Atmospheric River Modeling: Forecasts, Climate Simulations and Climate Projections

Based on a Draft Book Chapter

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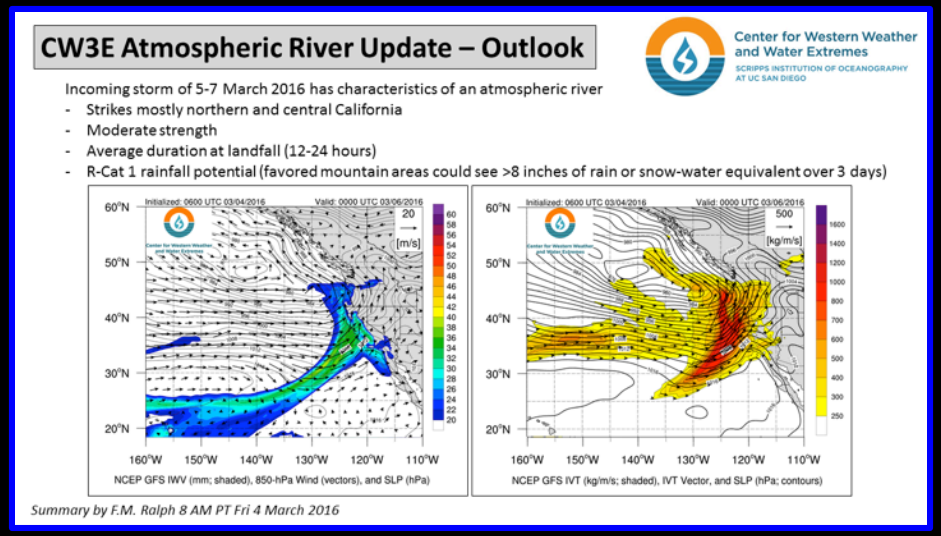
International Atmospheric River Conference
La Jolla, CA
August 8-11, 2016

Outline

- Weather Forecasting – hours to days, needed for operational decision support for resource management and hazard preparation/response.
- Climate Simulations – representation of key climate process influencing global water/energy cycles and distribution of extreme events.
- Climate Change Projections – impacts assessment for water availability, resource management, weather and water extremes, hazards, etc.

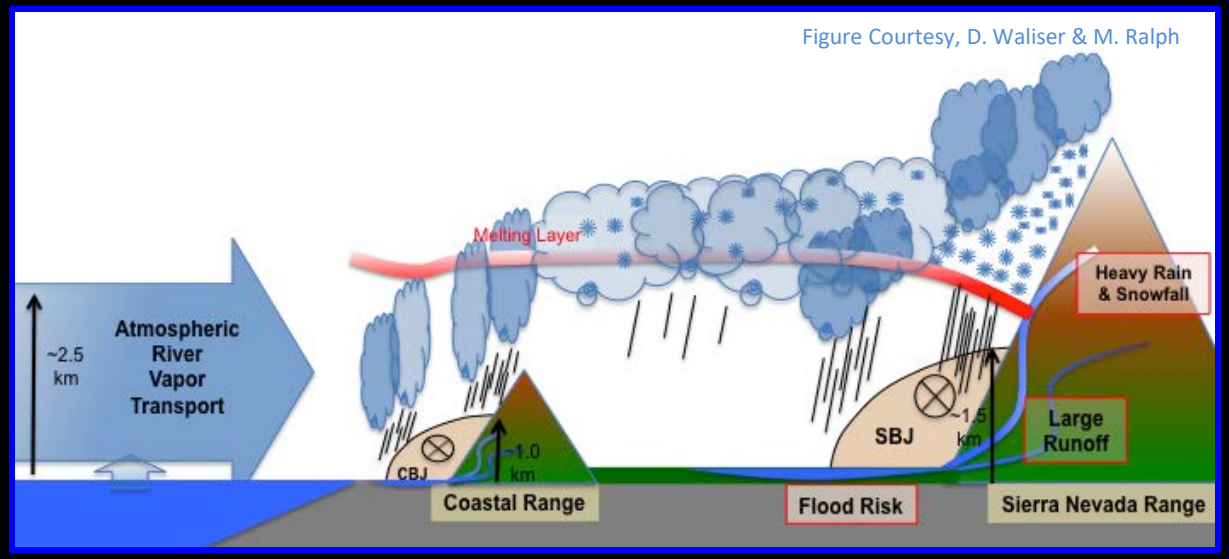
This chapter/presentation targets literature on modeling phenomena specifically identified as “atmospheric rivers”.

