Fidelity in Global Model Simulations and Predictions of Atmospheric Rivers

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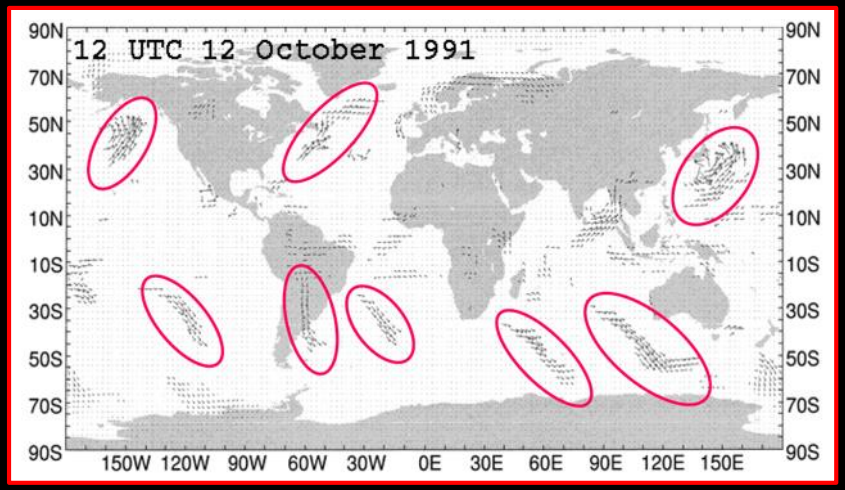
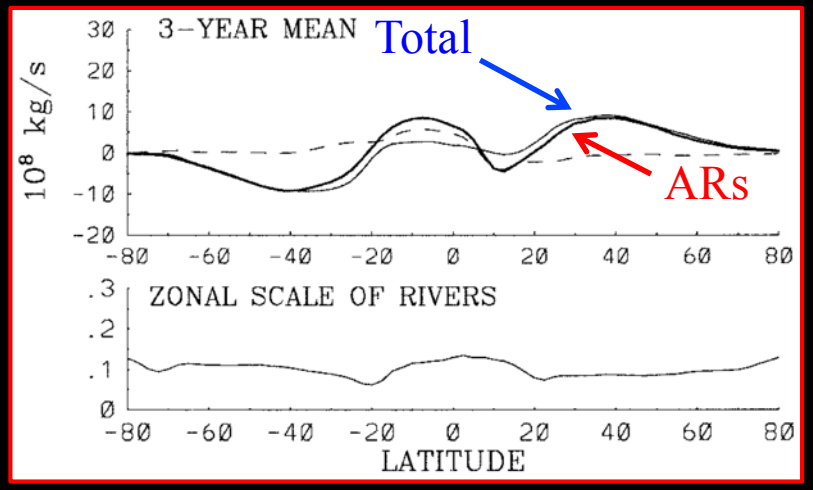
Pasadena, CA

8th EGU Leonardo Conference
October 2016; Ourense, Spain

ARs : Poleward Moisture Transports

Influencing global Climate & Water Extremes





Over 90% of poleward moisture transport at midlatitudes is by ARs that take up only ~10% of the zonal circumference; Zhu and Newell (1998)

For discussion on connections between ARs, Tropical Moisture Exports (TMEs) and Warm Conveyor Belts (WCBs), see Cordeira (2015).

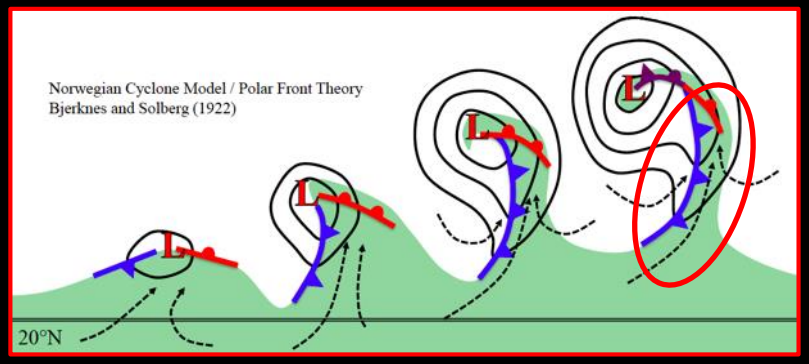
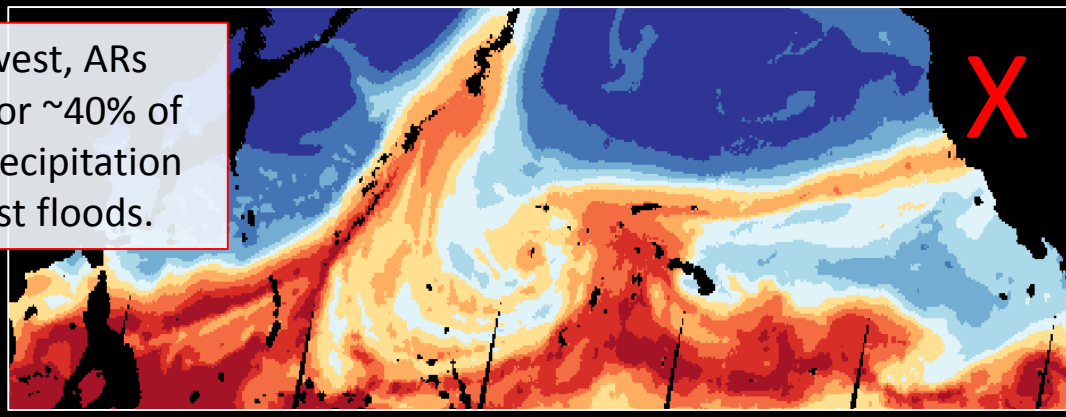


Figure courtesy J. Cordeira, Plymouth University

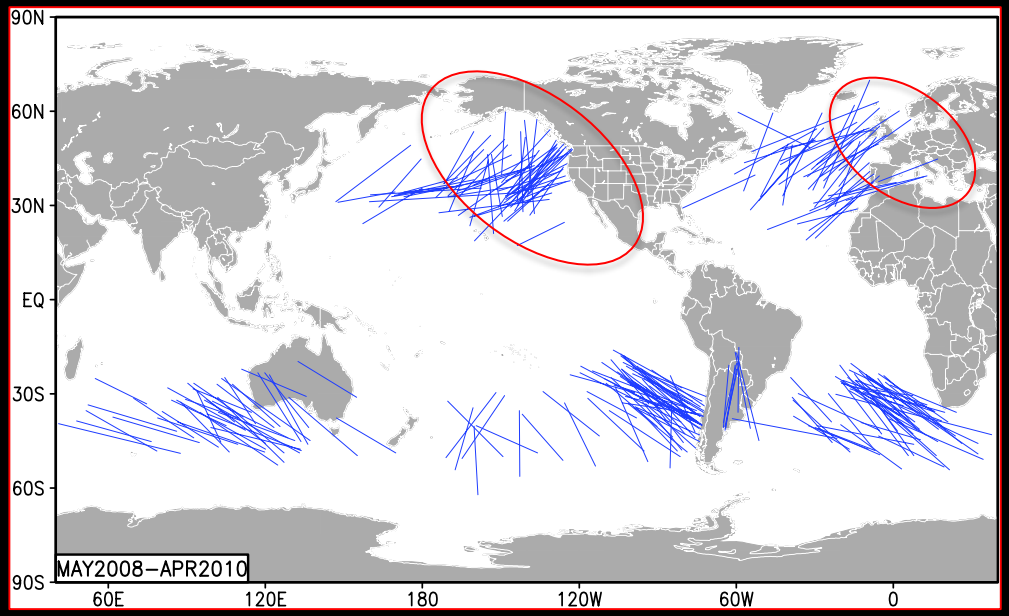
Few/No Global Studies of ARs

In the west, ARs account for ~40% of annual precipitation and most floods.



Regions of Concentrated AR Research

Isolated impact studies in a few other regions



Manually identified ARs for 2 year YOTC period; Waliser et al. (2012)

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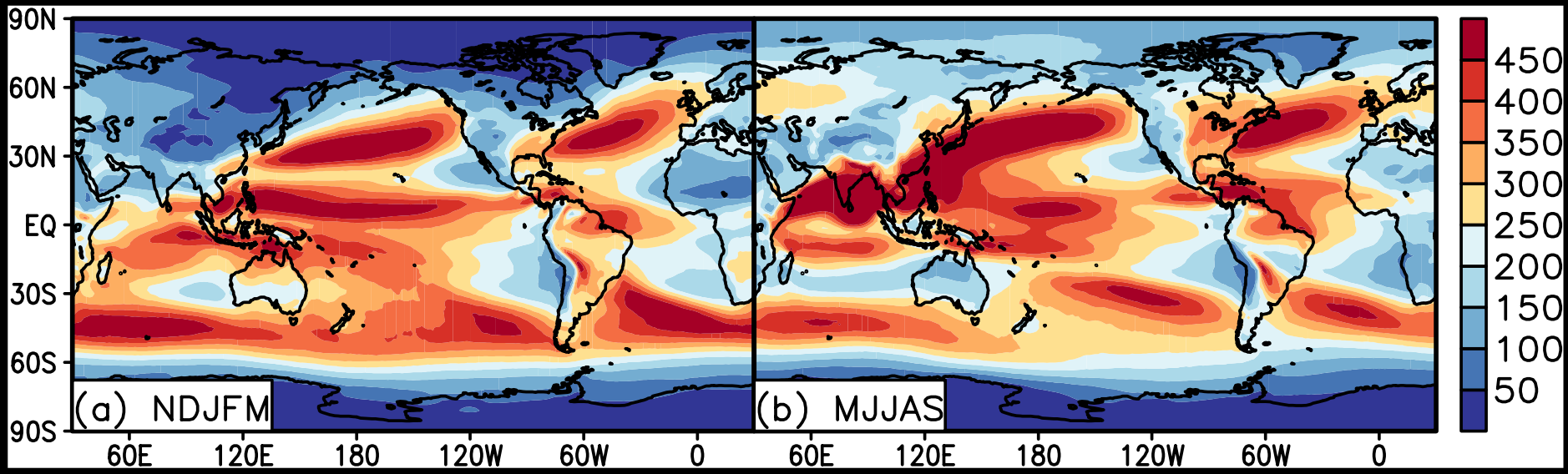
Global AR Detection

