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AR Prediction for Western US

In the Context of Global Weather/Climate Models

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With significant collaboration / support from the
Center for Western Weather and Water Extremes (M. Ralph et al.)
CA Department of Water Resources (J. Jones)
NASA Energy and Water Cycle Research Program (J. Entin)

Western States Water Council
May 17-19, 2017

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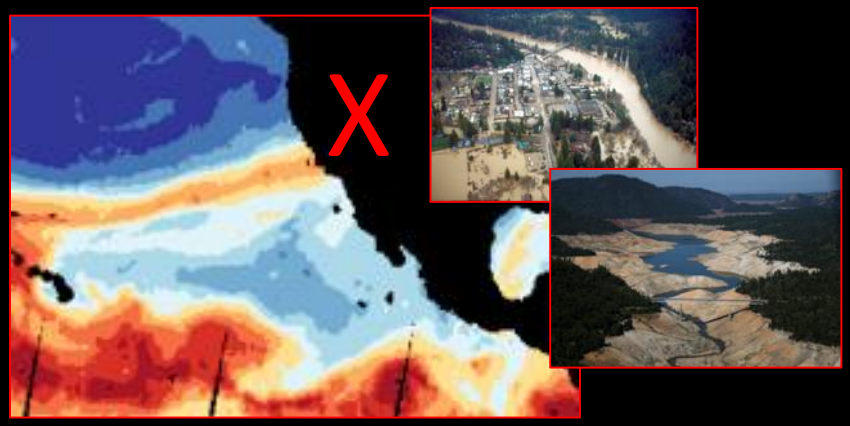
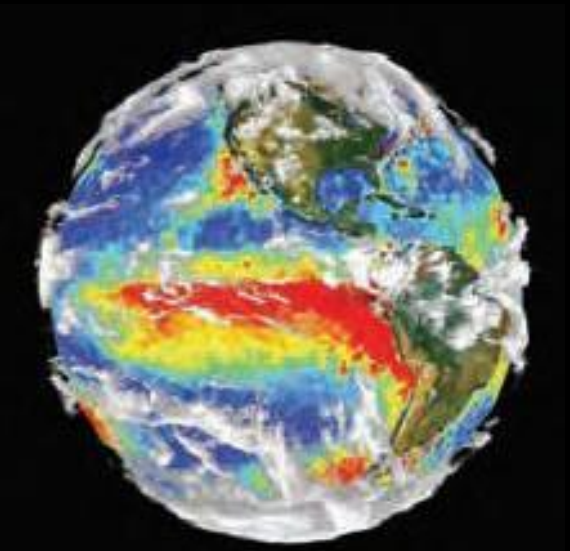
A Global Approach to ARs



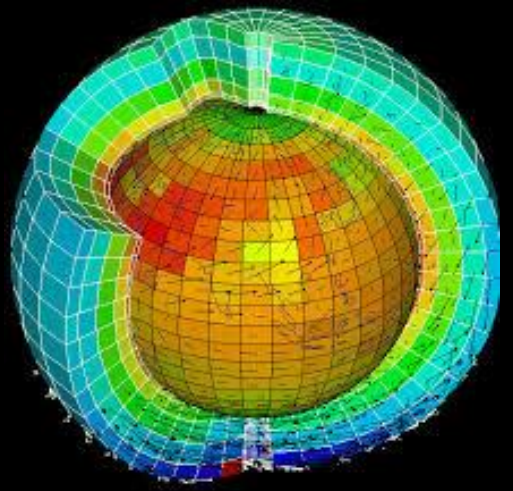
Objective:
Western US Water Predictions

“Think Regionally”



Key Considerations:
Long-Leads -> Global Circulation, Climate Modes

”Model & Forecast Globally”



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Outline

I. Background and Resources
- *Global AR Detection Algorithm*
- *Climate Mode Modulations of ARs*
- *WCRP/WWRP S2S Project & Database*

II. AR Predictions
- *Weather predictions of Individual ARs (e.g. 0-15 days)*
- ***Subseasonal predictions (e.g. 2-6 weeks)***
- *Climate change projections (e.g. 50-100 years)*

III. AR Global Model Evaluation & Improvement
- *Global/Regional & Bulk AR Characteristics*

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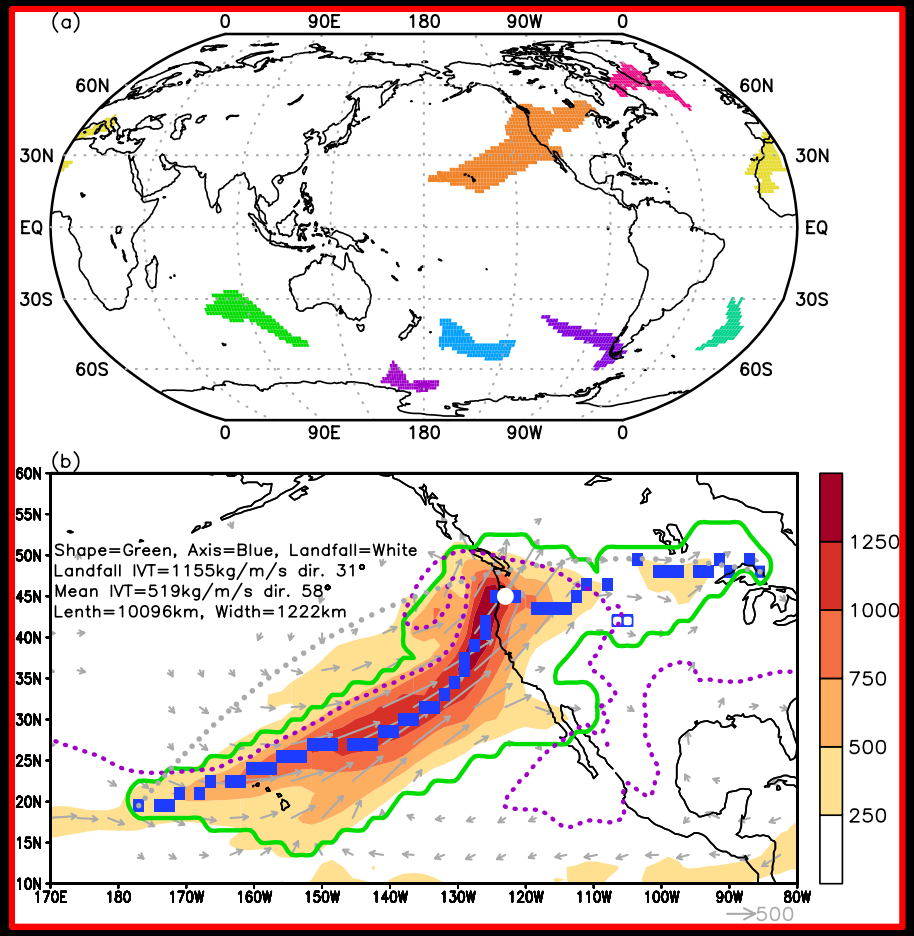
Global AR Detection Algorithm



Guan and Waliser (2015)

- Based on Integrated Vapor Transport (IVT) fields and a number of common AR criteria (e.g. Ralph et al. 2004).
- Developed for global studies and for observations/reanalysis and models.
- Applied to:
  - ERA-I, MERRA-2, CFSR, NCEP/NCAR
- Code and databases available at:
  - https://ucla.box.com/ARcatalog
- Databases include AR Date, $IVT_{x,y}$, Shape, Axis, Landfall Location, etc.

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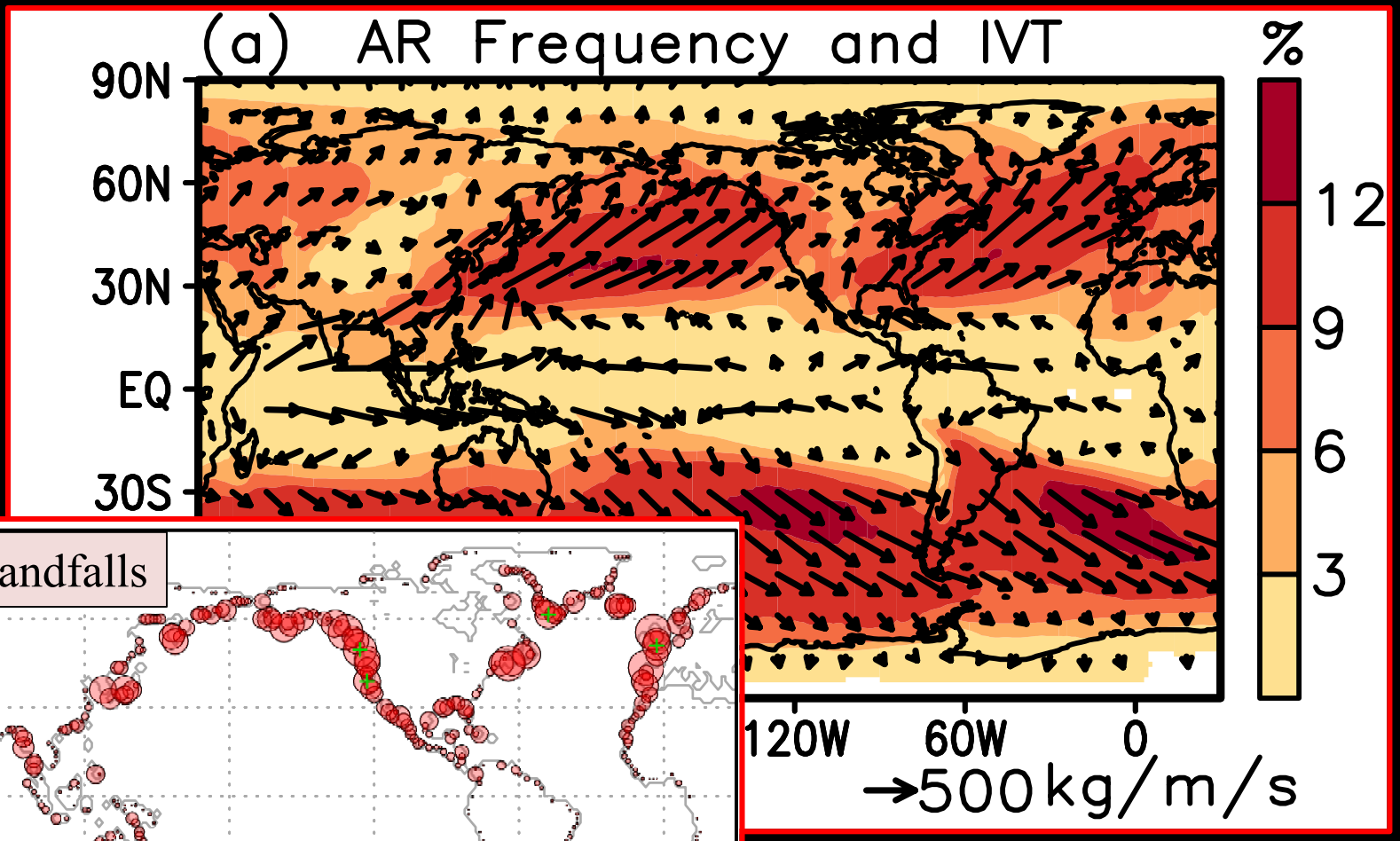
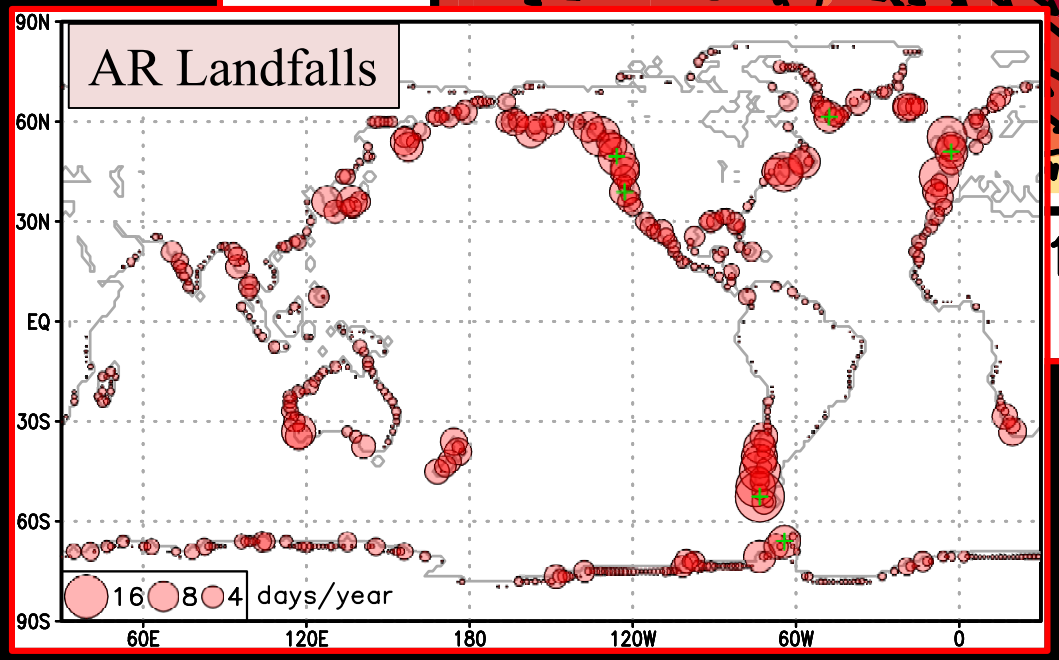
Global AR Frequency, IVT & Landfalls