Forecasting ARs: “Ingredients Based Approach”



Need to Account For:

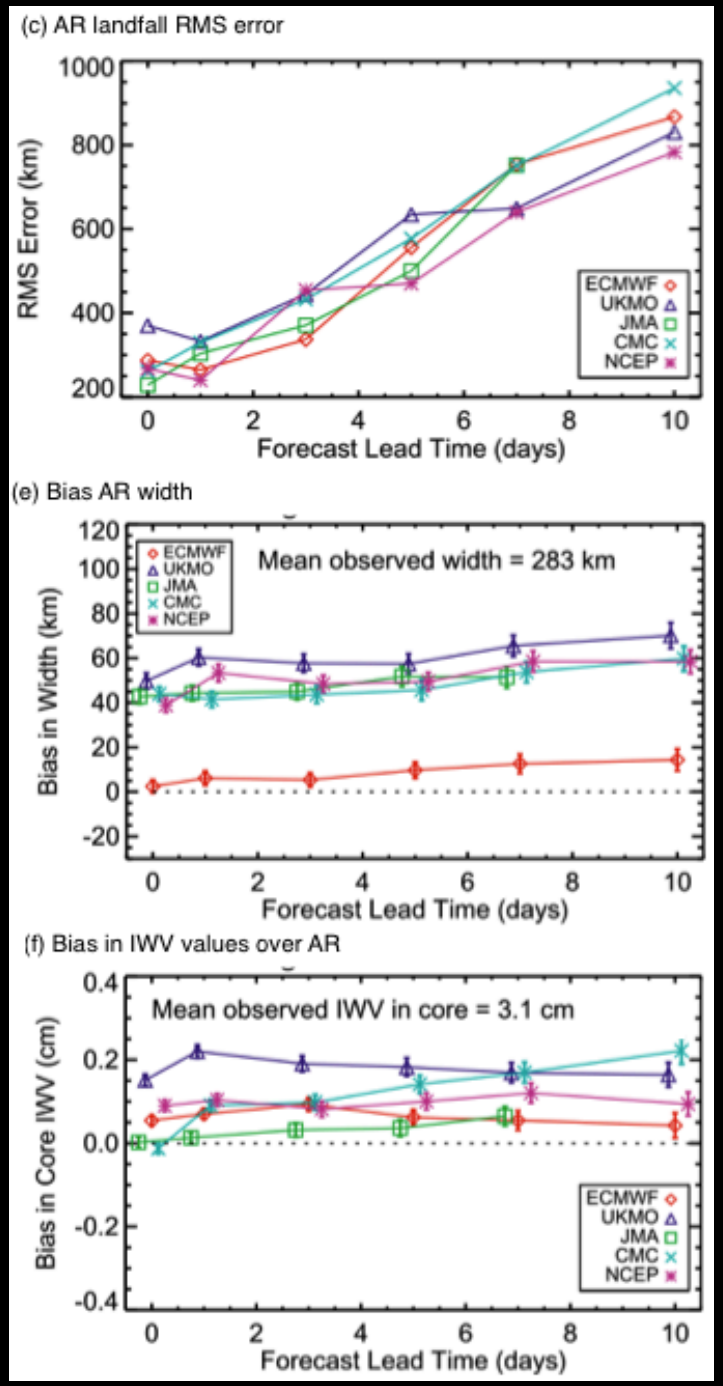
- Location, intensity, orientation and distributions of IWV & IVT
- Duration of AR conditions
- Lifting mechanisms – topography, barrier jets
- Freezing Level



Example

AR “upslope IVT” explains 75% of variance in total precipitation in California / Sierra Nevada Region

Ralph et al (2006)



AR Prediction Skill

Western N. America

Wick et al. 2013

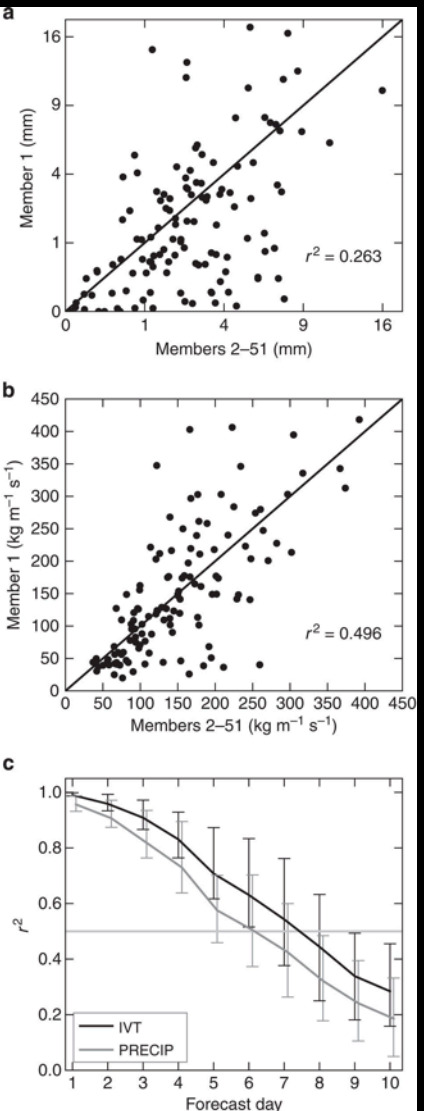
Quantified AR forecast skill in five operational models (NCEP, CMC, JMA, UKMO, ECMWF)

- Landfall errors ~500 km at 5 days (decrease ~ 75km / day)
- 4 of 5 models biased in AR width (~50km) as defined by IWV
- Models tend to be biased high in IWV by about < ~5%

See Nayak et al. 2014 – Study over Central US

What are our expectations?

