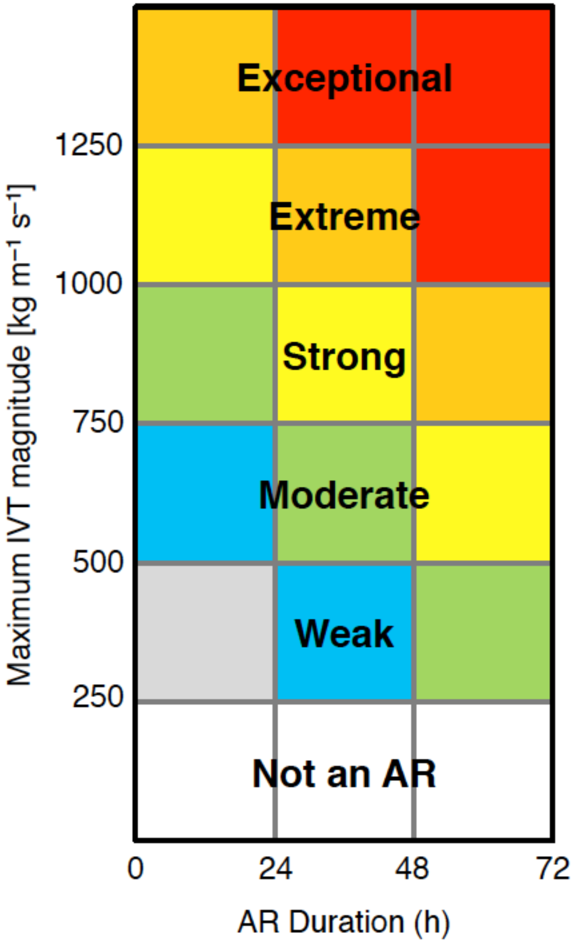
- Define a scale to characterize the strength and impacts of ARs



AR Scale Category	Max. IVT* (kg m^{-1} s^{-1})	Duration of AR Conditions (h)	Benefits vs. Hazards of Impacts
	< 250	N/A	Beneficial
AR Cat 1	250–500	< 24	Primarily beneficial
AR Cat 2	500–750	24–48	Mostly beneficial, but also hazardous
AR Cat 3	750–1000	24–48	Balance of beneficial and hazardous
AR Cat 4	1000–1250	24–48	Mostly hazardous, but also beneficial
AR Cat 5	> 1250	> 48	Primarily hazardous

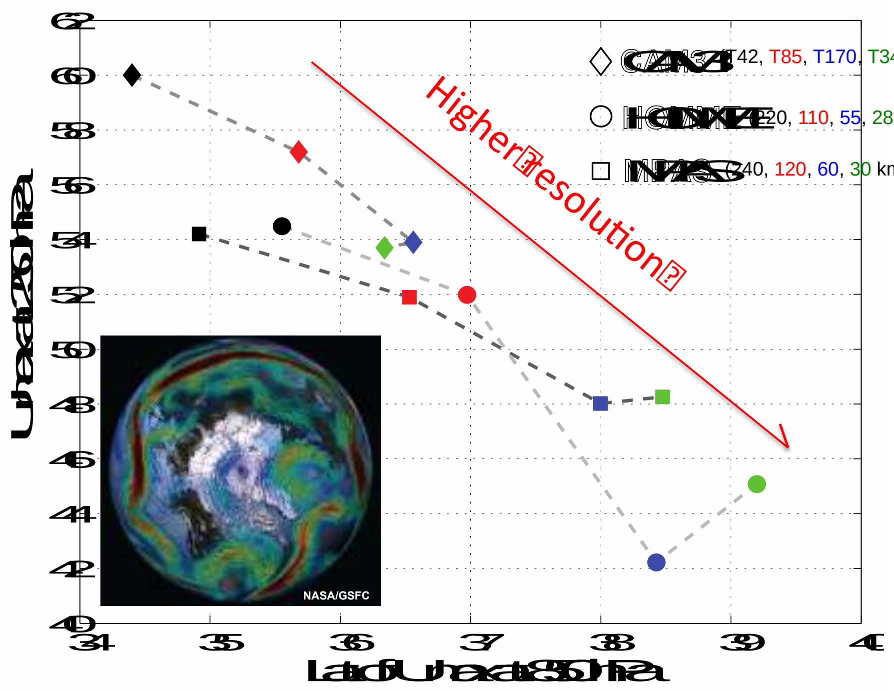
- Cat 5 – Primarily hazardous
- Cat 4 – Mostly hazardous, also beneficial
- Cat 3 – Balance of beneficial and hazardous
- Cat 2 – Mostly beneficial, also hazardous
- Cat 1 – Primarily beneficial

(Ralph et al. 2018 BAMS)

AR research need: modeling

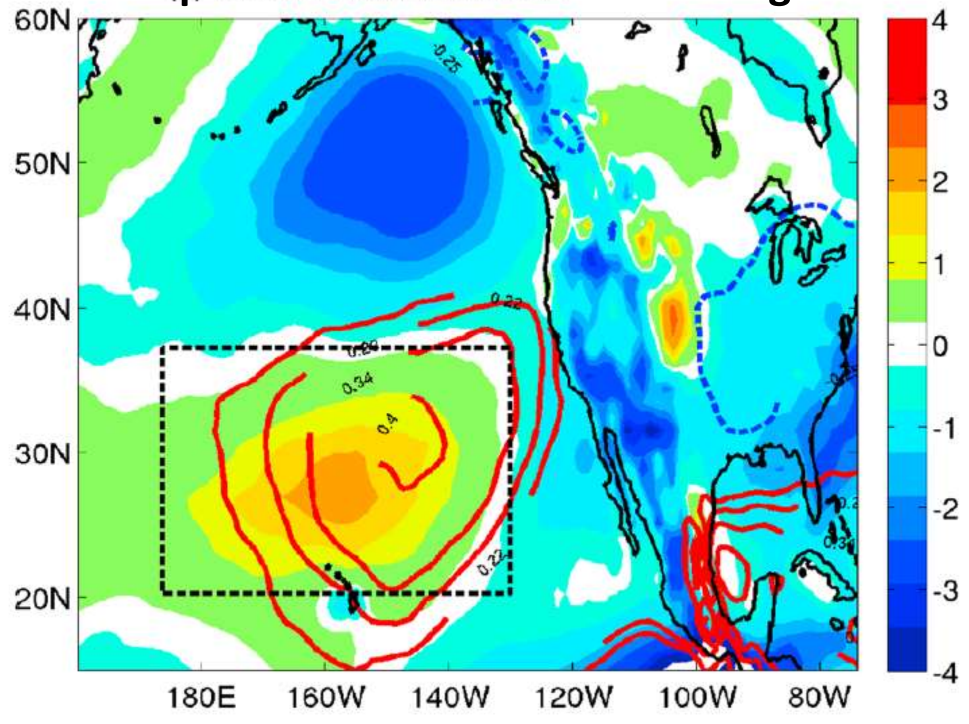
- Subtropical jet in models is sensitive to resolution, with a hint of convergence at ~50 km grid spacing
- AR frequency bias correlates strongly with subtropical jet bias

Subtropical jet location and strength are sensitive to model resolution



(Lu et al. 2015, JCLIM)

CESM-LE (1 degree) simulates subtropical jet with equatorward bias and too strong



(Hagos et al. 2016, GRL)