Guan and Waliser (2015)

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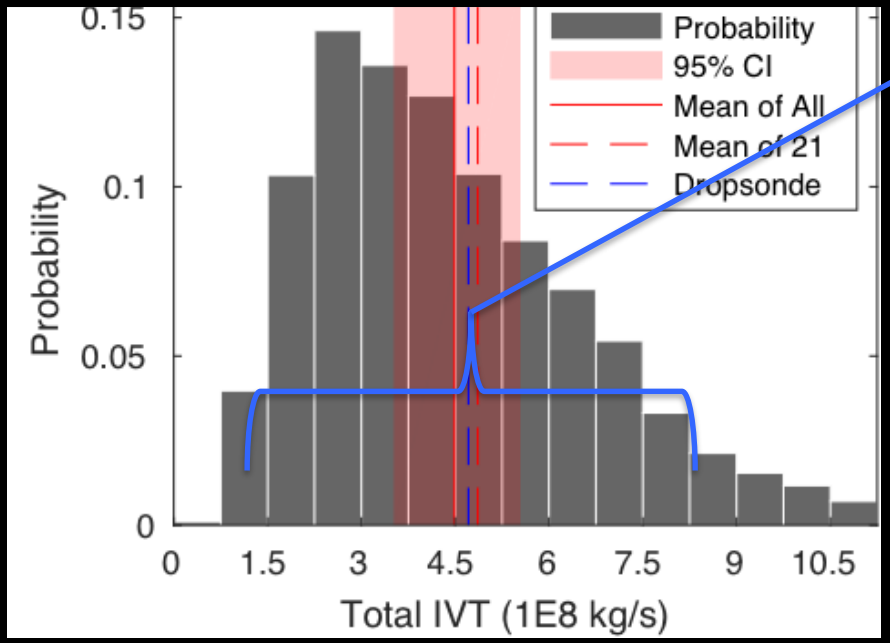
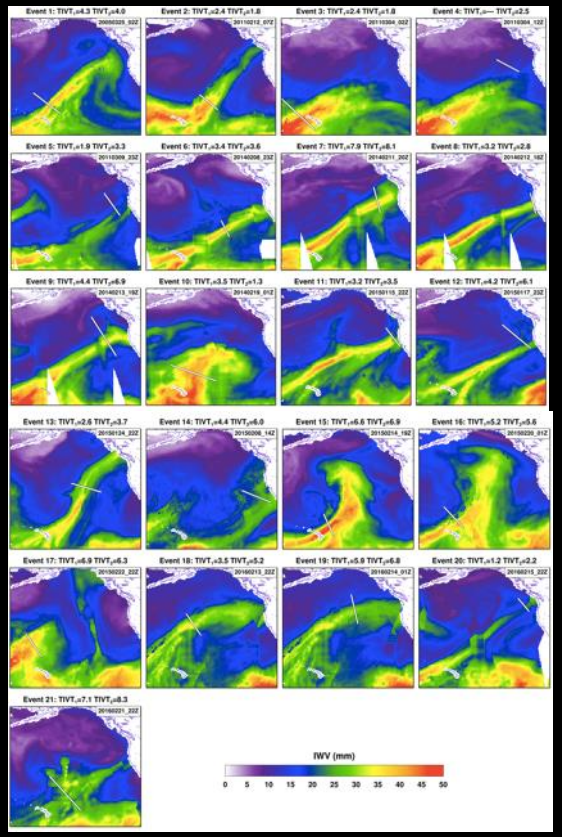
CalWater Validation Support of Algorithm

IVT Histogram Based On
5636 NE Pacific ARs
125-163W, 23-46N
Jan 15-Mar 25 1979-2016



Guan, Waliser and Ralph (2017, In Prep)

21 AR Event Transects
4.7 +/- 1.9kg/s
Min 1.3; Max 8.3



Ralph et al. (2017, Under Revision)

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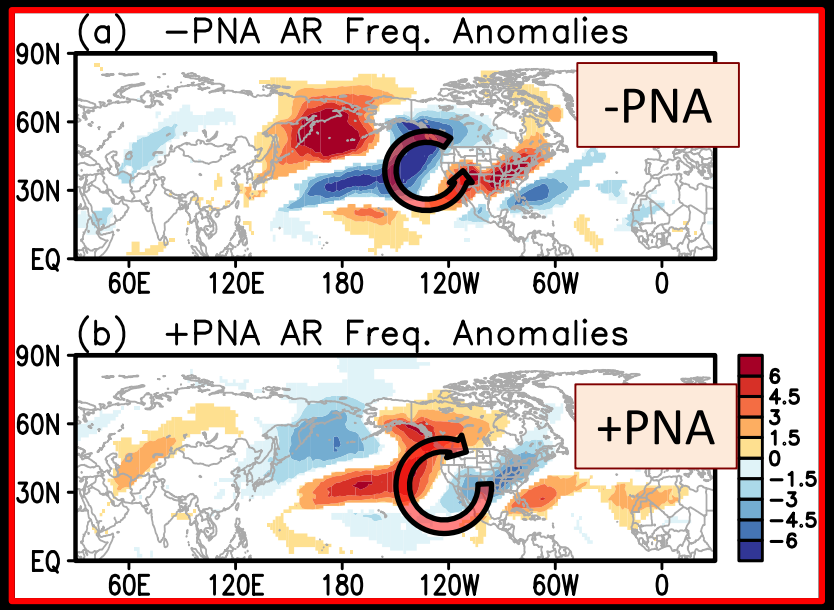
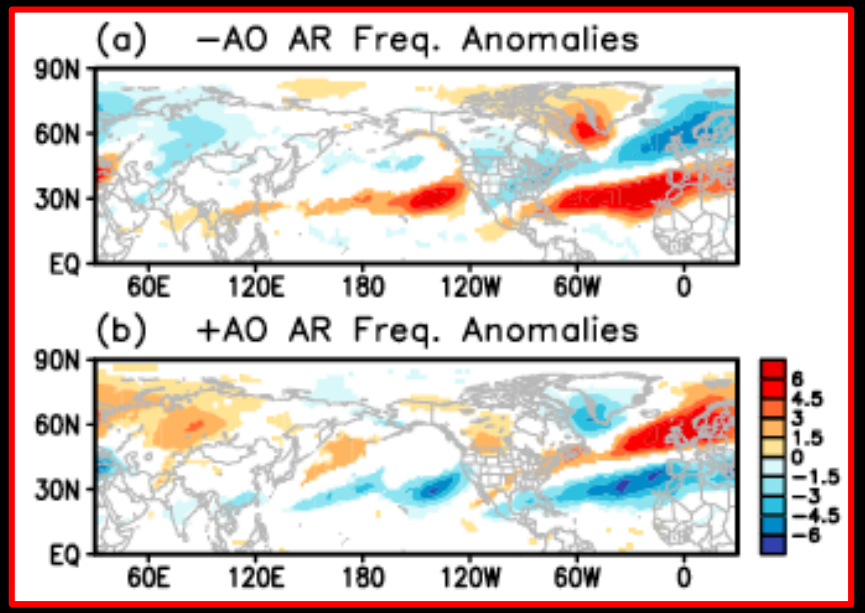
Climate Patterns and ARs

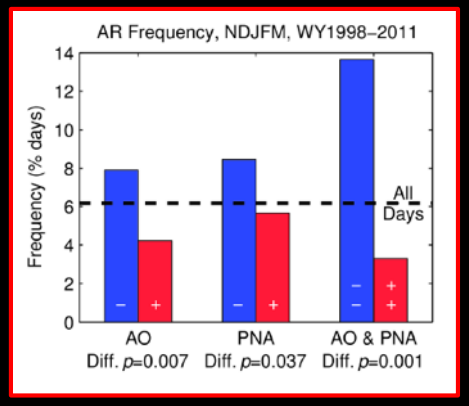
Pacific-North American (PNA)



Arctic Oscillation (AO)



Guan and Waliser (2015)



When PNA & AO are both in “negative” phases, there is a doubling of the frequency of ARs.