AR Predictability
Europe

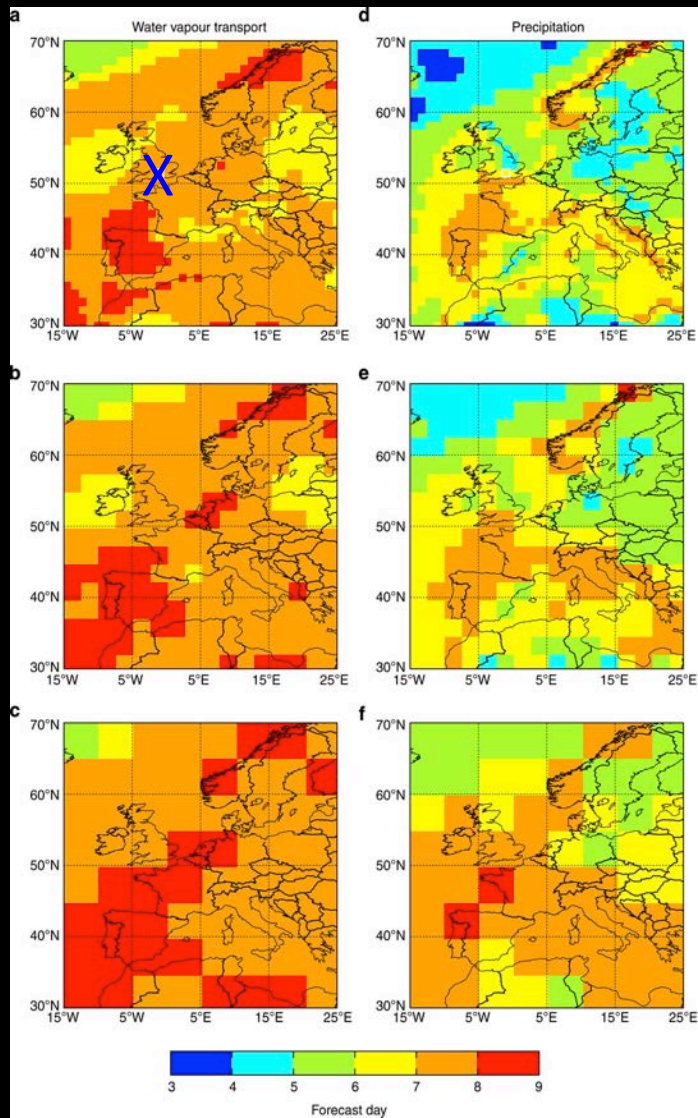


Lavers et al. 2014

Estimate AR predictability

IVT exhibits greater predictability than precipitation by ~2 days

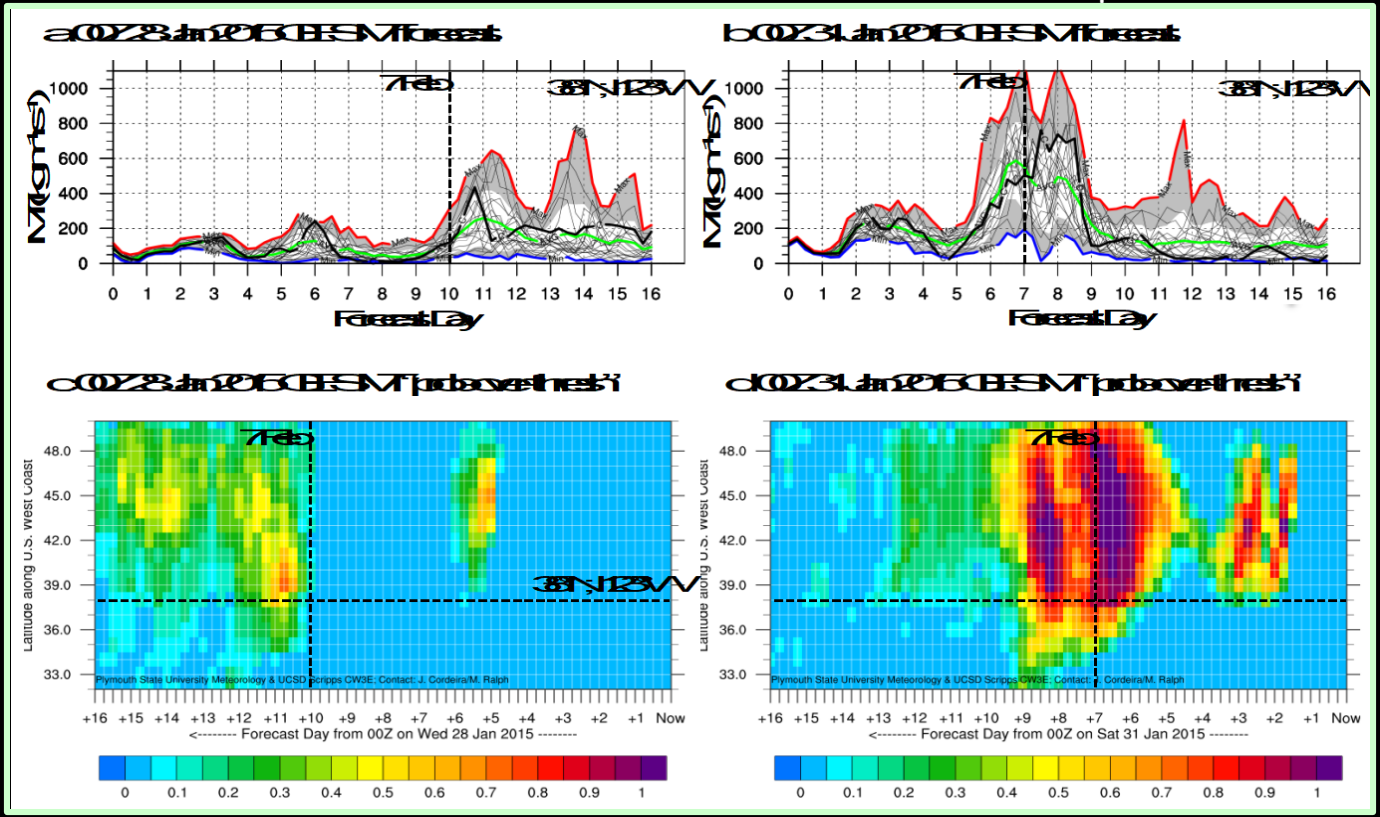
Predictability increases with larger spatial scales



Forecasting Tools

AR Portal

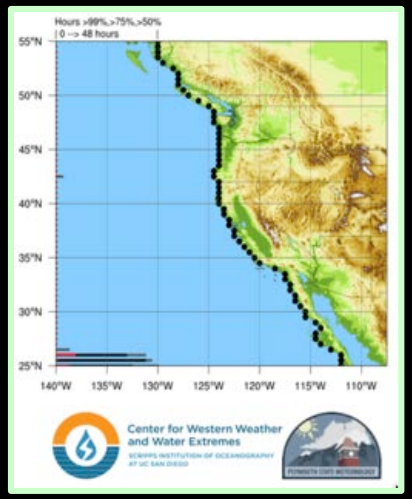
arportal.ucsd.edu



Source information includes NCEP Global Forecast System (GFS) and Global Ensemble