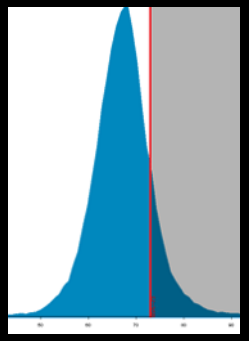
Guan & Waliser 2015

Based on Integrated Vapor Transport (IVT)



Intensity threshold:

IVT > max(85th percentile, 100 kg m-1 s-1)

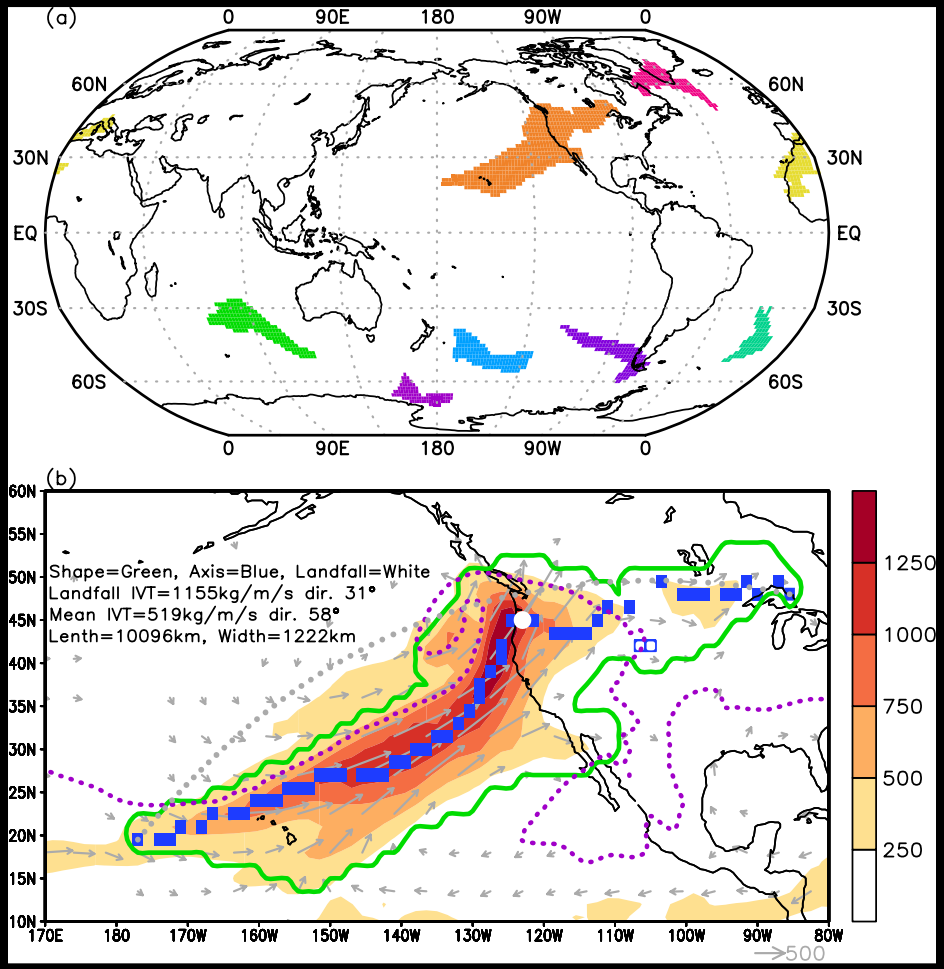


Geometry threshold:

Length > 2000 km, Length/Width > 2

Global AR Detection

AR Date, Transports, Shape, Axis, Landfall Location, Etc.



Based on ERA-Interim 6-hourly IVT

Over ~90% agreement in detected AR landfall dates compared to 3 independent studies in western US, Britain, and East Antarctica (Neiman et al. 2008; Lavers et al. 2011; Gorodetskaya et al. 2014)

Applications

- Global characterization
- GCM evaluation
- Forecast assessment
- Climate change

Guan and Waliser (2015)

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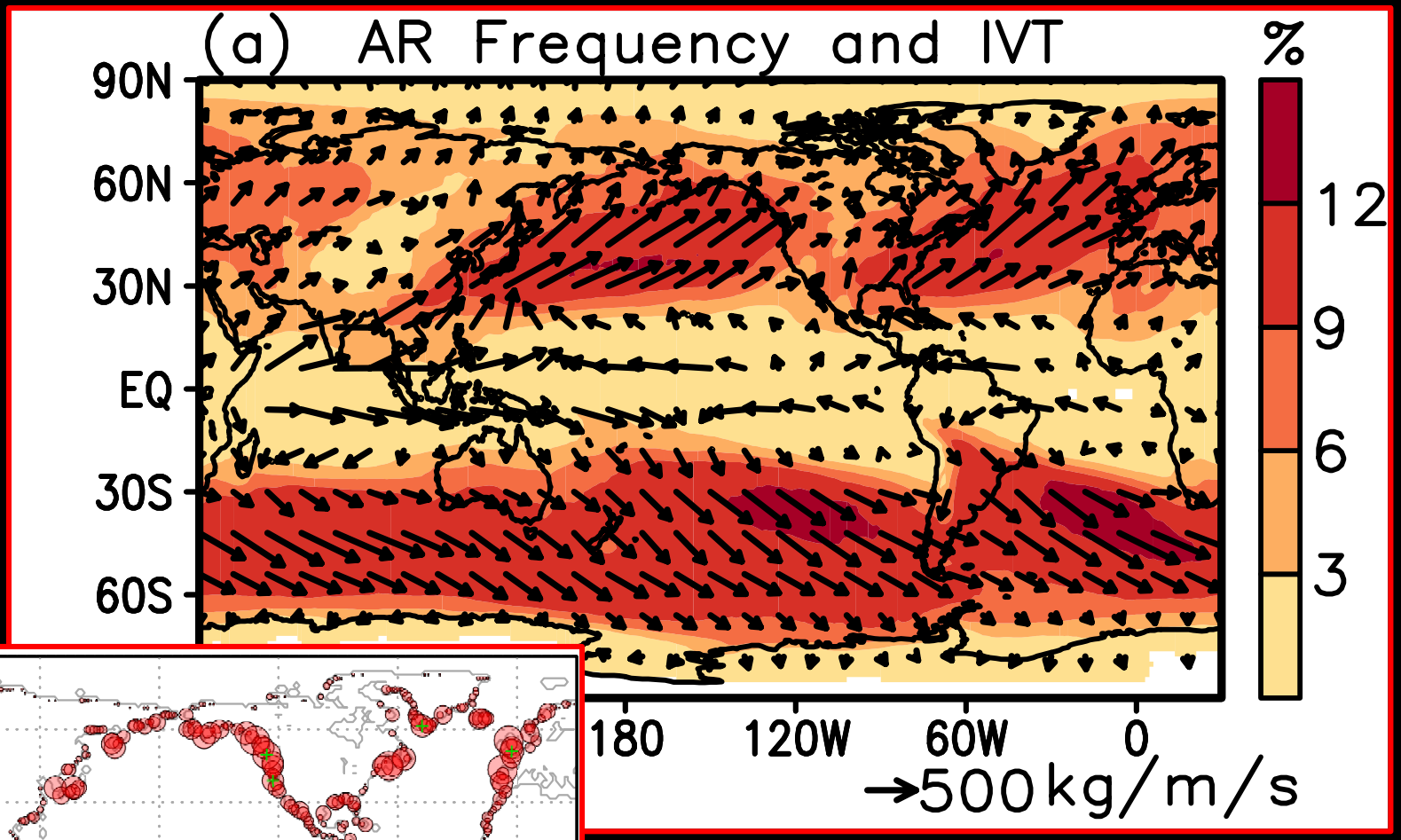
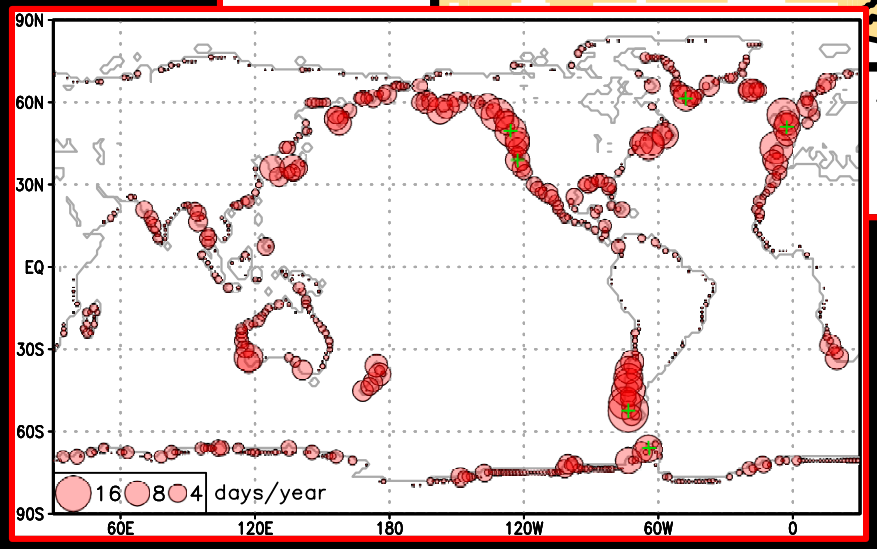
Global AR Frequency, IVT & Landfalls





Guan and Waliser (2015)