Guan et al. 2013; using Neiman et al., 2008 AR database

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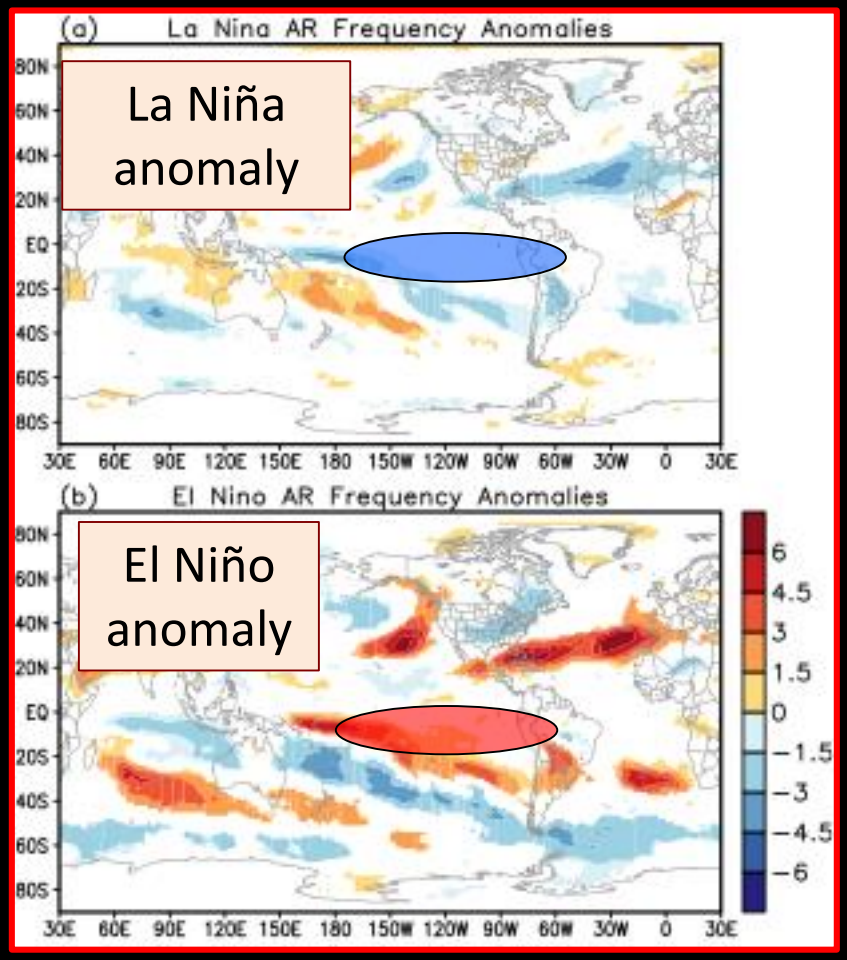
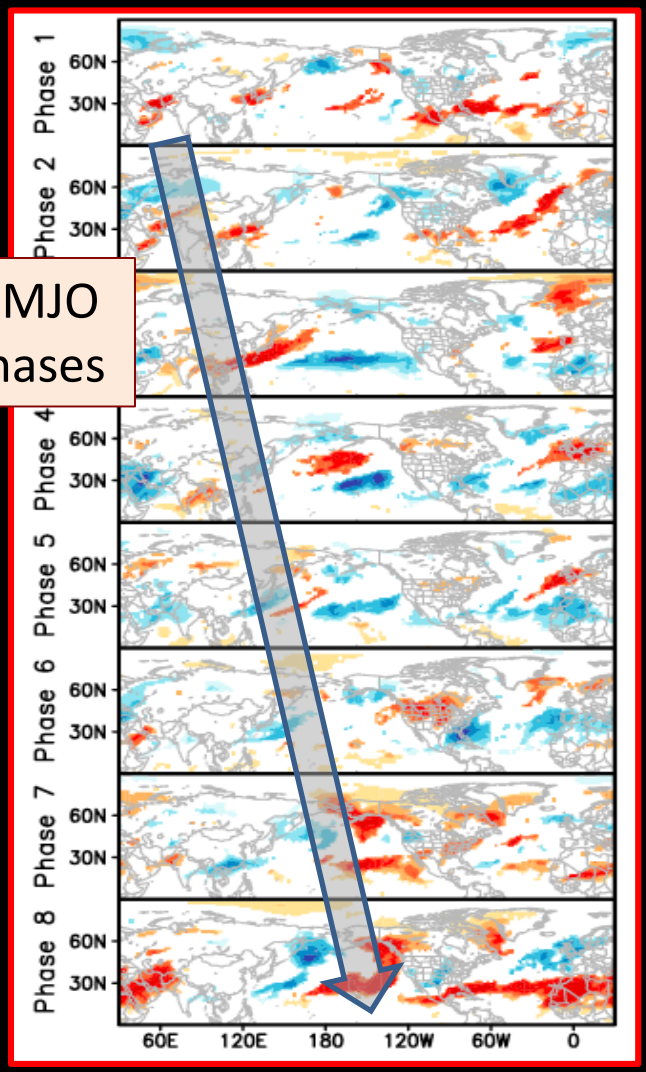
Climate Patterns and ARs

El Nino Southern Oscillation (ENSO)



Guan and Waliser (2015)

Madden-Julian Oscillation (MJO)



See also Guan et al. (2012)

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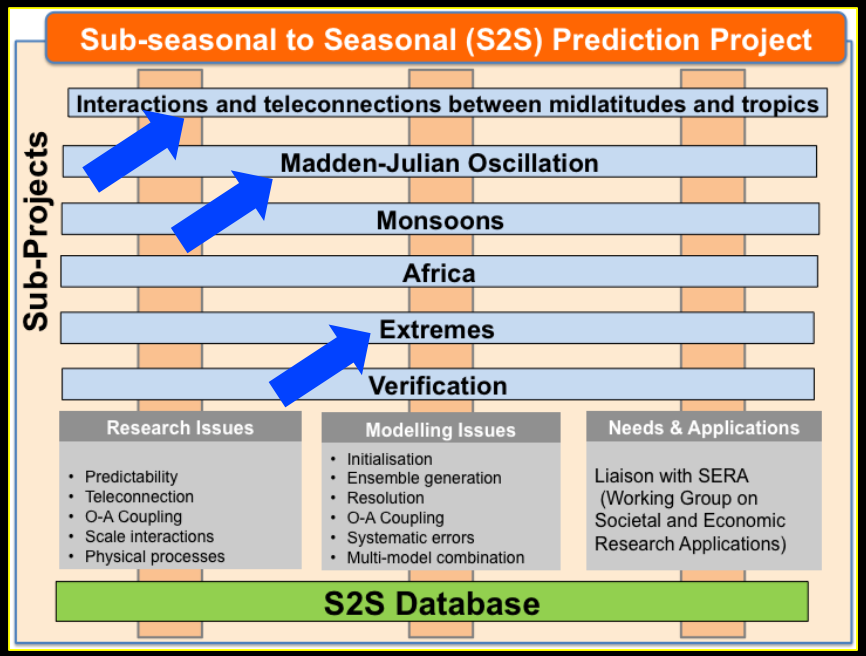
Subseasonal Forecast Database

WCRP-WWRP S2S Project

International Program for S2S Research



S2S Database

	Time-range	Resol.	Ens. Size	Freq.	Hcsts	Hcst length	Hcst Freq	Hcst Size
ECMWF	D 0-46	T639/319L91	51	2/week	On the fly	Past 20y	2/weekly	11
UKMO	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
NCEP	D 0-44	N126L64	4	4/daily	Fix	1999-2010	4/daily	1
EC	D 0-32	0.6x0.6L40	21	weekly	On the fly	1995-2014	weekly	4
CAWCR	D 0-60	T47L17	33	weekly	Fix	1981-2013	6/month	33
JMA	D 0-34	T319L60	25	2/weekly	Fix	1981-2010	3/month	5
KMA	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
CMA	D 0-45	T106L40	4	daily	Fix	1886-2014	daily	4
CNRM	D 0-32	T255L91	51	Weekly	Fix	1993-2014	2/monthly	15
CNR-ISAC	D 0-32	0.75x0.56 L54	40	weekly	Fix	1981-2010	6/month	1
HMCR	D 0-63	1.1x1.4 L28	20	weekly	Fix	1981-2010	weekly	10

- Downloaded U,V,Q fields from all models' multi-decade subseasonal hindcasts.
- Computed IVT and Applied AR Detection on ECMWF, others in progress.
- Utilizing for AR forecast assessments, including model sensitivity.

Vitart, F., et al. (2017), The Sub-seasonal to Seasonal Prediction (S2S) Project Database, BAMS.

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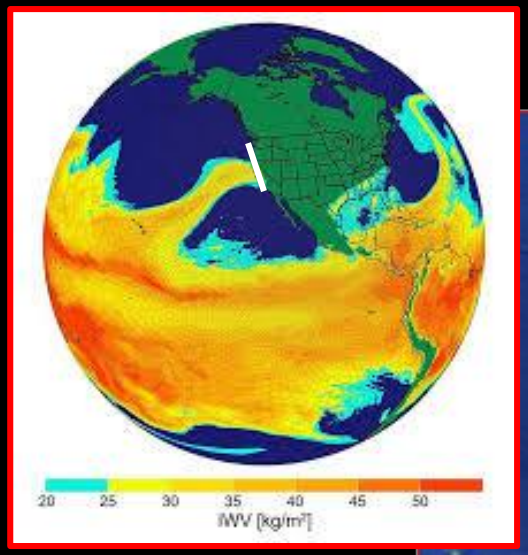
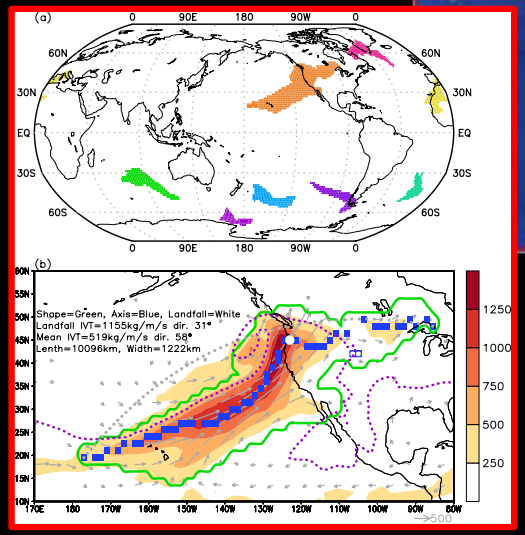
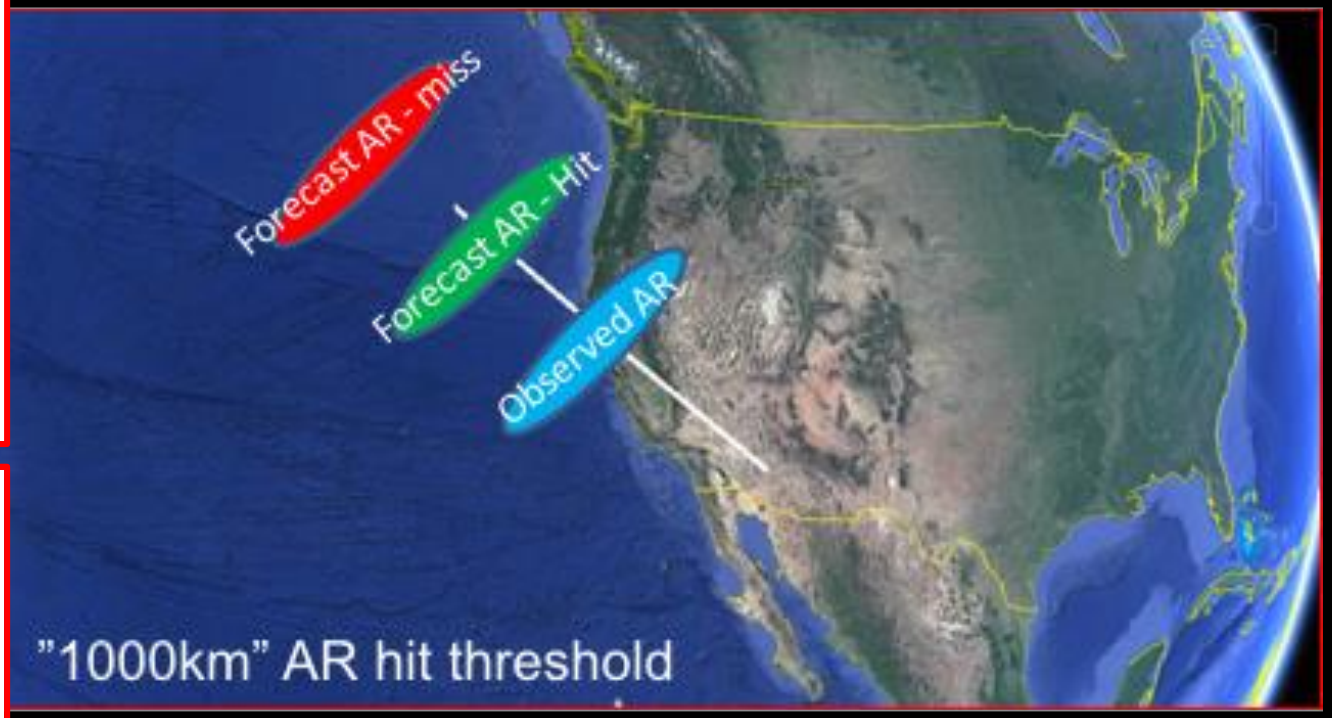
AR Event Prediction Skill