Contains archived and real-time observations, gridded analyses, and gridded forecasts of AR-related information over the N. E. Pacific & western U.S.

Cordeira et al. (2016)

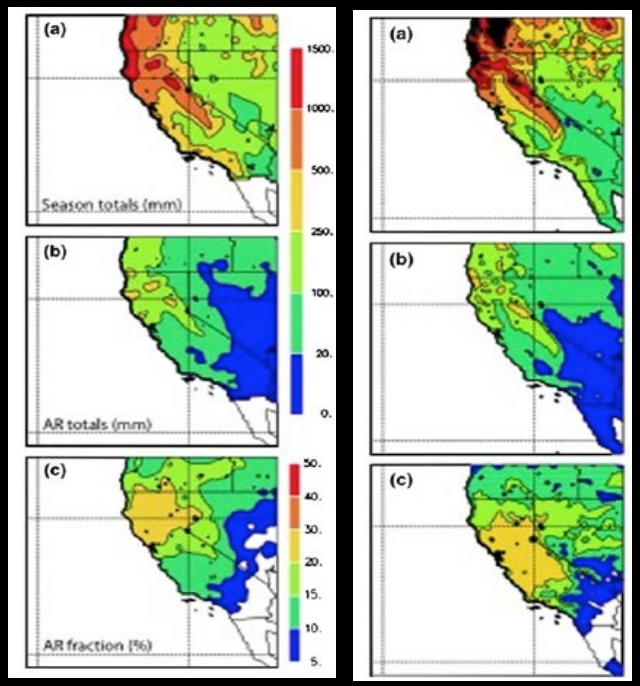


Other Key Resources for AR forecasting and validation studies

Observations: Local networks (e.g. HMT-West), satellite observations (e.g. IWV), analyses fields (e.g. IVT).