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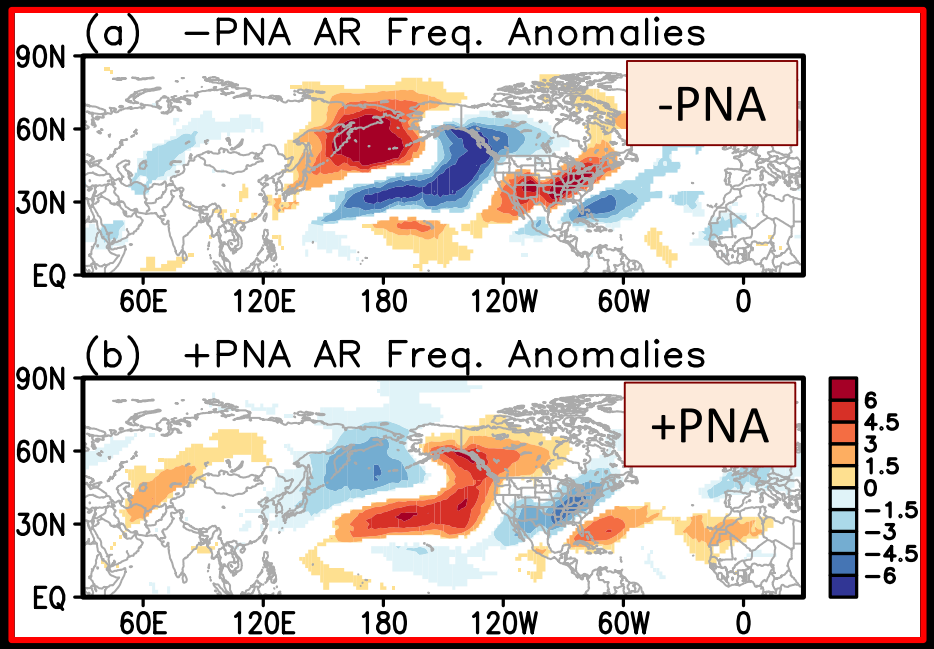
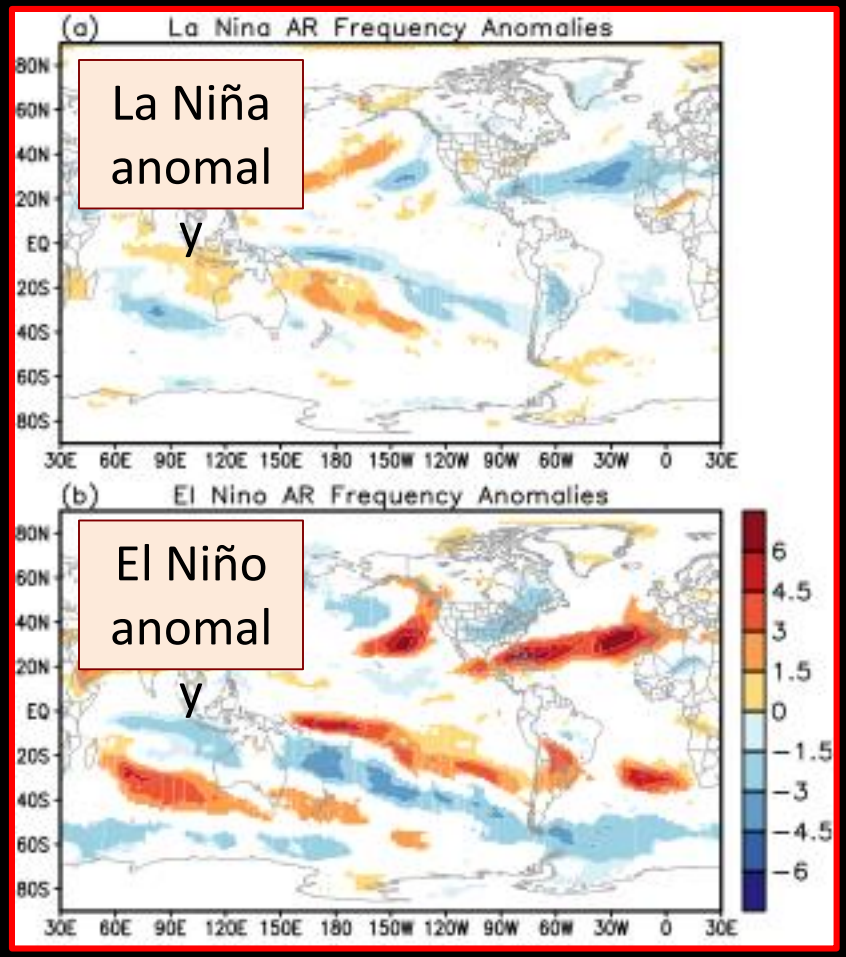
Global Climate Variability & ARs

Pacific-North American (PNA)



Also for AO & MJO

El Nino Southern Oscillation (ENSO)



Guan and Waliser (2015)

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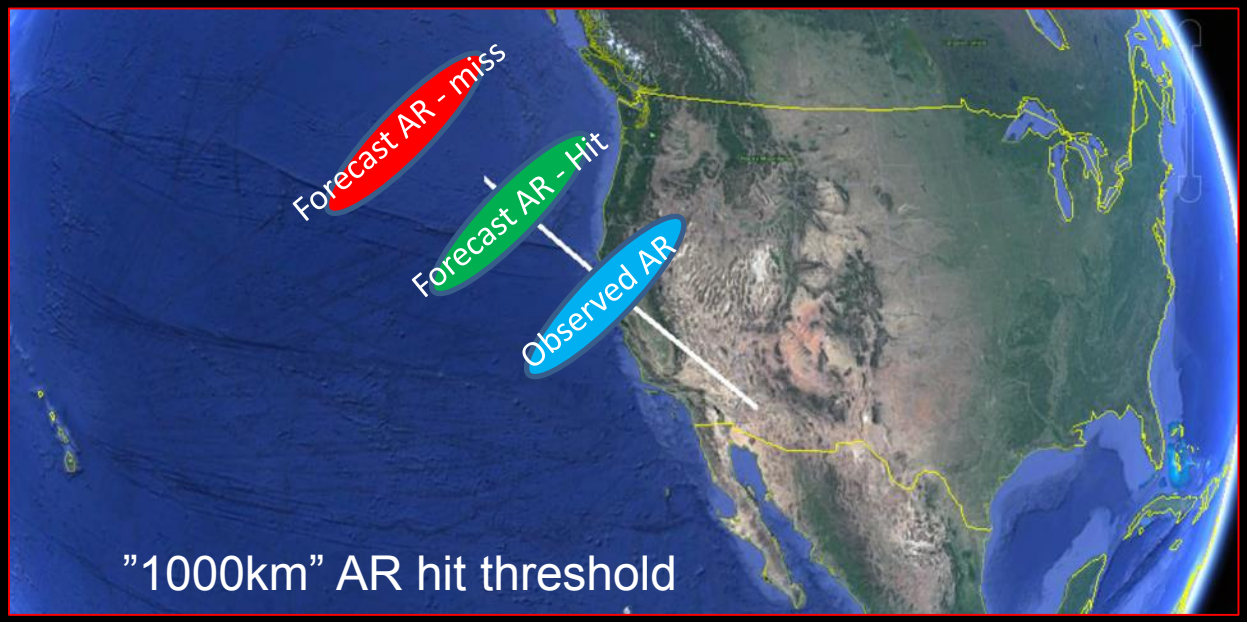
Global AR Prediction Skill

DeFlorio, Waliser, Guan et al. (2016, In Prep)

S2S Project Hindcasts - ECMWF (1996-2014)
Observations - ERA-Interim



- Global detection algorithm applied to observations and each ensemble member.
- Count fraction of number of “hits” vs leadtime, etc.