DeFlorio, Waliser, Guan, Lavers, Ralph, Vitart (2017, In Revision)



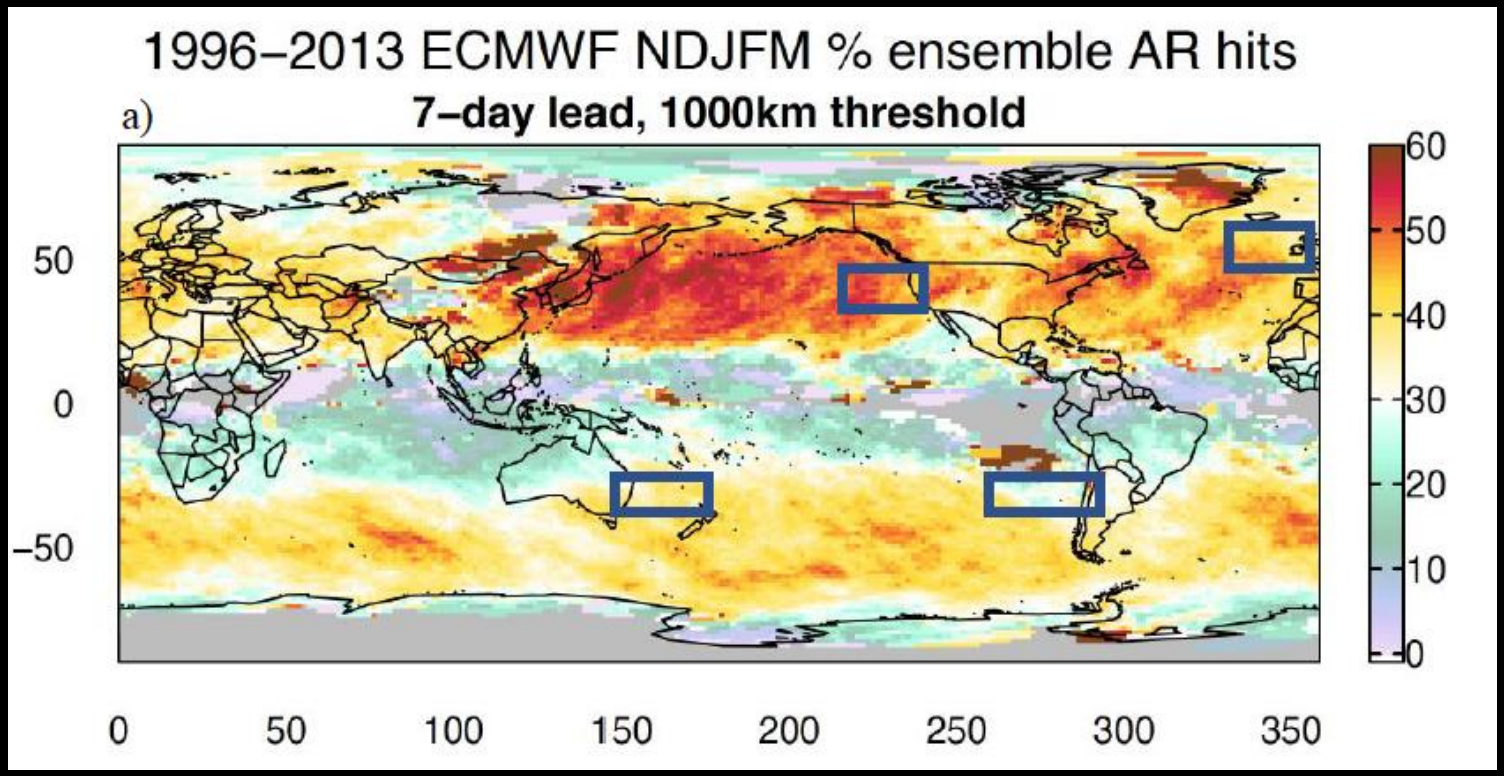


Builds on CA Regional study by Wick et al. 2013



How well do our global S2S models – ECMWF in this case - predict AR occurrence/position?

Global AR Prediction Skill



Including sensitivity of prediction skill on season, lead time, distance threshold and climate mode variations.

DeFlorio, Waliser, Guan, Lavers, Ralph, Vitart (2017, In Revision)

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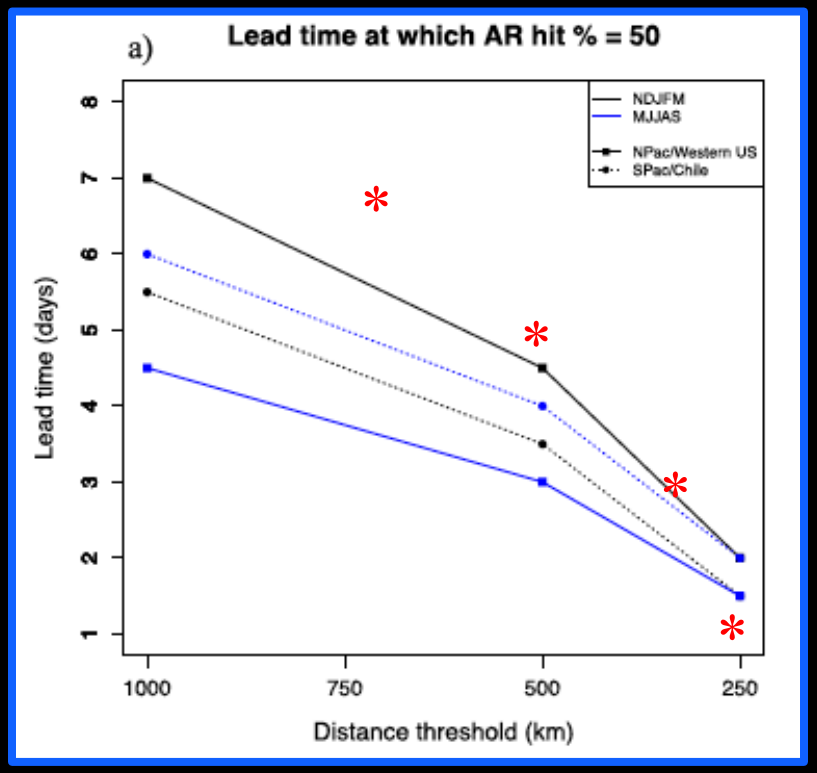
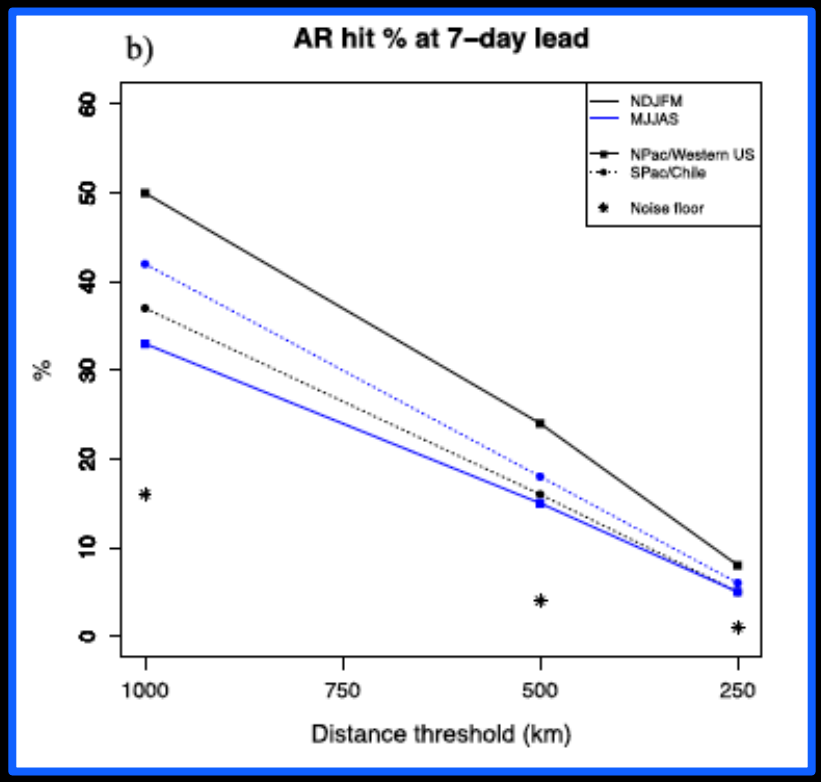
AR Landfall Predictions & Water/Flood Management

When do I need to know, and with what confidence?





DeFlorio, Waliser, Guan, Lavers, Ralph, Vitart (2017, In Revision)

Ensemble / probabilistic information complements the AR landfall prediction study of Wick et al. 2013 (*)

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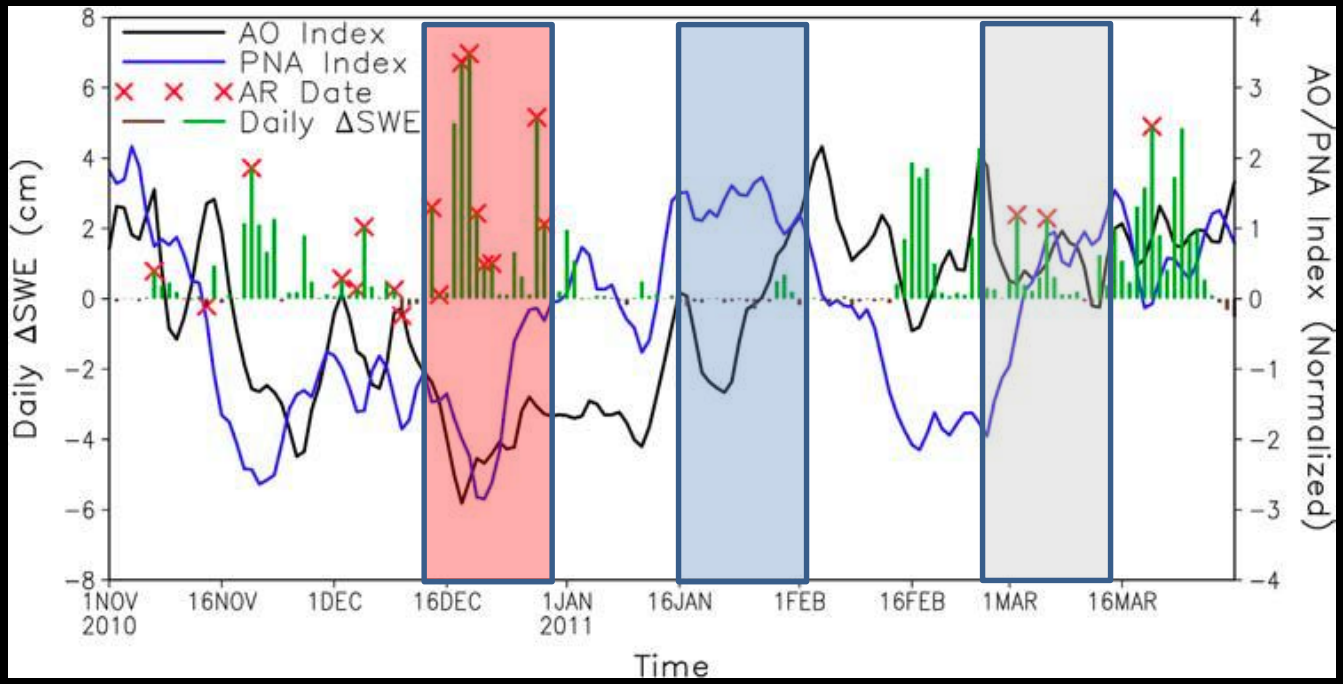
Subseasonal AR Prediction

DeFlorio, Waliser, Guan, Ralph…. (2017, In Prep)



How well do our global S2S models

– ECMWF in this case –

predict high & low AR periods at subseasonal time scales?