AR Detection Algorithms: Regional/IWV/IVT (Wick et al. 2013,2014), Global/IVT (Guan and Waliser, 2015)

Regional Climate Simulations



Kim et al. (2013)

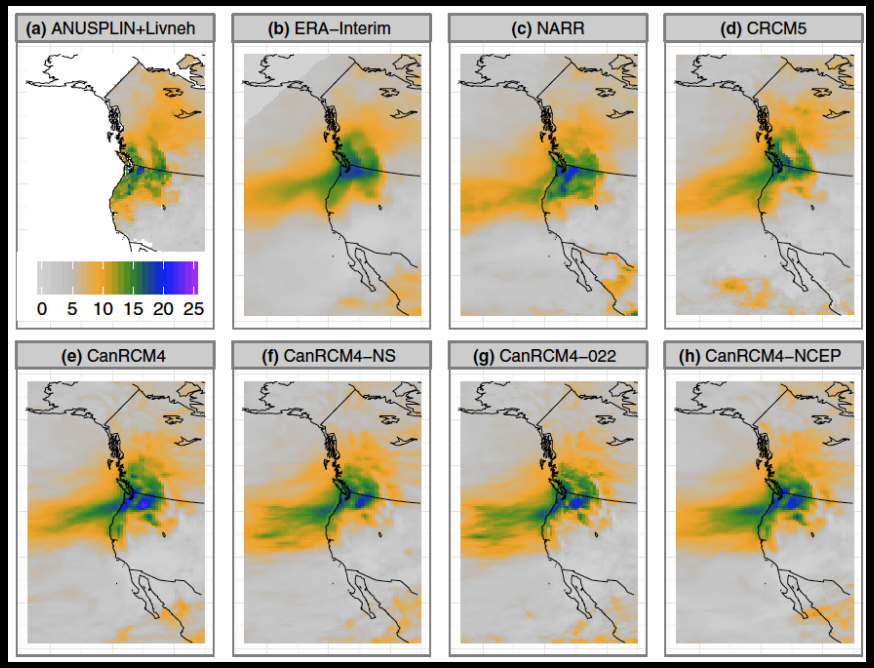
WRF – 0.36°, nested domain 0.09°; 10 Yrs

- Sys Biases in (AR) Precip Representation
- Interannual Variations Relatively Good
- Freezing level anomalies with ARs Good

Whan and Zwiers (2016)