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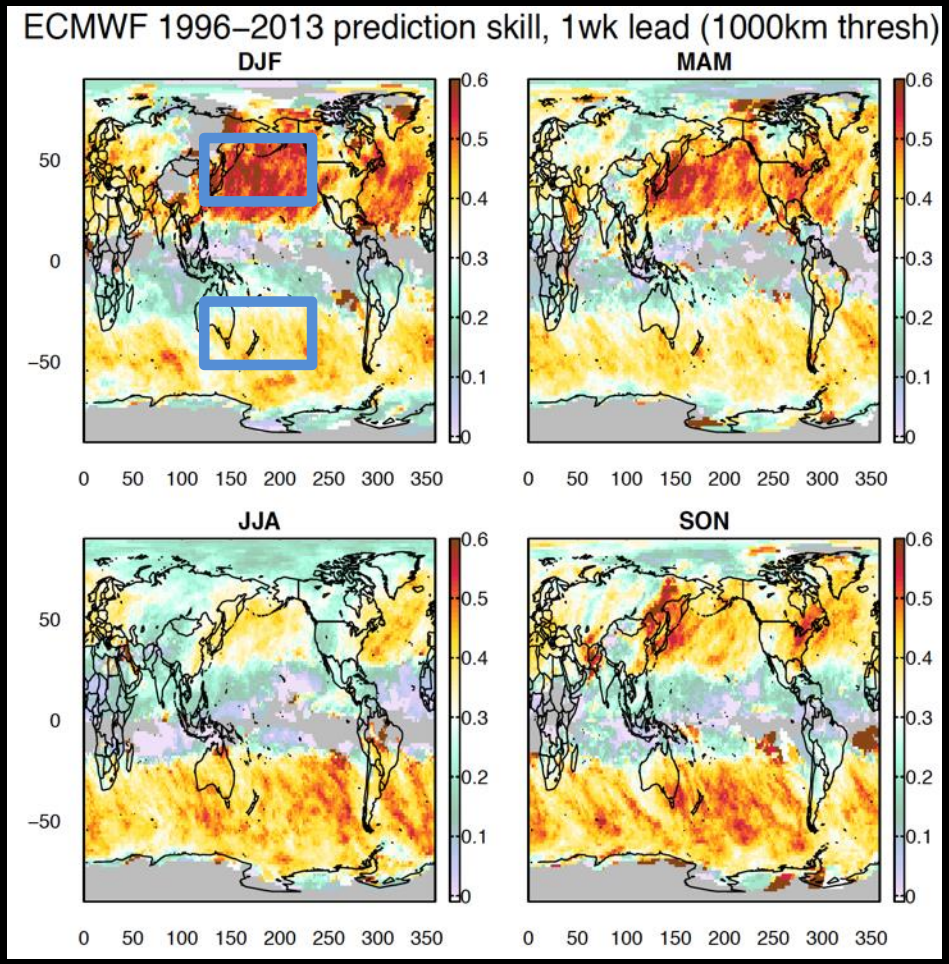
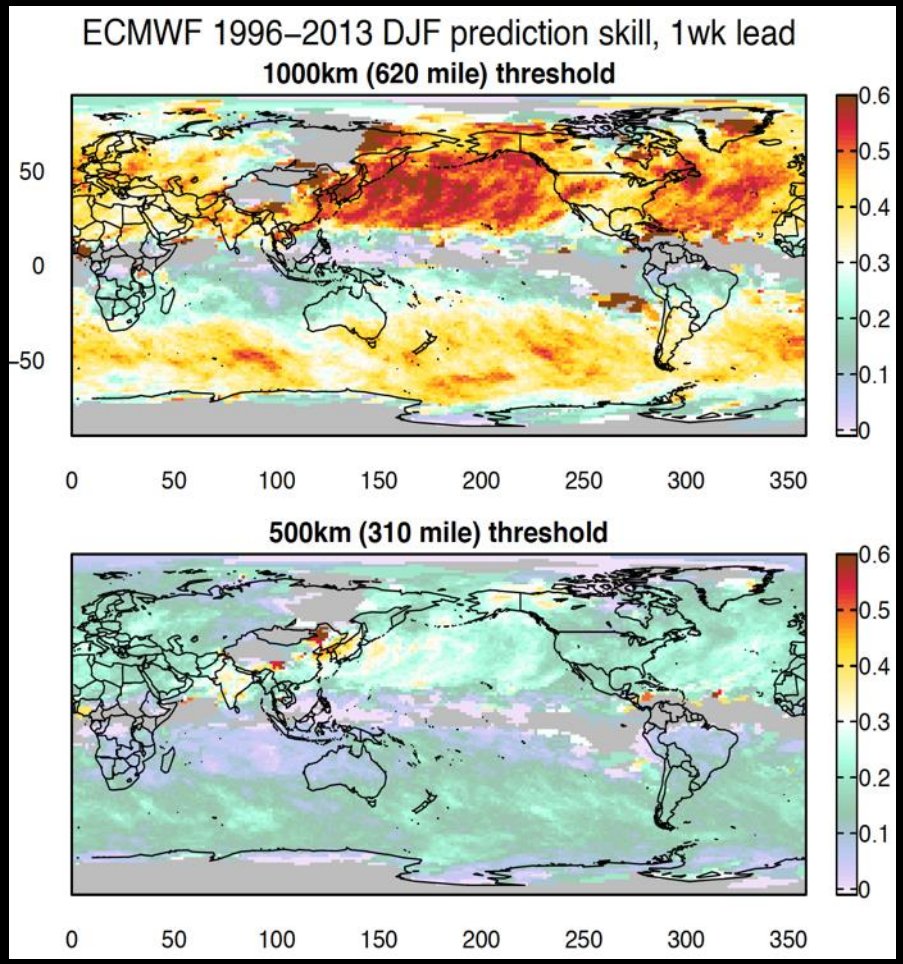
Global AR Prediction Skill

Seasonal Variability



Sensitivity To Distance Threshold



DeFlorio, Waliser, Guan et al. (2016, In Prep)

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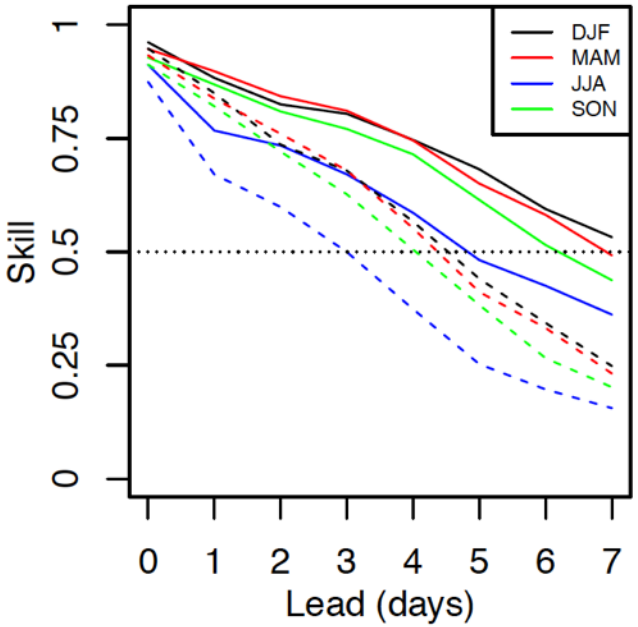
Global AR Prediction Skill

Dependence of prediction skill on season, lead time and geography

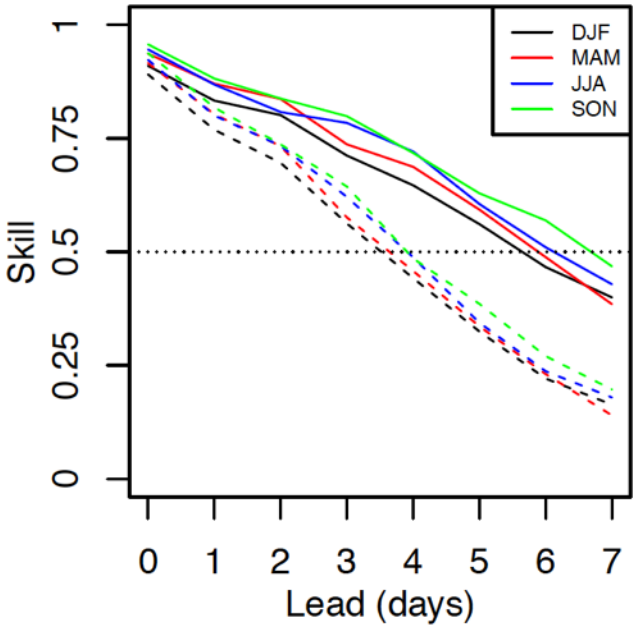
- Solid lines = 1000km threshold
- Dashed lines = 500km threshold

DeFlorio, Waliser, Guan et al. (2016, In Prep)

AR prediction skill, N. Pac. (140E–230E, 30N–60N)



AR prediction skill, S. Pac. (140E–230E, 30S–60S)



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Climate Change & ARs

Frequency & Transports

Example Result for GFDL CM3 GCM

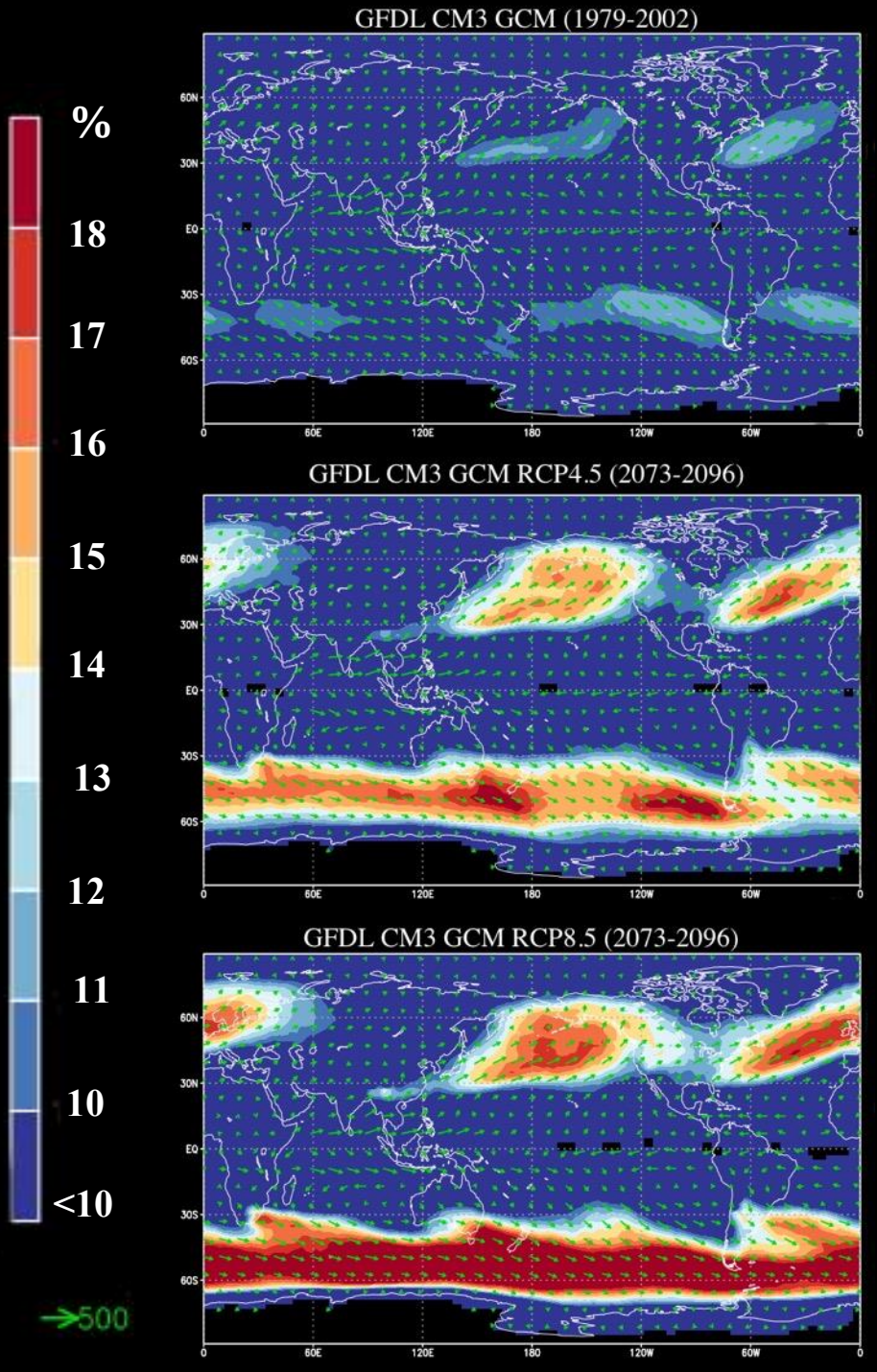
North Pacific Ocean

Historical: ~10 % AR Days
RCP4.5: ~ 14 % AR Days
RCP8.5: ~ 16 % AR Days

Southern Ocean

Historical: ~10 % AR Days
RCP4.5: ~15 % AR Days
RCP8.5: ~19 % AR Days

Espinoza, Waliser, Guan, Lavers (2016, In Prep)