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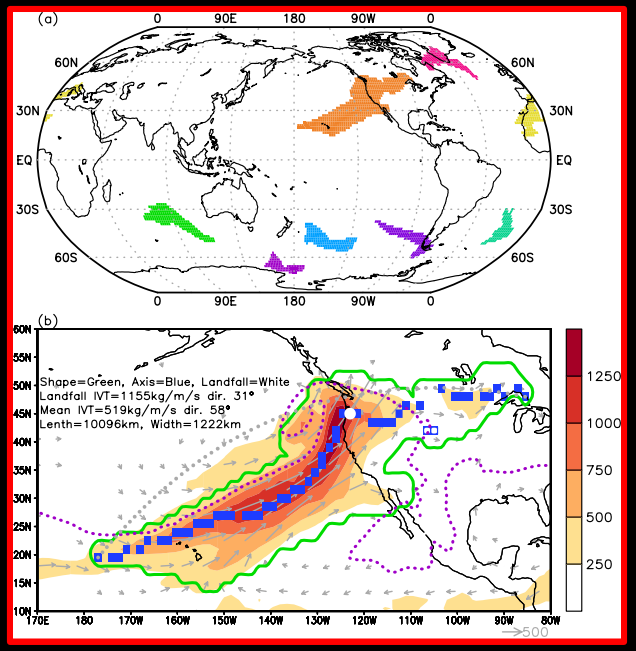
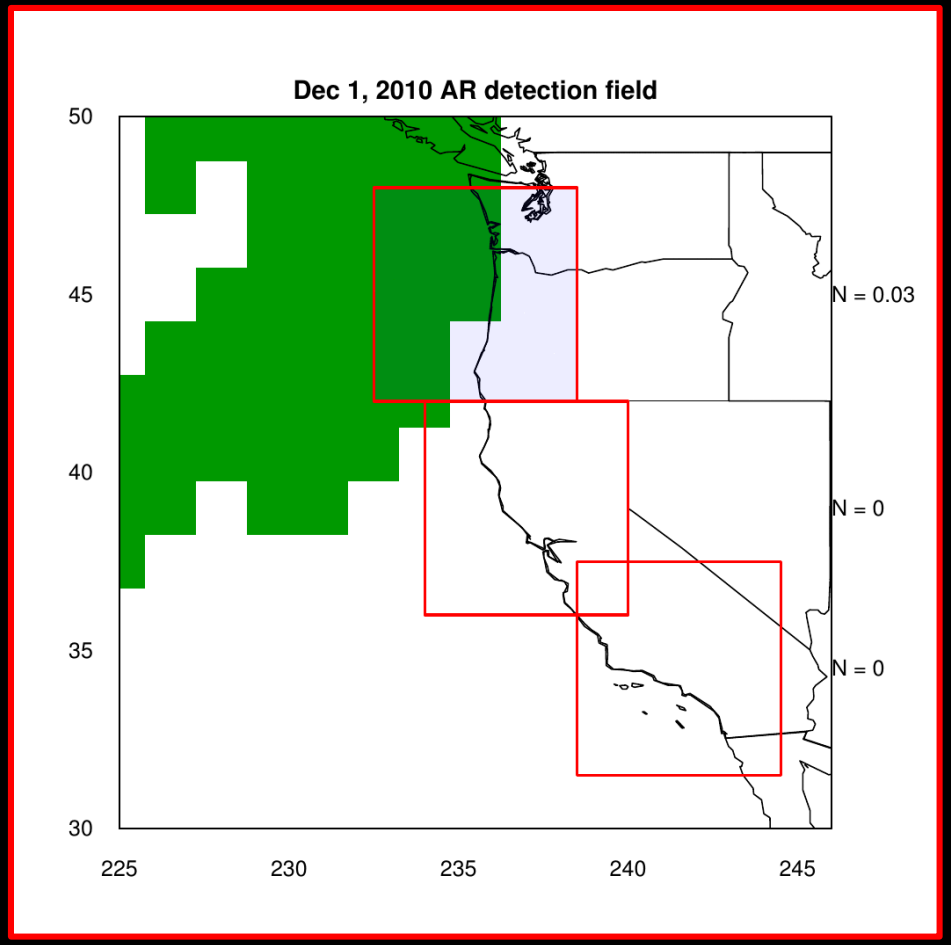
Subseasonal AR Prediction

DeFlorio, Waliser, Guan, Ralph, Barbour…. (2017, In Prep)





Compute fraction of space & time a given region has an AR for a 2 week period

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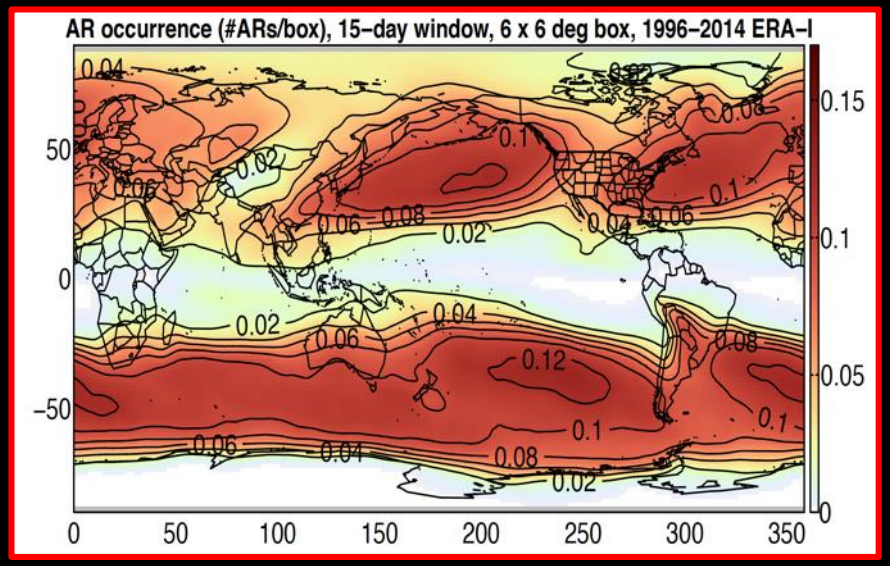
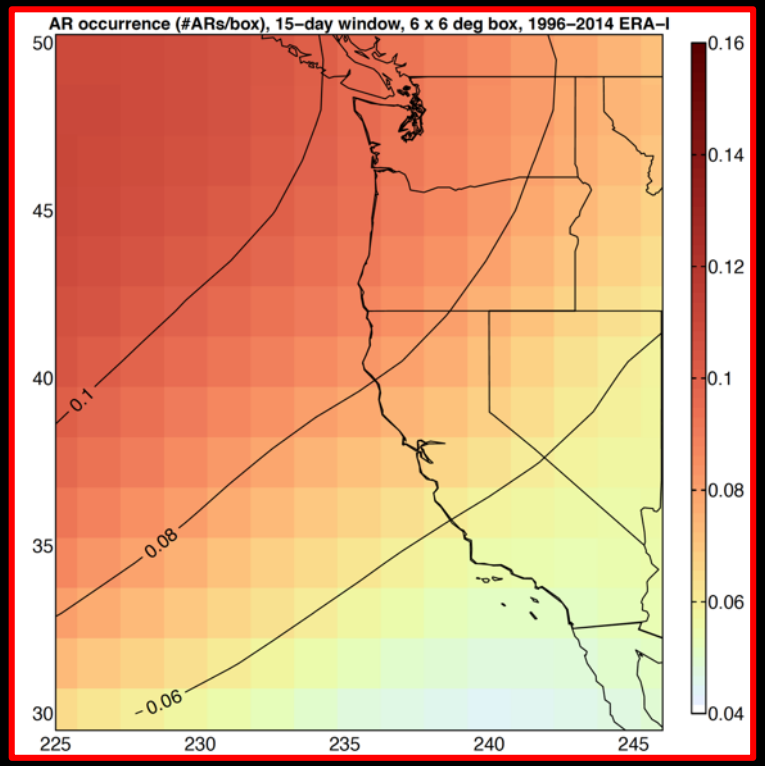
Subseasonal AR Prediction

(for 2-week averages of AR frequency)





Fraction of space & time a given region has an AR occurrence, when considering a 2 week period and the surrounding 6°x6° degree area.