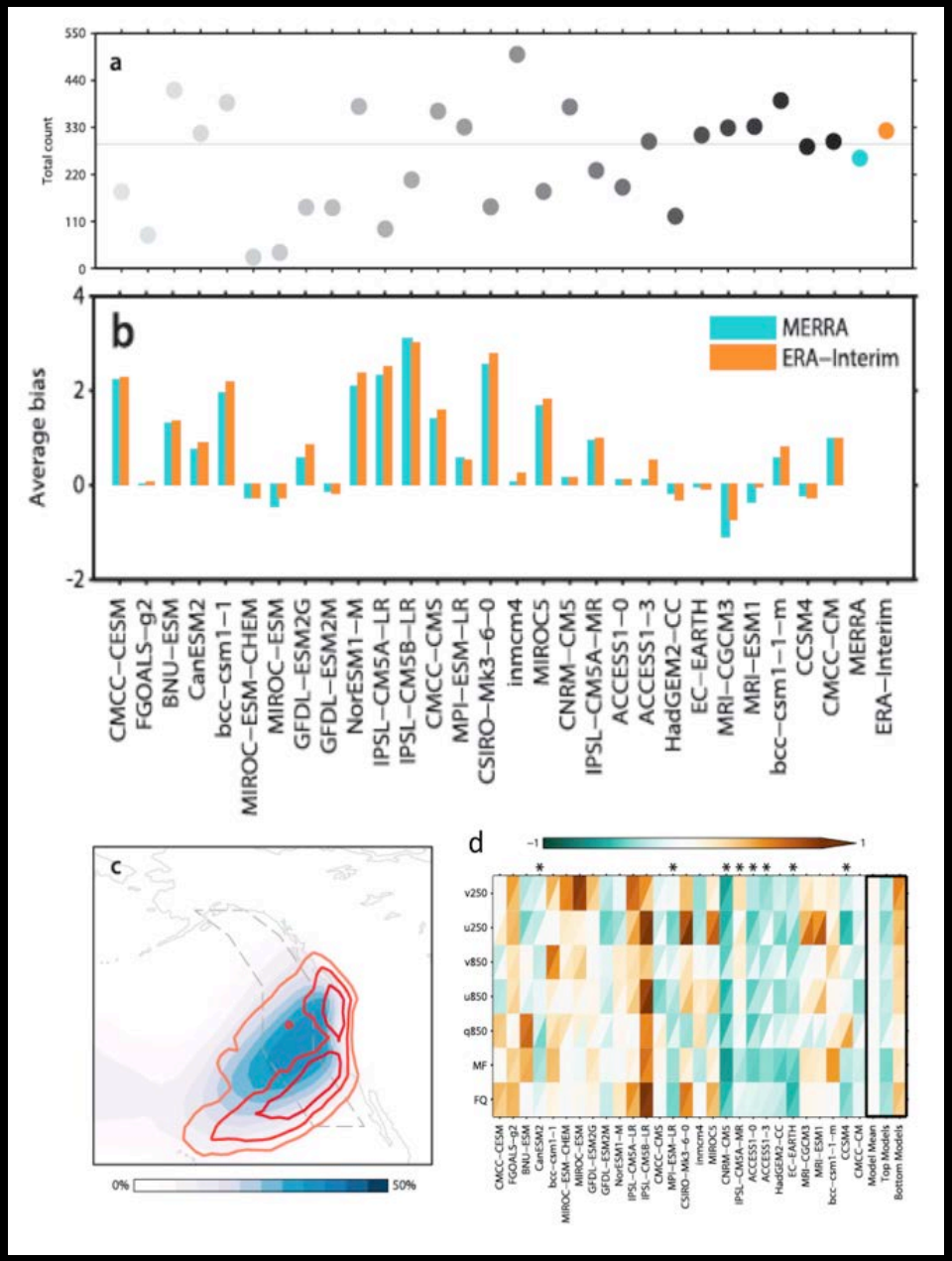
CanRCM4 & CRCM5; 0.22° vs 0.44°; 20 Yrs

- AR Fraction Represented Well
- Inter-Mountain Gap Difficult
- Nudging – improved landfall hit rate w/o impact on extremes



3rd Study: Fan et al. (2014) ARs & Cloud-Aerosol Interactions Process Modeling Study

(Global) Climate Simulations



Simulation/Analysis Period 1980-2005

Payne and Magnusdottir (2015)

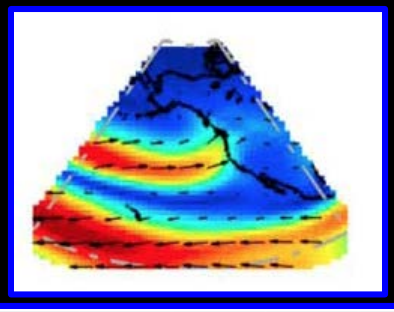
CMIP5 Model Evaluation for US West Coast Landfalling ARs