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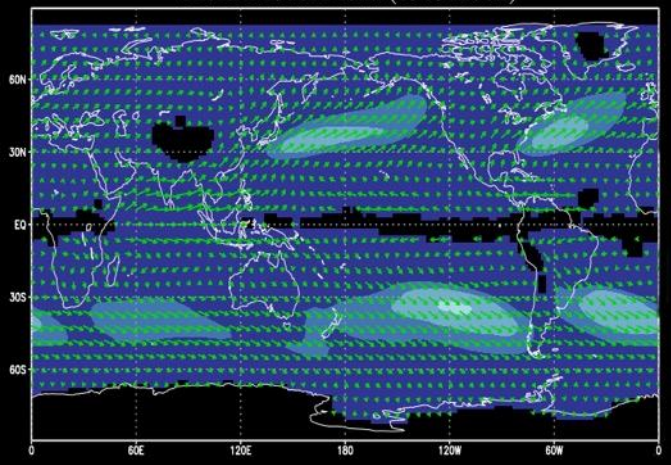
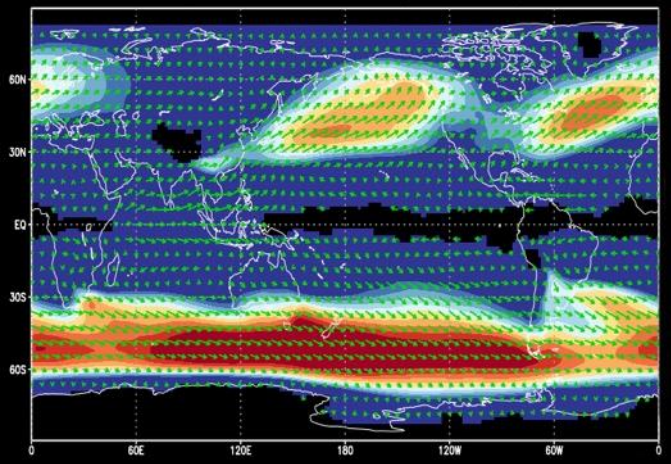
Climate Change & ARs

%
18
17
16
15
14
13
12
11
10

Multi-Model Mean (1979-2002)

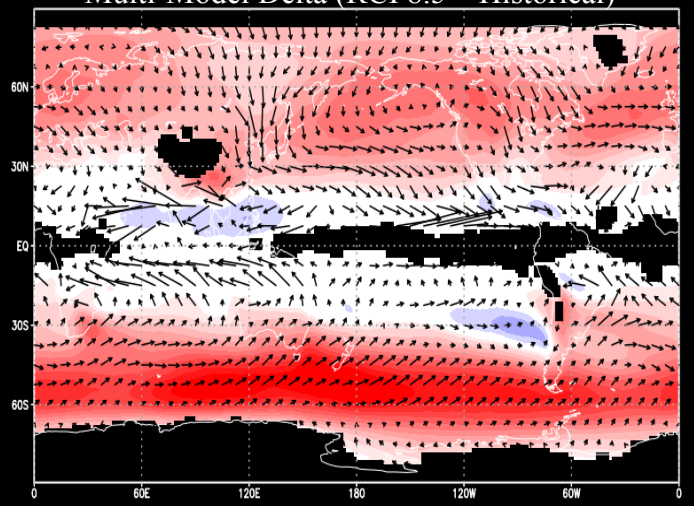


Multi-Model Mean RCP8.5 (2073-2096)



CMIP6
Multi-Model Mean

Multi-Model Delta (RCP8.5 – Historical)



Vectors *10

- Extra-tropics Increase
- S. Ocean Increases Most
- A Few Regions Decrease

%
10
9
8
7
6
5
4
3
2
1
0.5
-0.5
-1
-2
-3
-4
-5

→500

Espinoza, Waliser, Guan, Lavers (2016, In Prep)

Evaluating Weather/Climate Simulations of ARs

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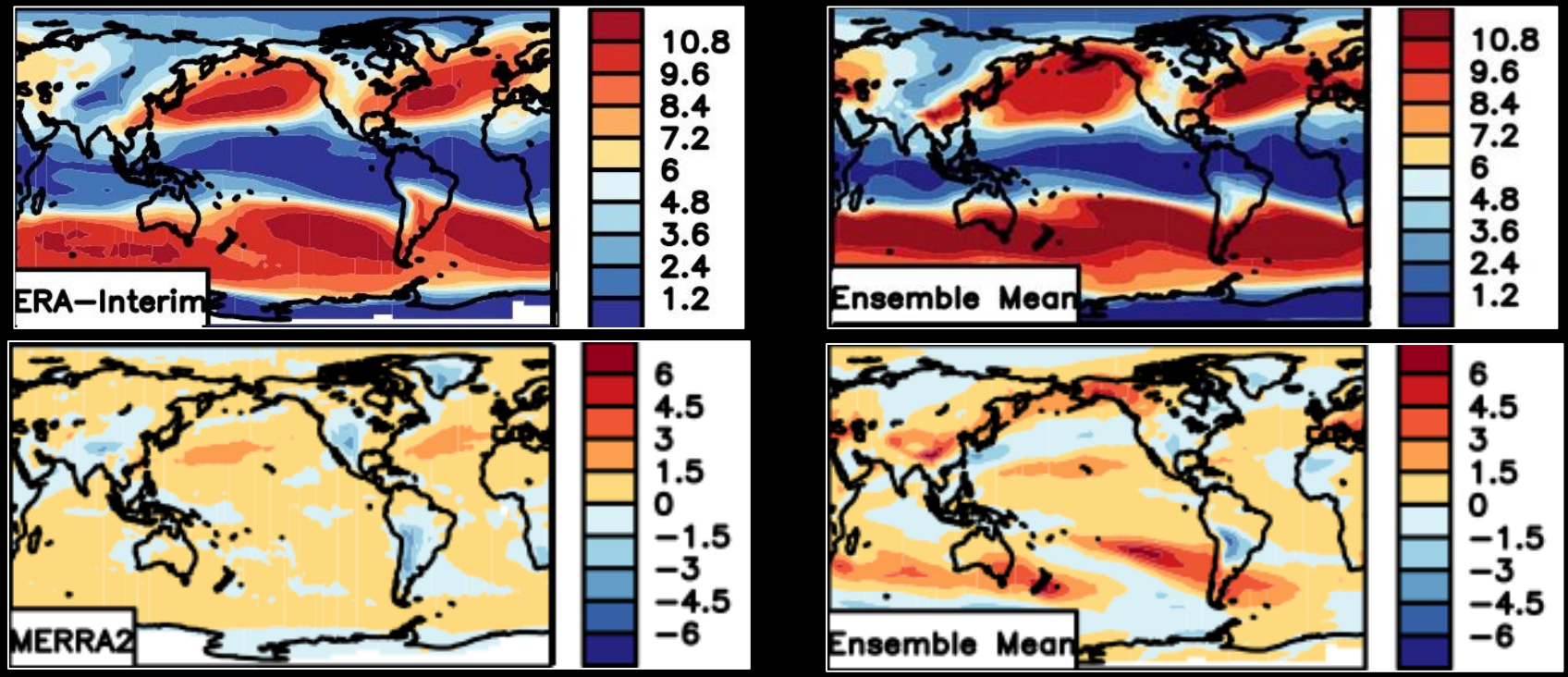
Observed Frequency; ERA-Interim