DeFlorio, Waliser, Guan, Ralph, Barbour…. (2017, In Prep)

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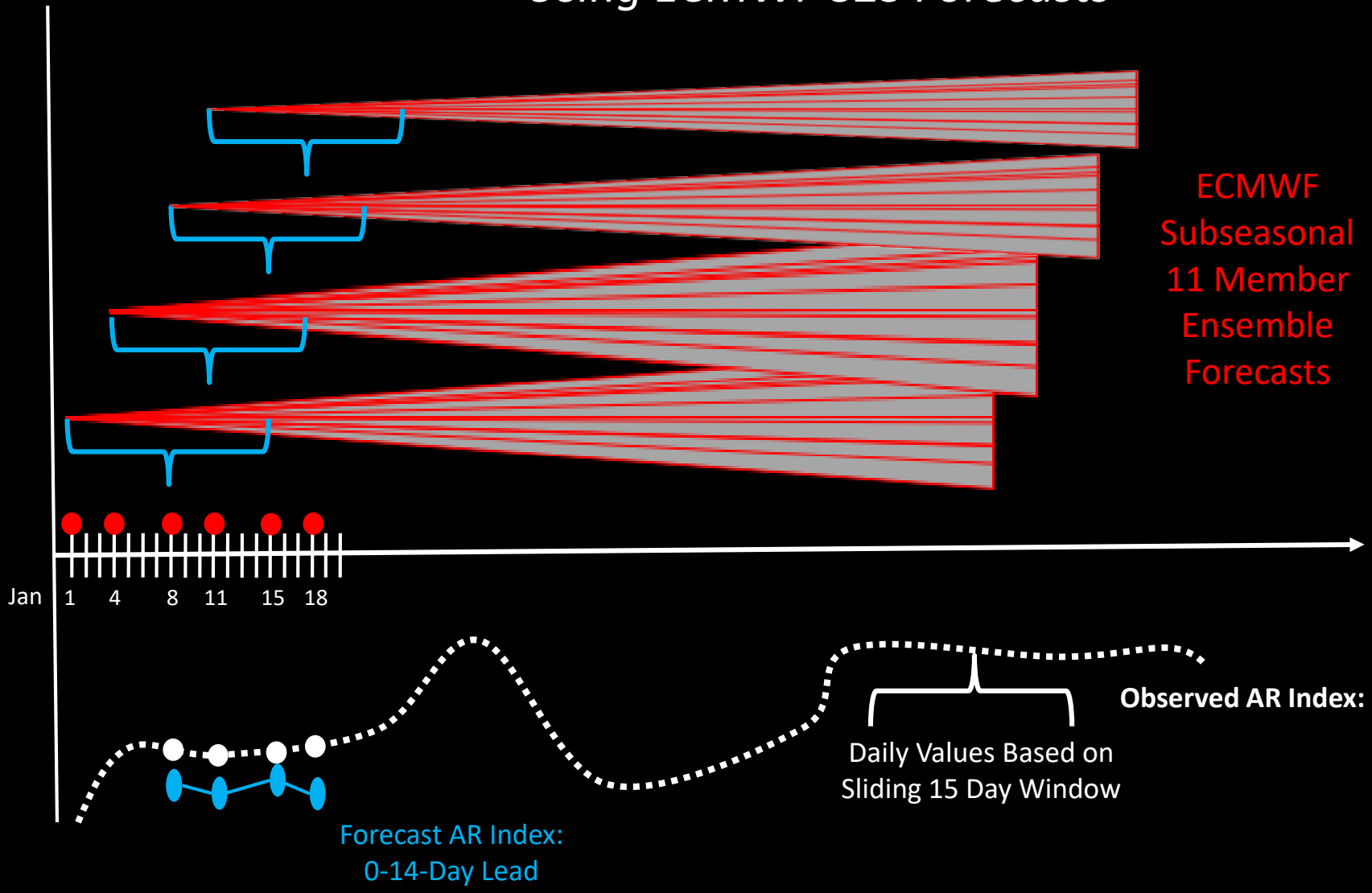
Subseasonal AR Prediction

Using ECMWF S2S Forecasts



DeFlorio, Waliser, Guan, Ralph, Barbour…. (2017, In Prep)

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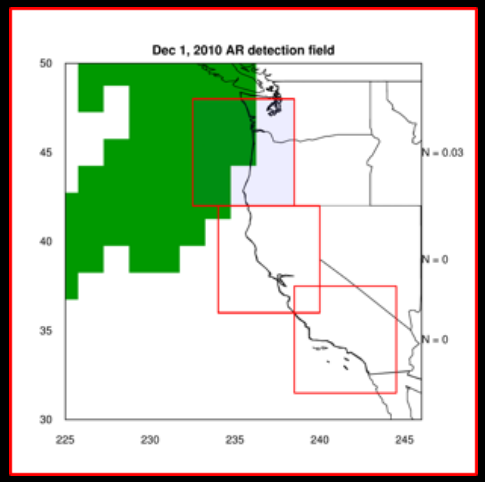
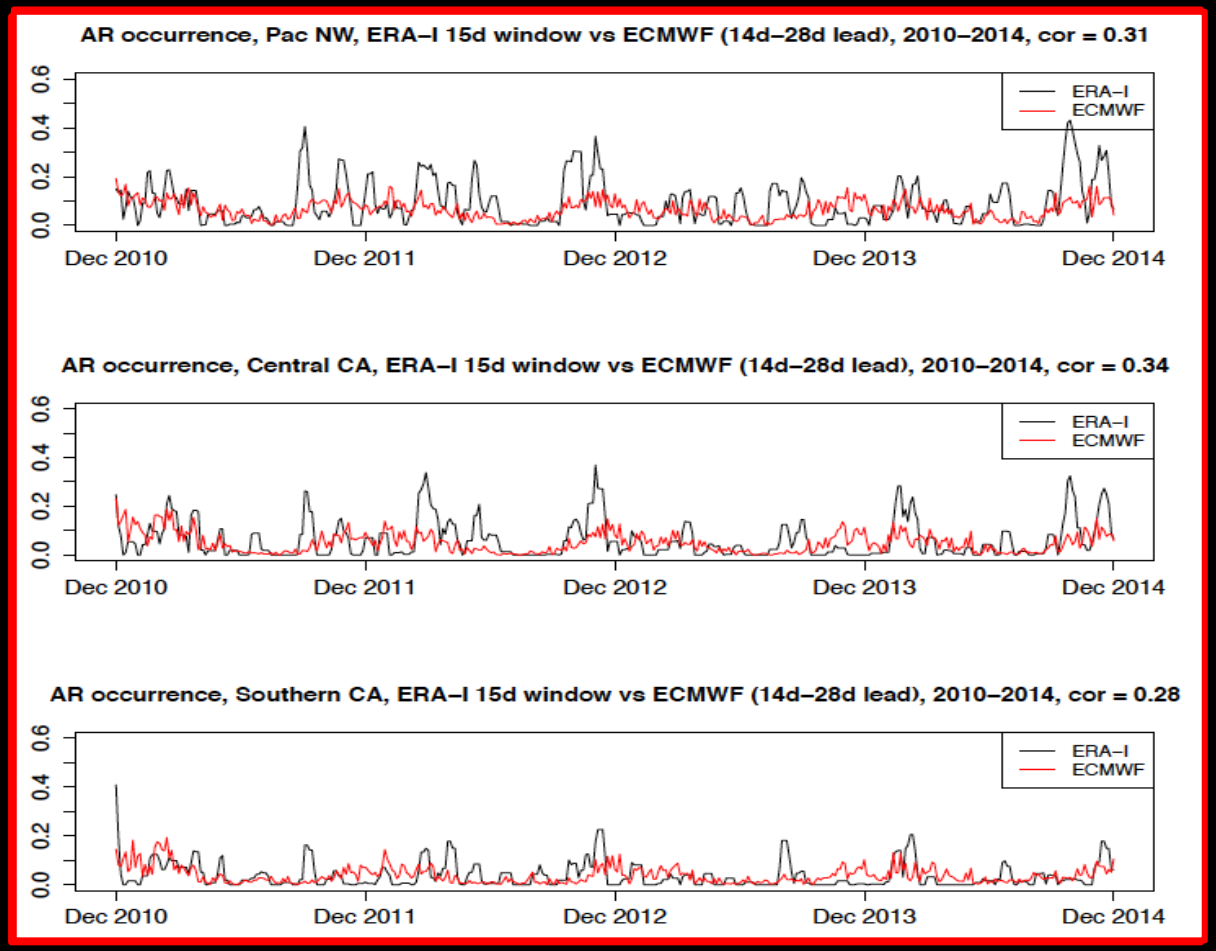
Subseasonal AR Prediction

DeFlorio, Waliser, Guan, Ralph, Barbour…. (2017, In Prep)

US West Coast





How well do our global S2S models

– ECMWF in this case –

predict high & low AR periods at subseasonal time scales?

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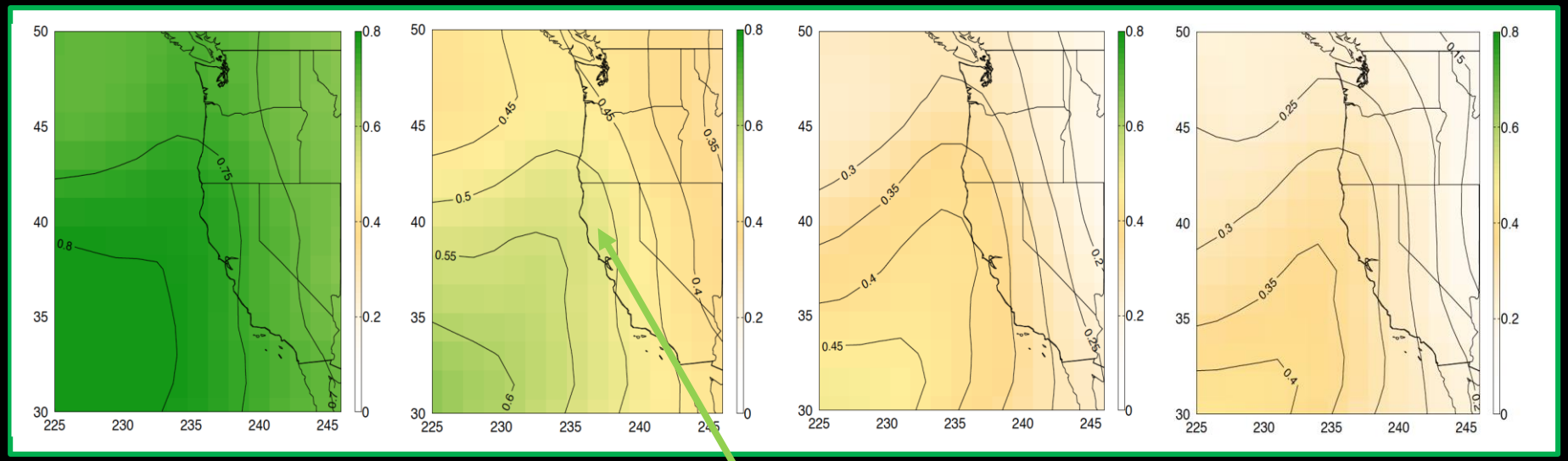
Western US AR Prediction Skill

Forecast vs Observation Time Series Correlations



0-14 Days | 7-21 Days | 14-28 Days | 21-35 Days

e.g. 0.5 for 2 week average for week 2 & 3

DeFlorio, Waliser, Guan, Ralph, Barbour…. (2017, In Prep)