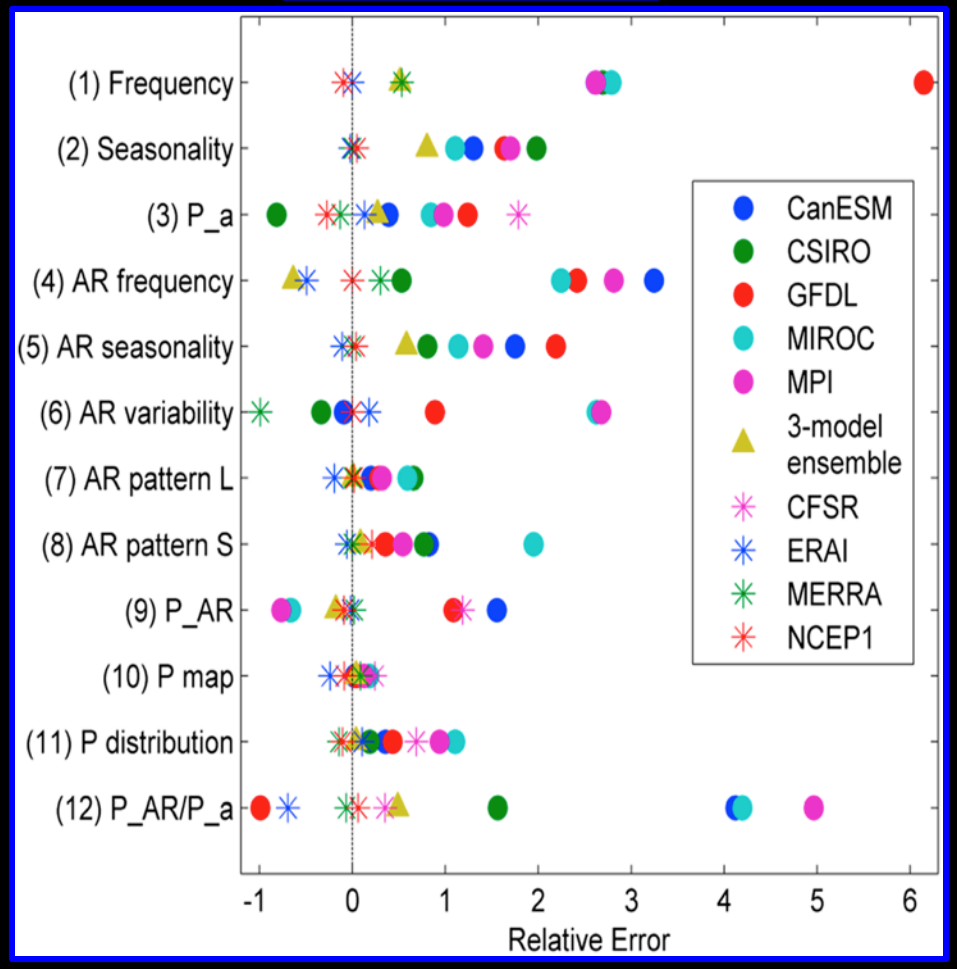
Multi-Model Evaluation Results

- High variation in # AR landfalls
- Model Resolution Sensitivity
- Coarse model frequency biased high
- Model disagreement at southern flank of mean landfall location
- Multi-variate approach provided means of identifying models for climate change analysis

(Global) Climate Simulations

Radić et al. (2015)





Simulation/Analysis Period 1980-2005

CMIP5 Model Evaluation for Landfalling ARs in Coastal British Columbia

Defined

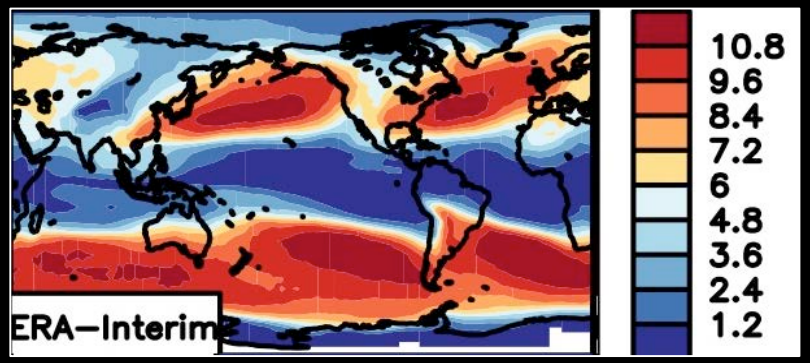
- Typical Reanalysis Err (TRE) = median error from 4 Products
- Relative Err = (Model Err – TRE)/TRE

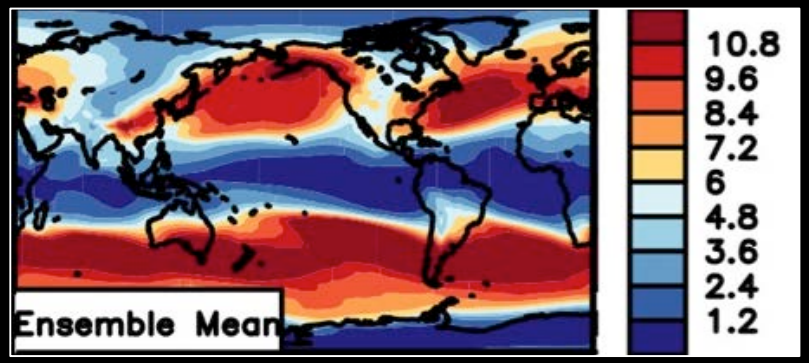
- Analyses errors relatively small
- Model errors = 2 -3 x TRE
- Mean Patterns in Prec & IVT Good
- Difficulties with AR frequency, seasonality, AR/total ratio.
- 3-member multi-model ensemble outperforms other models.