20-year simulations from 24 global climate/weather models



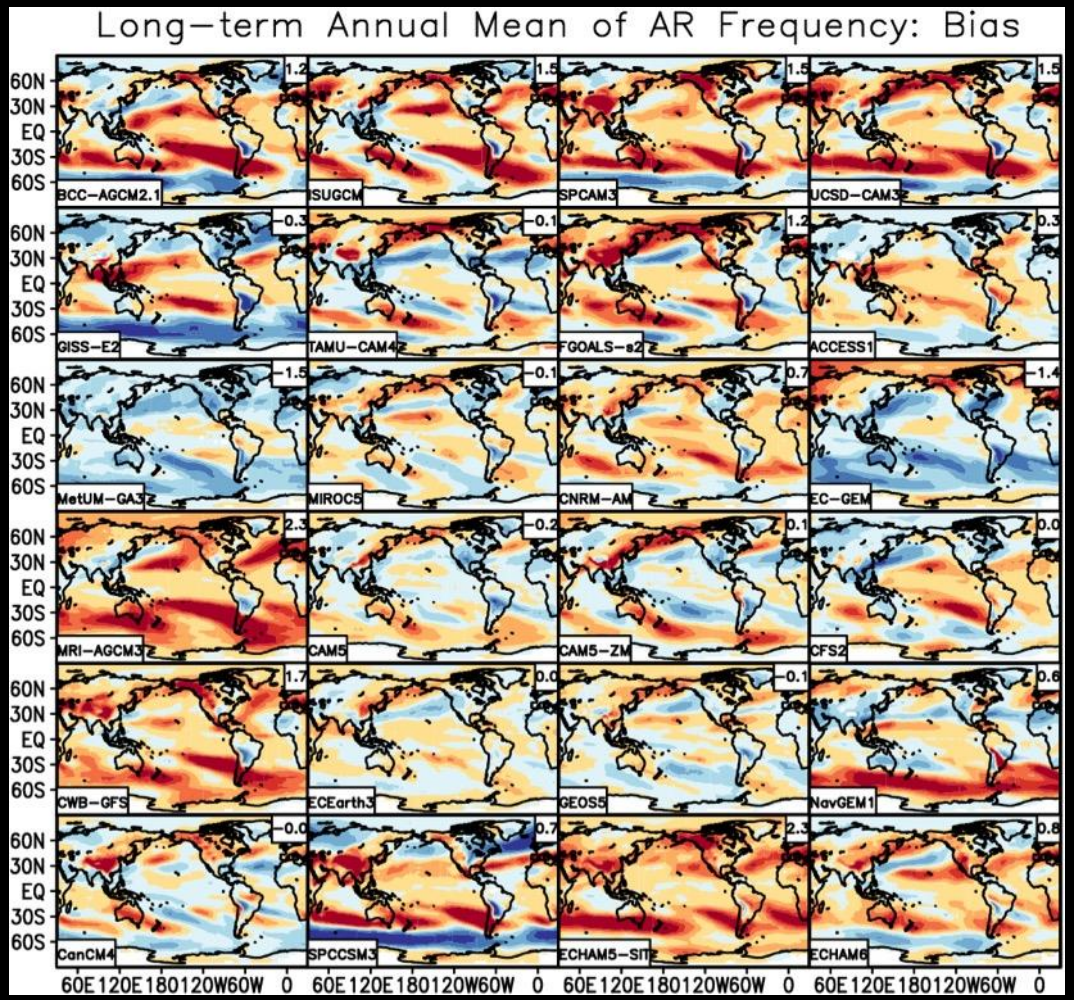
Difference with 2nd Observation Reference; MERRA-2

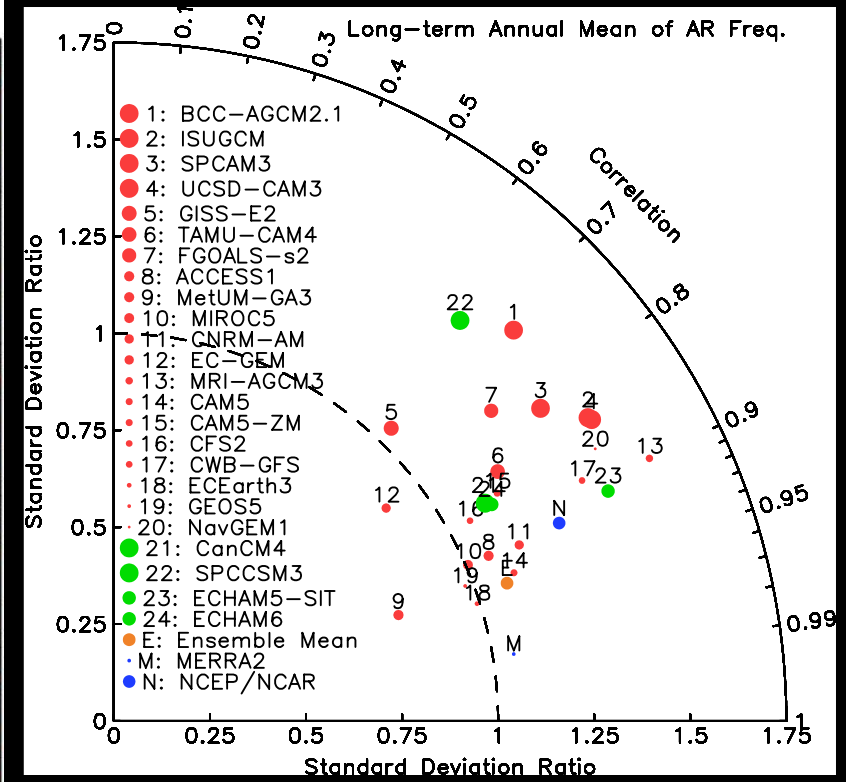
Modeled – Observed

- Broad-scale distribution of AR frequency reasonably represented in ensemble mean
- Biases are in general within reanalysis uncertainty, except in Southeastern Pacific

GEWEX / YOTC / MJO TF Multi-Model Experiment

Evaluating Weather/Climate Simulations of ARs

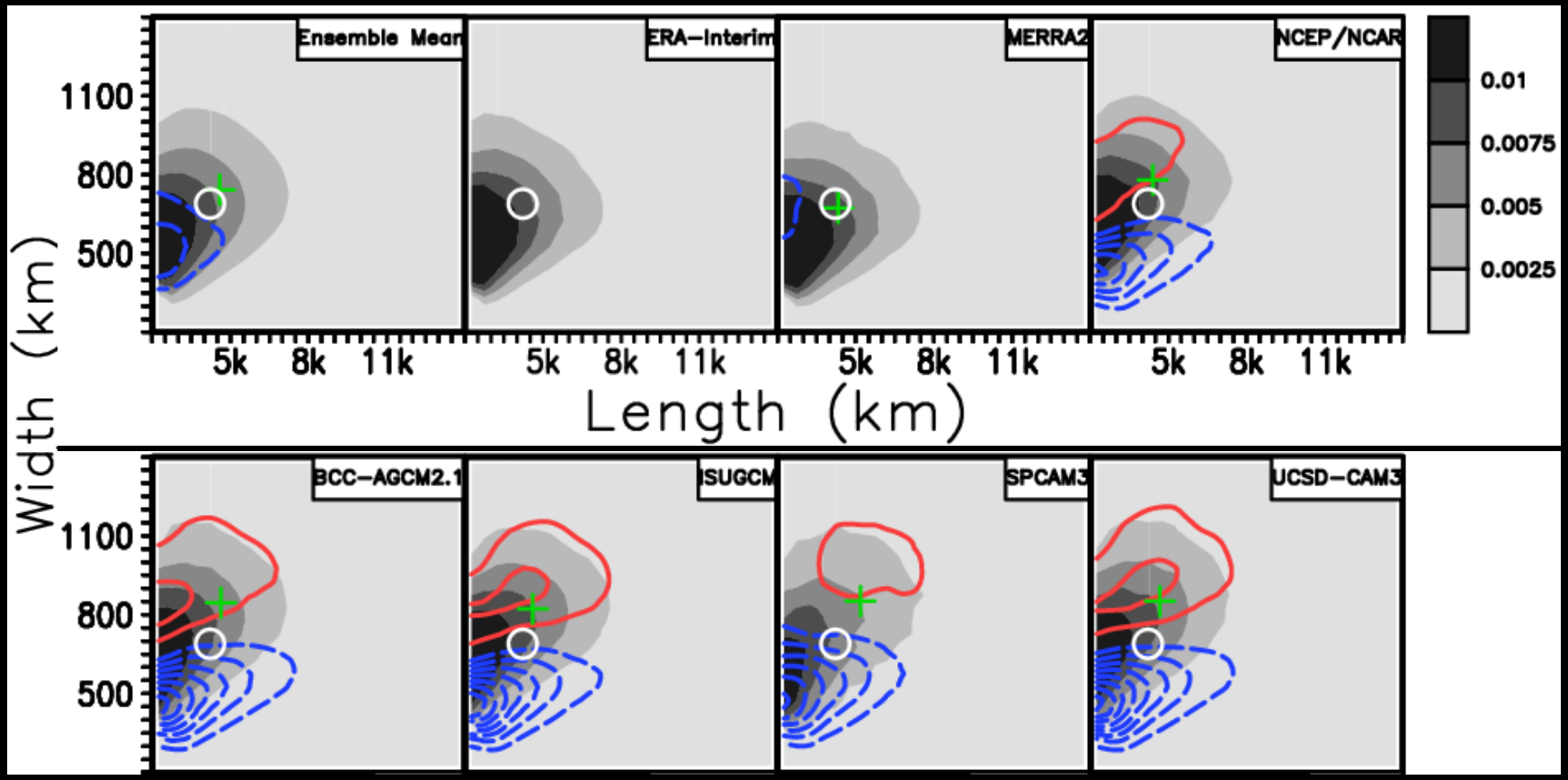




- Significant variation in model fidelity in biases and spatial patterns of AR frequency
- Largest errors tend to occur in models with coarsest resolutions, and some coupled models
- Experiment's model output allows interrogation of AR processes –> Future Work

Evaluating Weather/Climate Simulations of ARs

AR Widths and Lengths



- AR geometry reasonably represented in ensemble mean (only slightly wider/longer than reference)
- *Large biases in coarsest-resolution models: too many wide ARs / too few narrow ARs*