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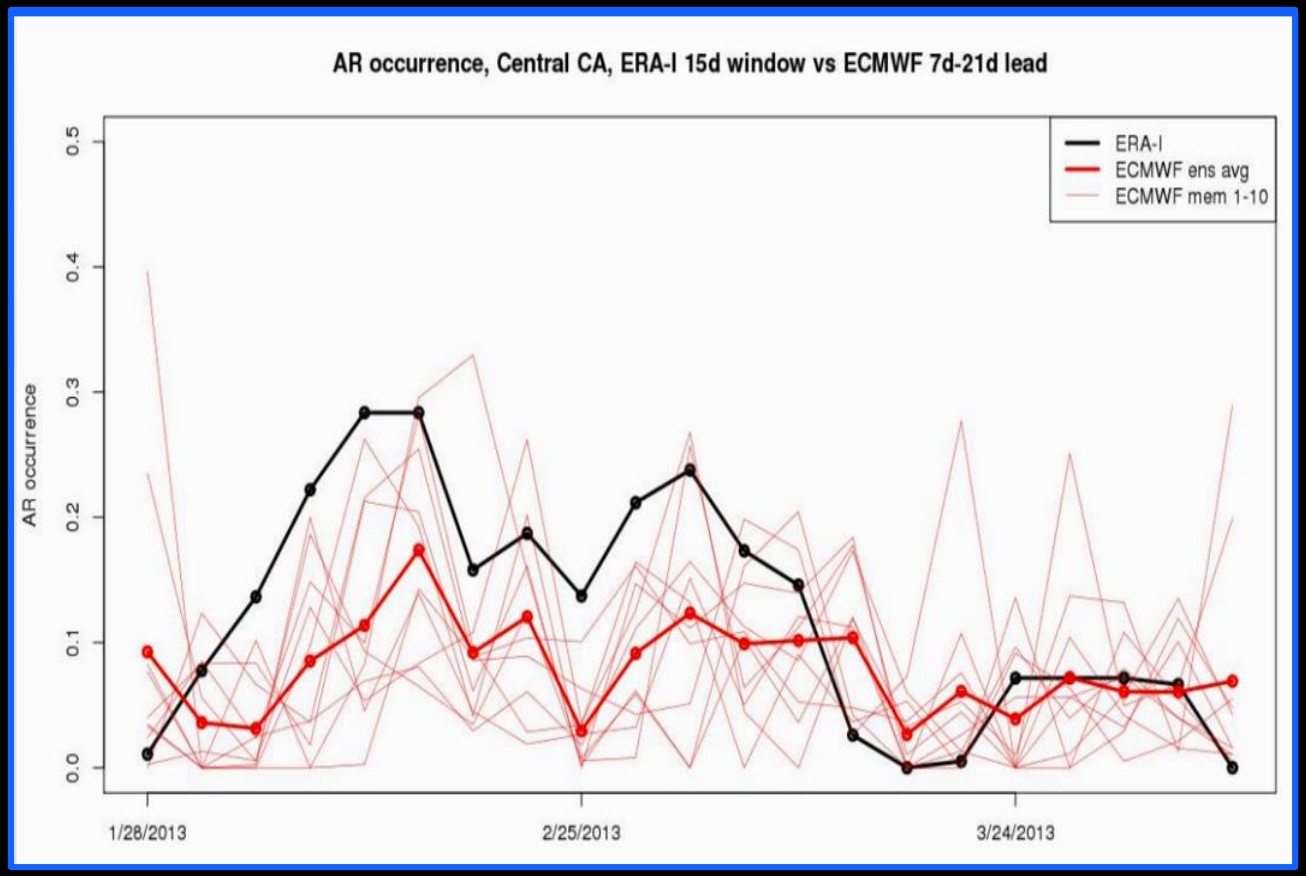
AR Landfall Predictions & Water/Flood Management

Experimental Forecasts?



DeFlorio, Waliser, Guan, Ralph, Barbour…. (2017, In Prep)

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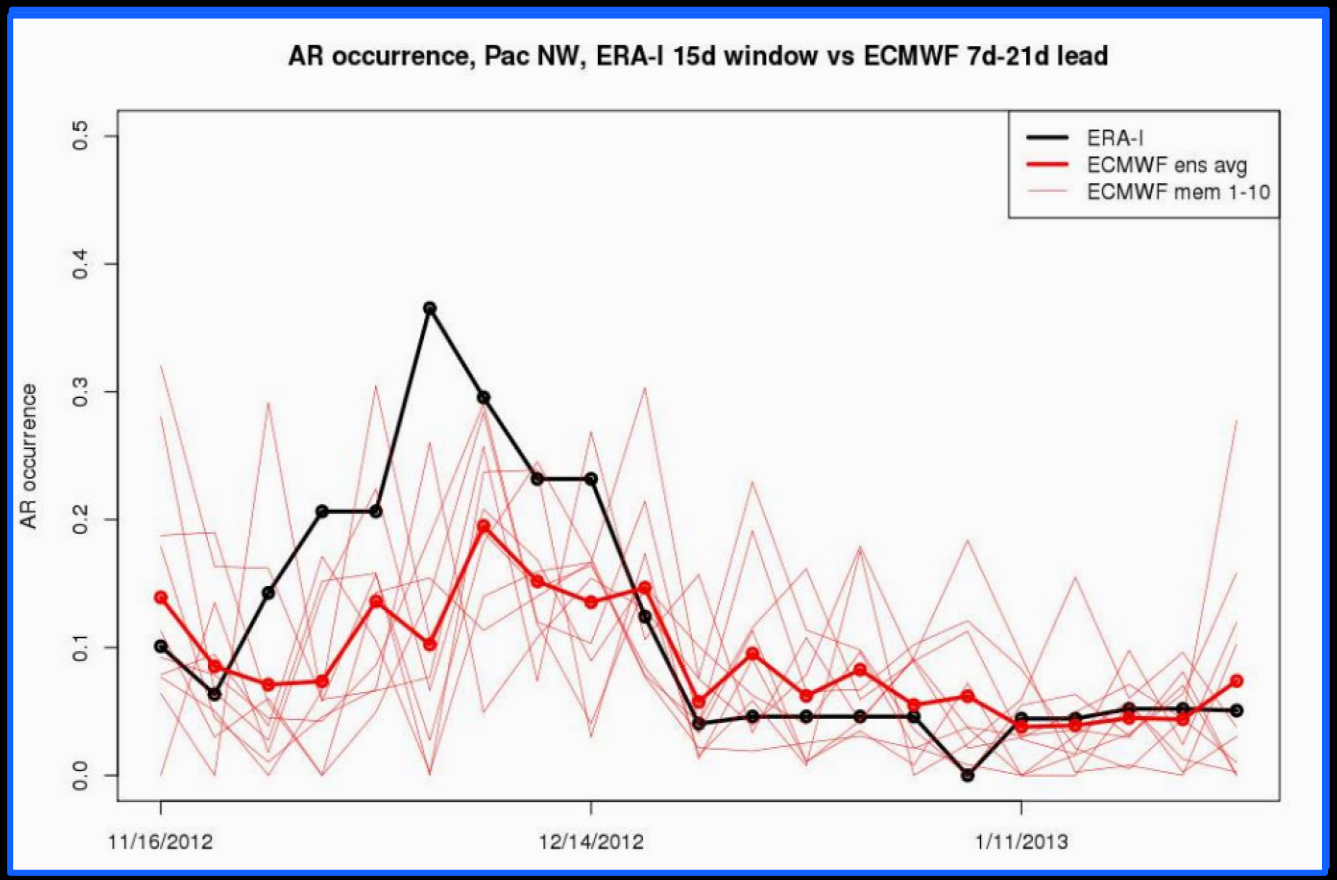
AR Landfall Predictions & Water/Flood Management

Experimental Forecasts?



DeFlorio, Waliser, Guan, Ralph, Barbour…. (2017, In Prep)

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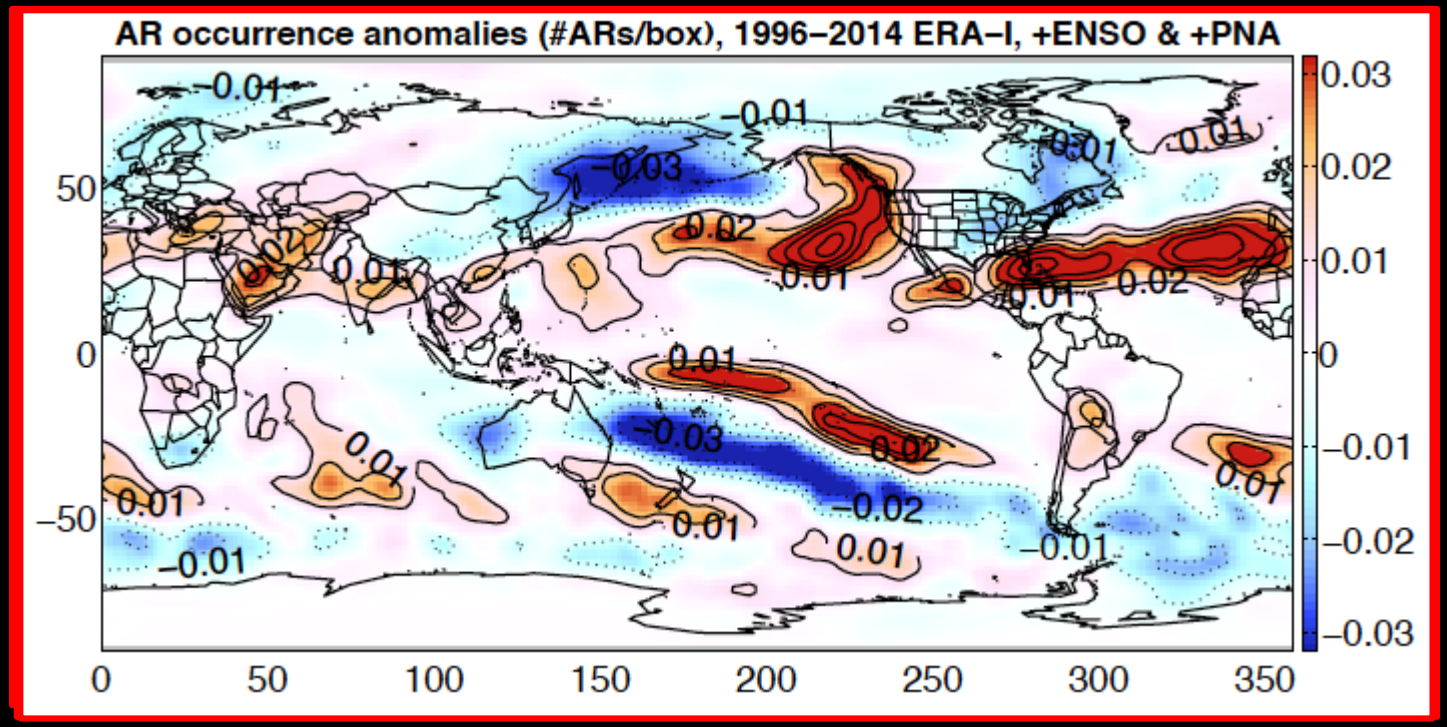
Climate Modes & "Forecasts of Opportunity"



Both +PNA and +ENSO increase the subseasonal AR frequency measure, particularly when combined.

Such periods yield a stronger signal and possibly better skill, TBD

DeFlorio, Waliser, Guan, Ralph, Barbour…. (2017, In Prep)

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Summary

- We're leveraging global AR databases, S2S Predictions, and climate variations to explore/quantify AR prediction capabiilites.
- We're quantifying skill in the present-day ECMWF forecast for:
  - *Individual AR Detection*
  - *Subseasonal AR Frequency of Occurrence*
- We'd like to leverage this research work to explore the development and use of an experimental product.

- We have some comprehensive global weather /climate model evaluation results (24 models, 17 metrics) to help identify model weaknesses and guide improvements (Guan and Waliser, 2017)
- We have produced the first global analysis of projected 21ST century climate changes in ARs (Espinoza et al. 2017, In prep)

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Wick, G. A., P. J. Neiman, F. M. Ralph, and T. M. Hamill (2013), Evaluation of Forecasts of the Water Vapor Signature of Atmospheric Rivers in Operational Numerical Weather Prediction Models, Weather and Forecasting, 28(6), 1337-1352.