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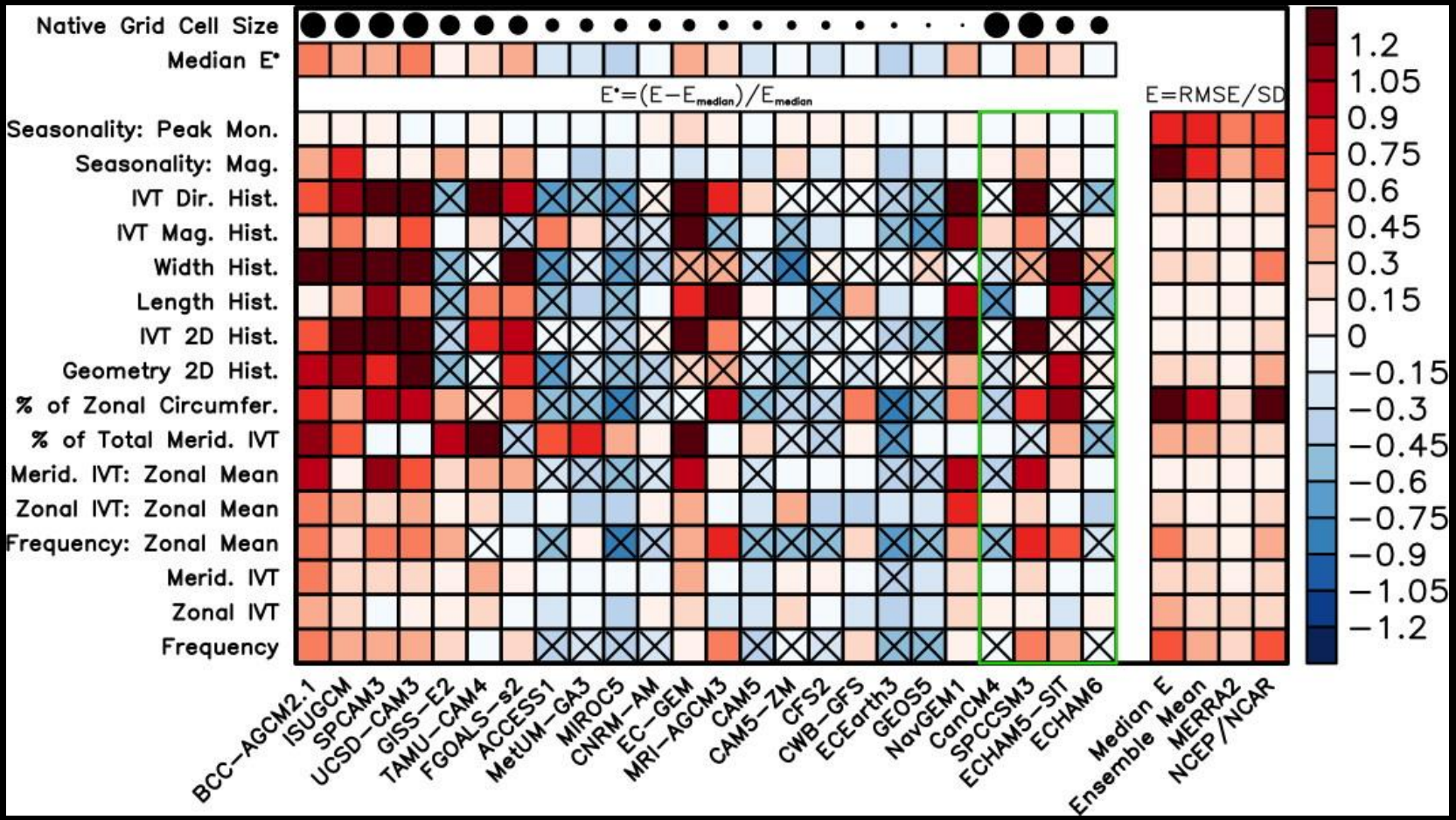
Evaluating Weather/Climate Simulations of ARs

Portrait Diagram



Guan and Waliser (2016, In Prep)

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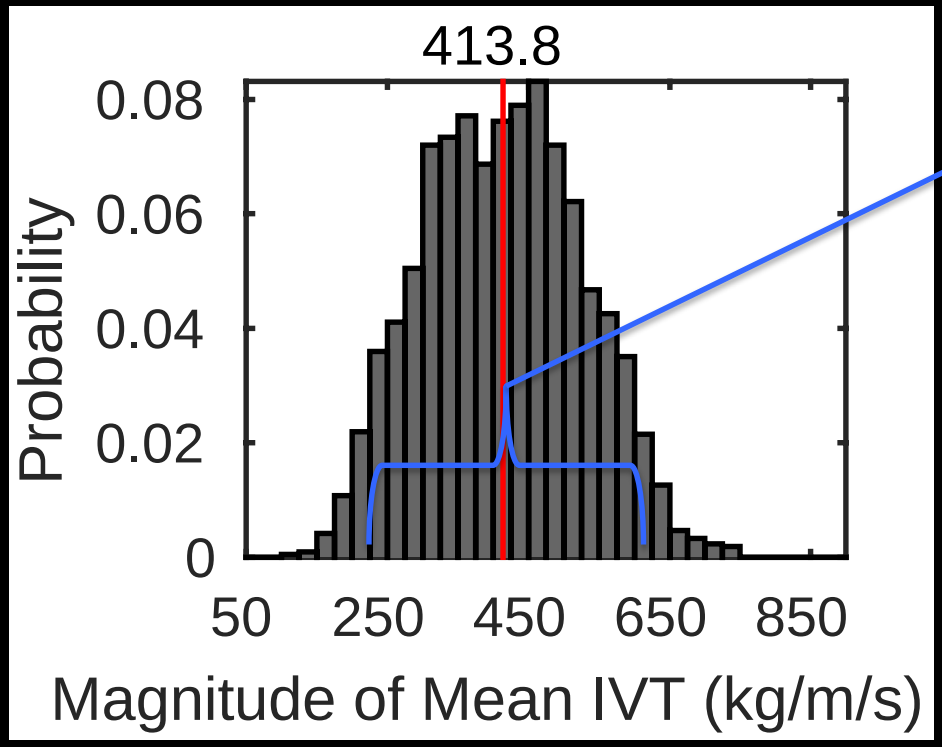
Summary

- Atmospheric Rivers are a global phenomena that shape the Earth's climate, water and energy cycles, as well as account for regional weather and water extremes.
- We've developed a detection algorithm that can be *consistently* used on global "observations" (i.e. re-analyses), climate simulations and forecast models.
- Using this detection algorithm, we are:
  - Examining climate variation of ARs (e.g. ENSO, PNA).
  - Evaluating AR model performance and identify weaknesses to guide model improvement.
  - Quantifying AR forecast skill in a suite of operational S2S/weather prediction models.
  - Characterizing projected 21ST century changes in ARs.

Extra Slides

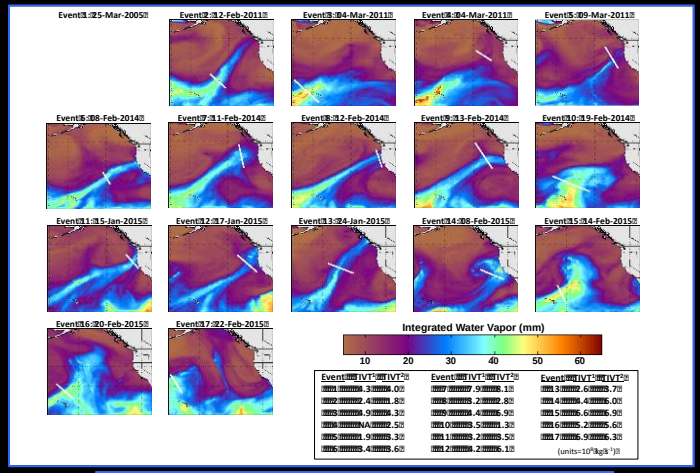
Comparison to CalWater Dropsonde Measurements

IVT Histogram Based On
2140 NE Pacific ARs
124-164W, 23-43N; Jan 15-Mar 25



Guan & Waliser 2015

17 AR Event Transcects
450 +/- 200 kg/m/s
Min 130; Max 810



Ralph et al. (2016)

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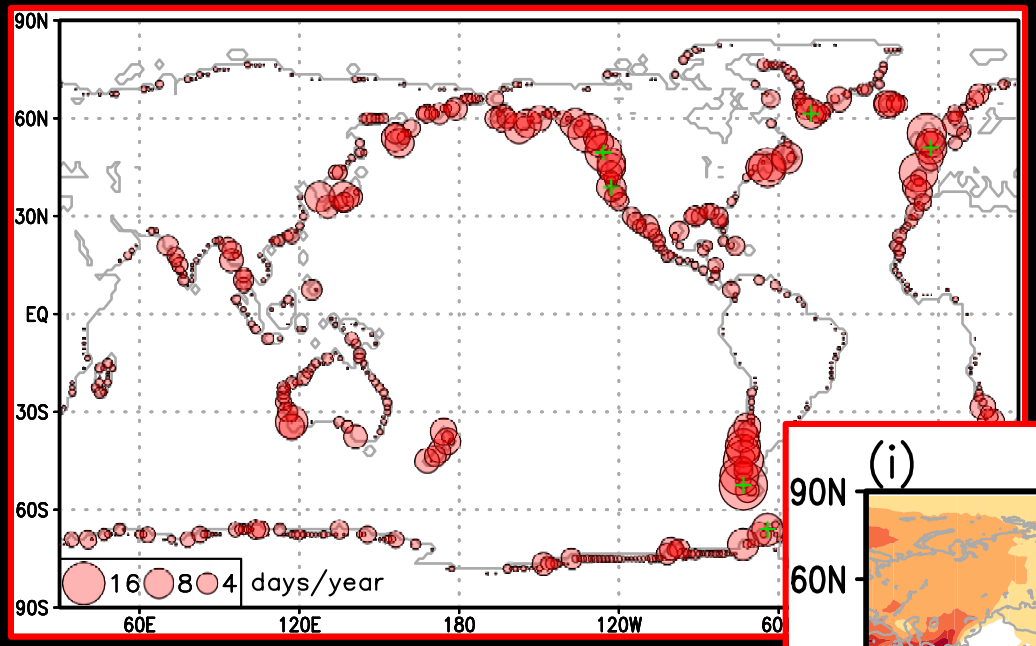
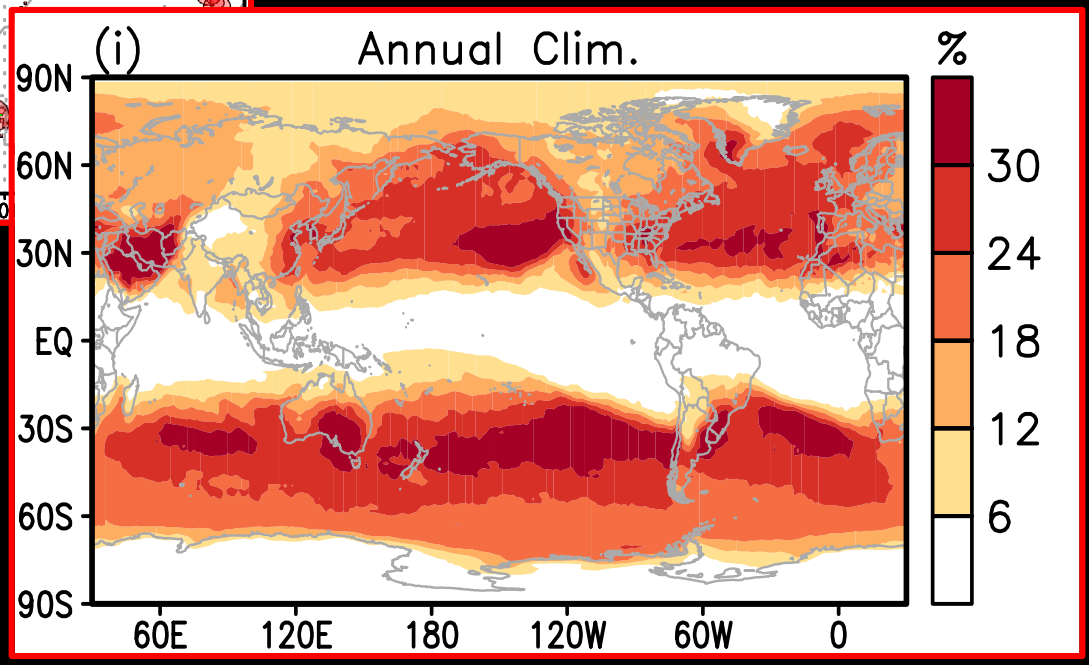
AR Landfalls Fraction of Annual Precipitation