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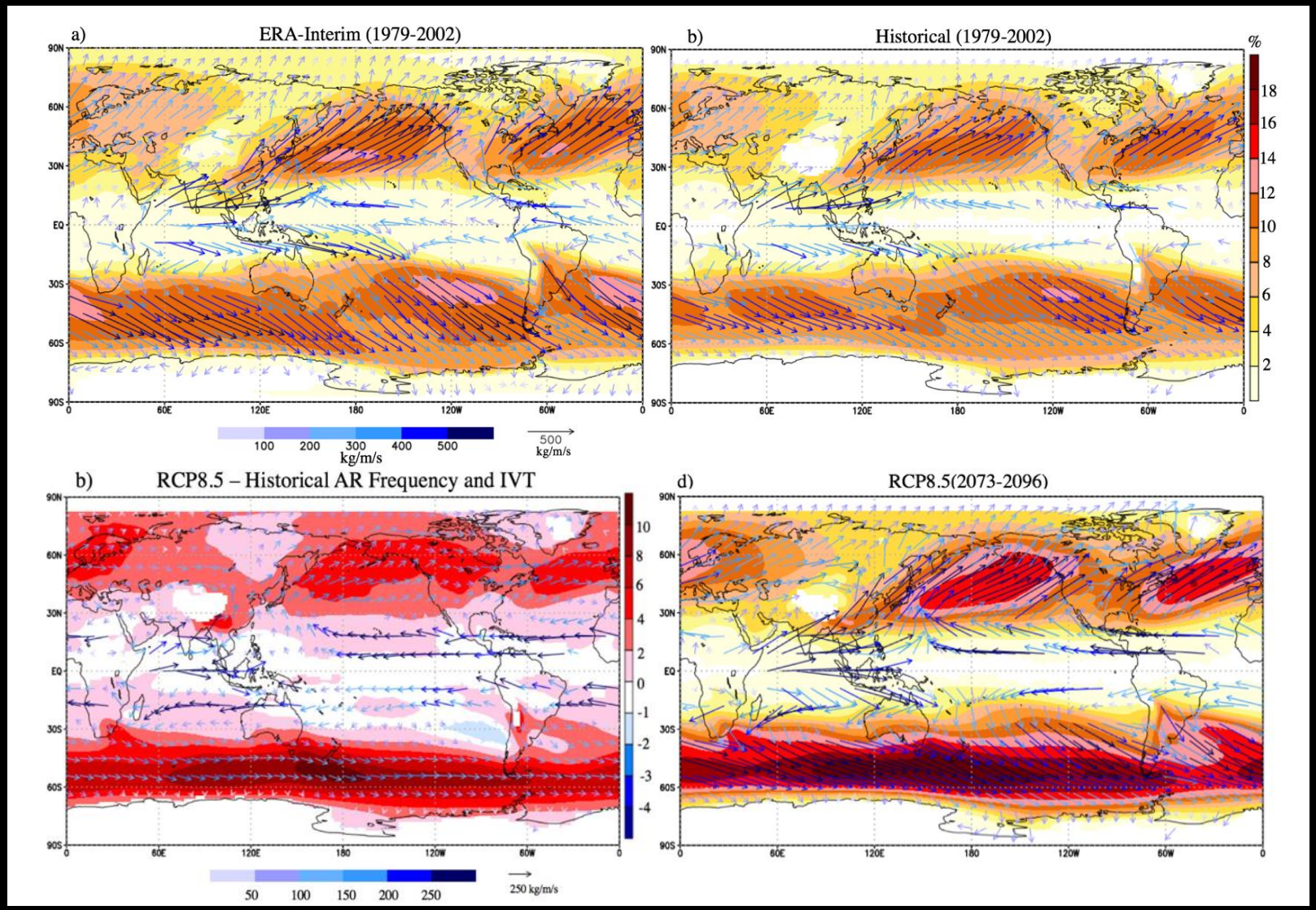
Climate Change & ARs

AR Frequency & Transport: 21 CMIP5 Models



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

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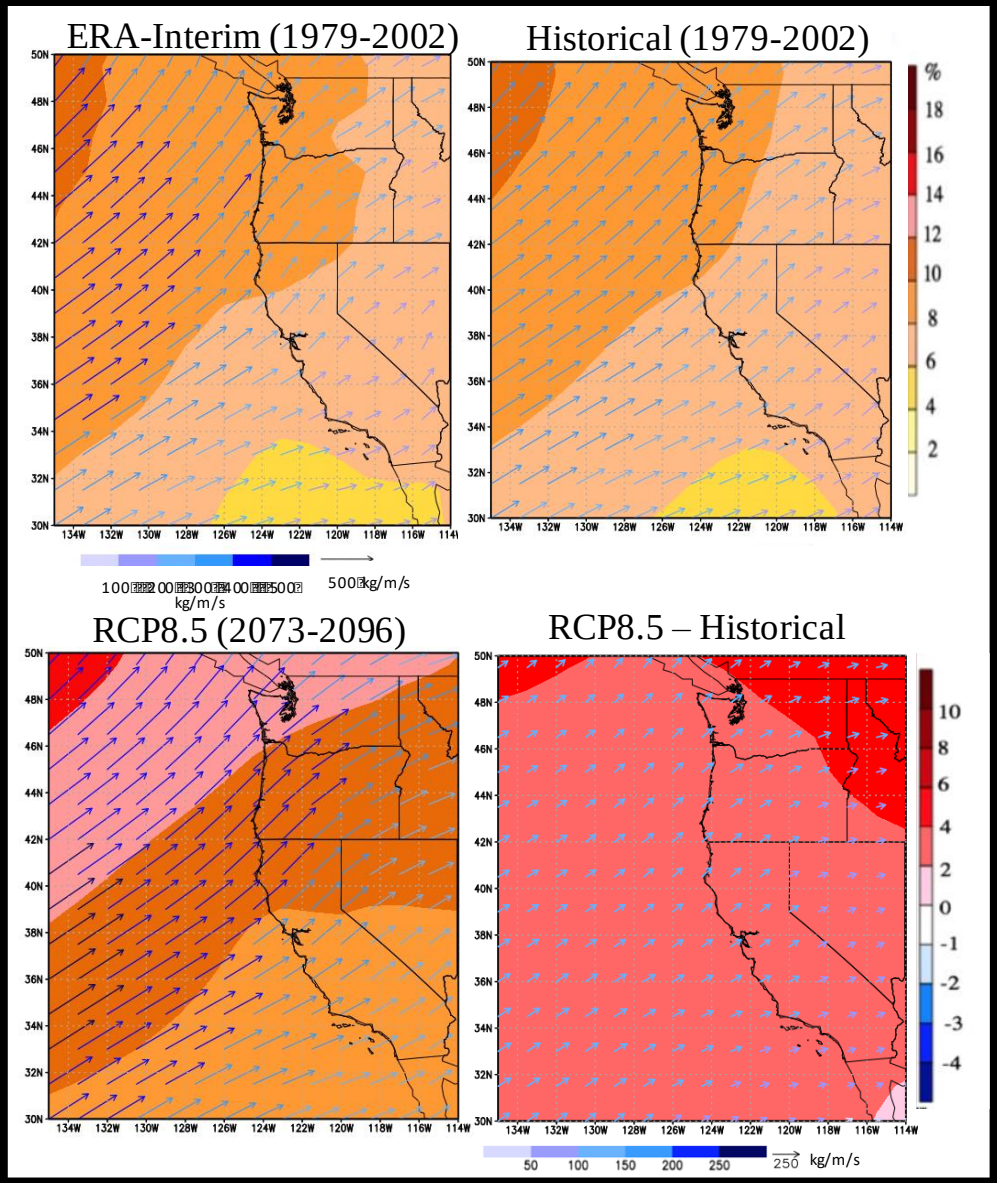
Climate Change & ARs

AR Frequency & Transport: 21 CMIP5 Models



% AR Frequency for Western US

- Historical/ERA-Interim AR Frequency: 7-9%
- RCP8.5 (2073-2096) AR Frequency: 9-13%
- AR Frequency Increase: 2-4%;
- Relative Increase 30-40%

IVT Increase for Western US

- Historical IVT ~250kg/m/s
- RCP8.5 IVT ~350 kg/m/s
- Relative Increase ~40%.

What does this imply about total precipitation?

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

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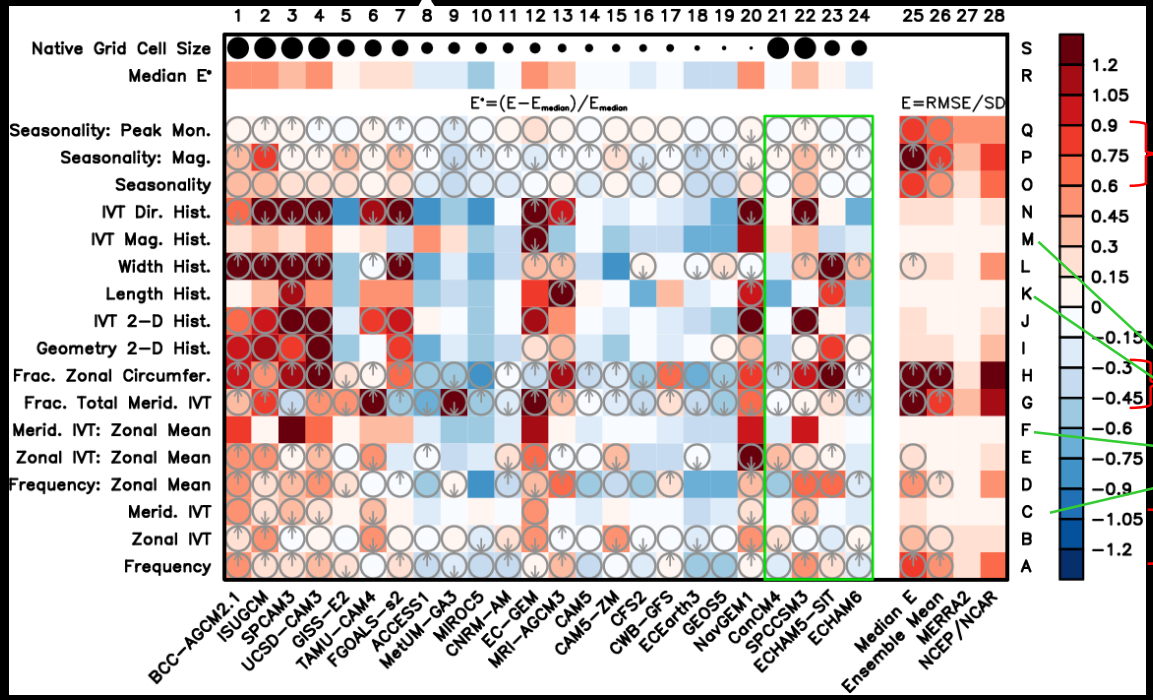
Weather/Climate Simulations of ARs

Models fidelity is resolution dependent, suggesting about 1.5 degree or better is a necessary but not sufficient condition [i.e. mostly red (blue) to the left (right)].



7 AR metrics relatively challenging:

- Seasonality (3 metrics)
- Fractional zonal circumference
- Fractional total meridional IVT
- Zonal IVT
- Frequency

4 AR metrics relatively good:

- IVT magnitude histogram
- Length histogram
- Meridional IVT, and its zonal mean

***CAPTION**: Portrait diagram showing evaluation result for 17 metrics, with cool (warm) colors indicating better(worse)-than-average models, gray circles (arrows) indicating large RMSE (bias) relative to observation. Green outline marks 4 coupled models. Top row indicates model horizontal resolution, with biggest (smallest) circle about 280 (40) km.*

Evaluation based on 20-year simulations from 24 global weather/climate models from the GASS-YOTC Physical Processes Experiment

Guan and Waliser (2017)