A Global Perspective



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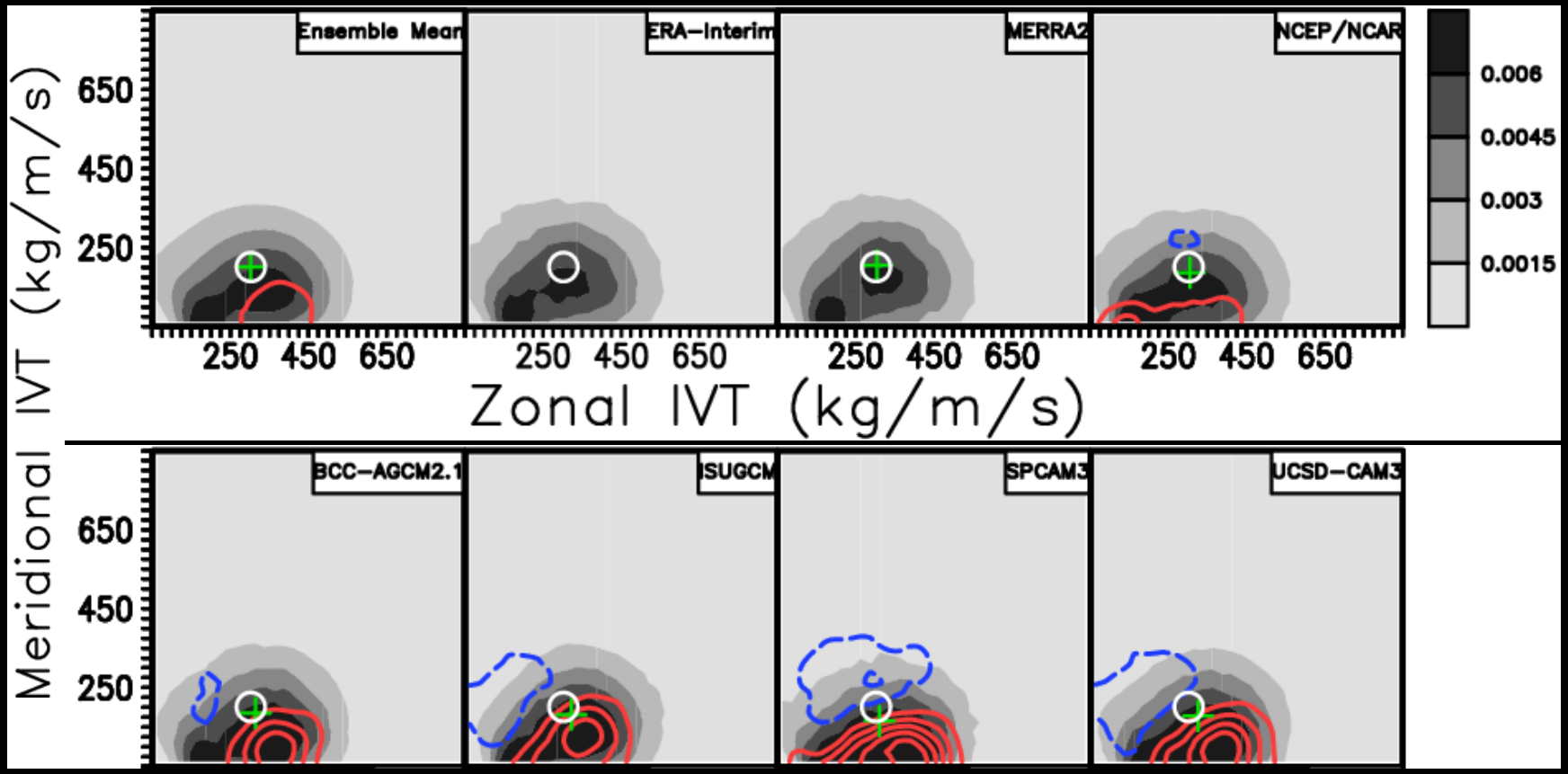
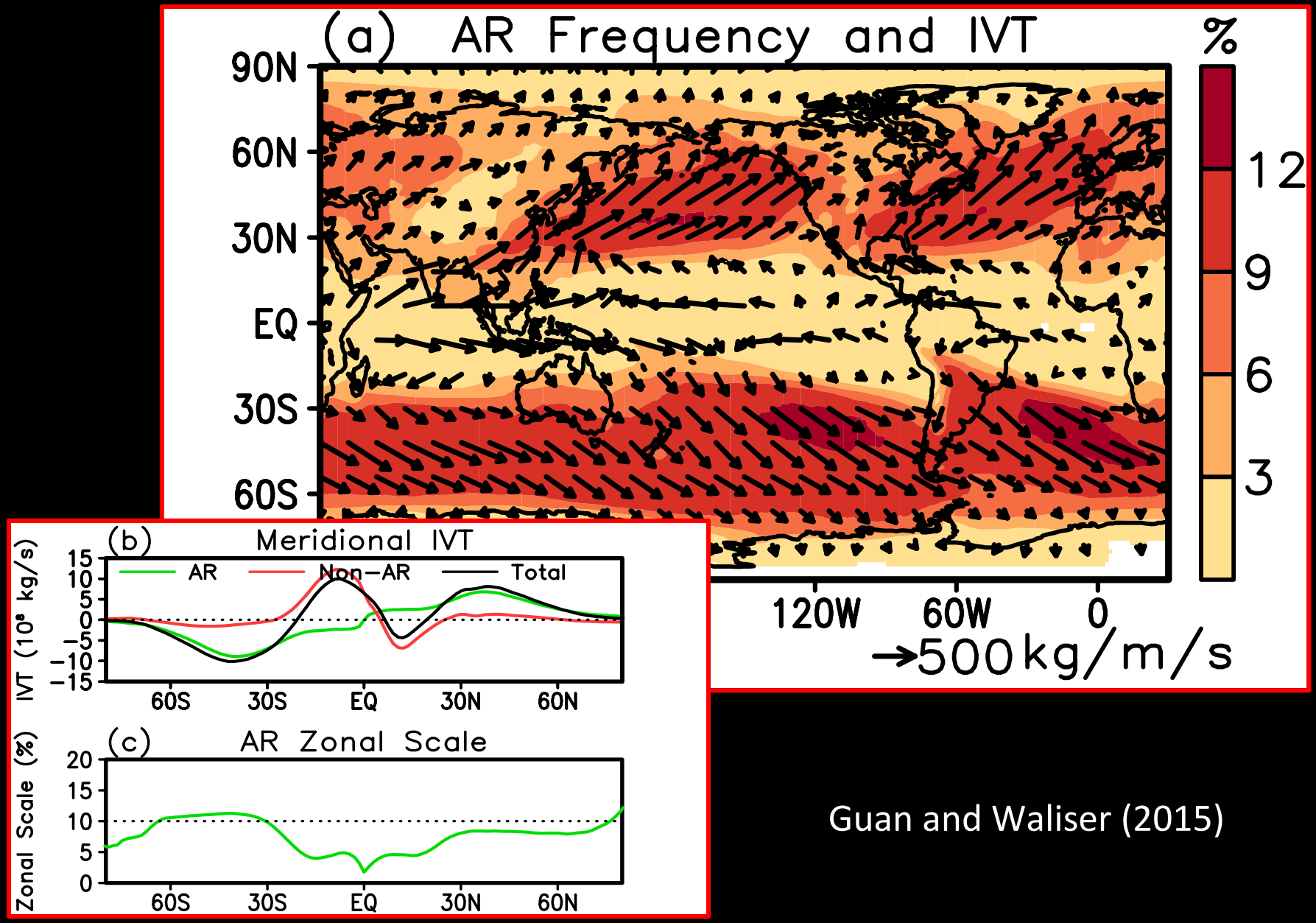
Evaluating Weather/Climate Simulations of ARs

Zonal and Meridional IVT Strength



- AR zonal & meridional IVT well represented in ensemble mean
- Notable biases in coarsest-resolution models, but not as strong as in AR geometry

Global Map of AR Frequency and IVT



Guan and Waliser (2015)