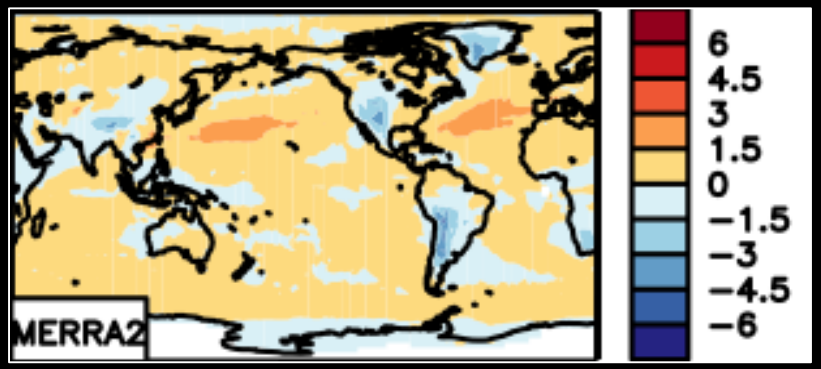
Global Climate Simulations

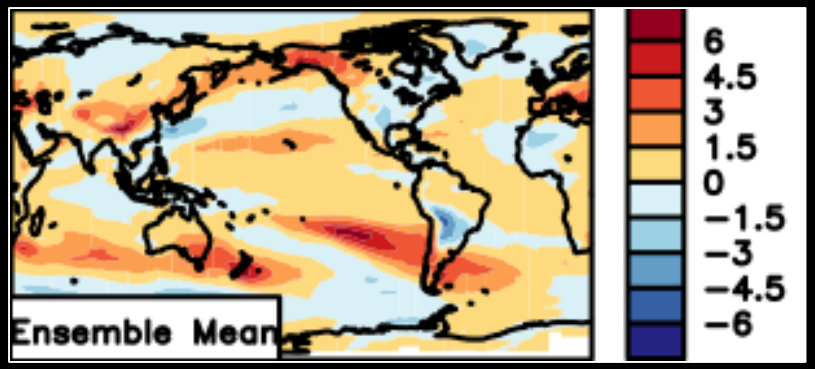
Observed Frequency; ERA-Interim

20-year simulations from 24 global climate/weather models









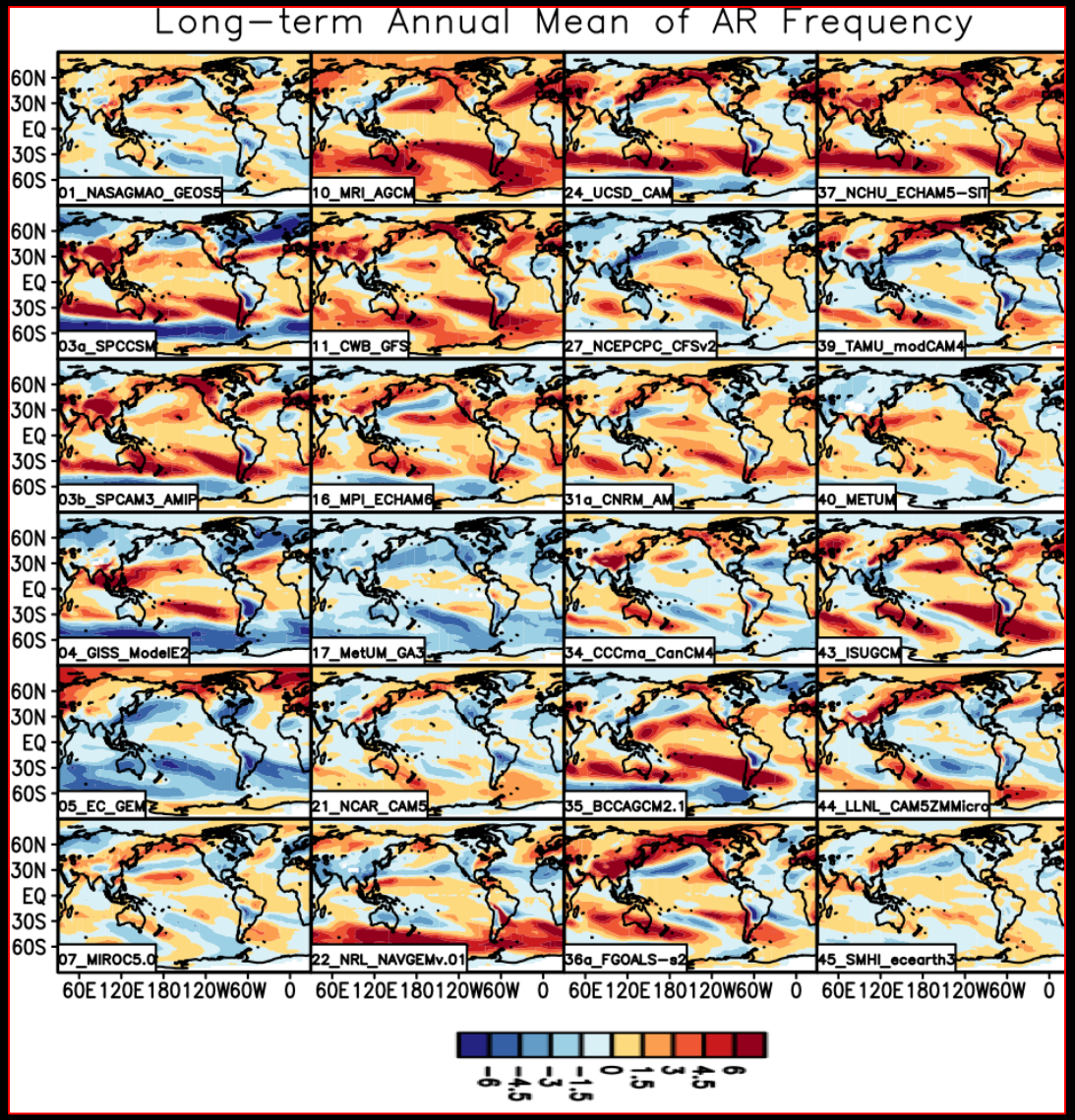
Difference with 2nd Observation Reference; MERRA-2

Modeled – Observed

Guan and Waliser (In Prep)

GEWEX / YOTC / MJO TF Multi-Model Experiment

Global Climate Simulations

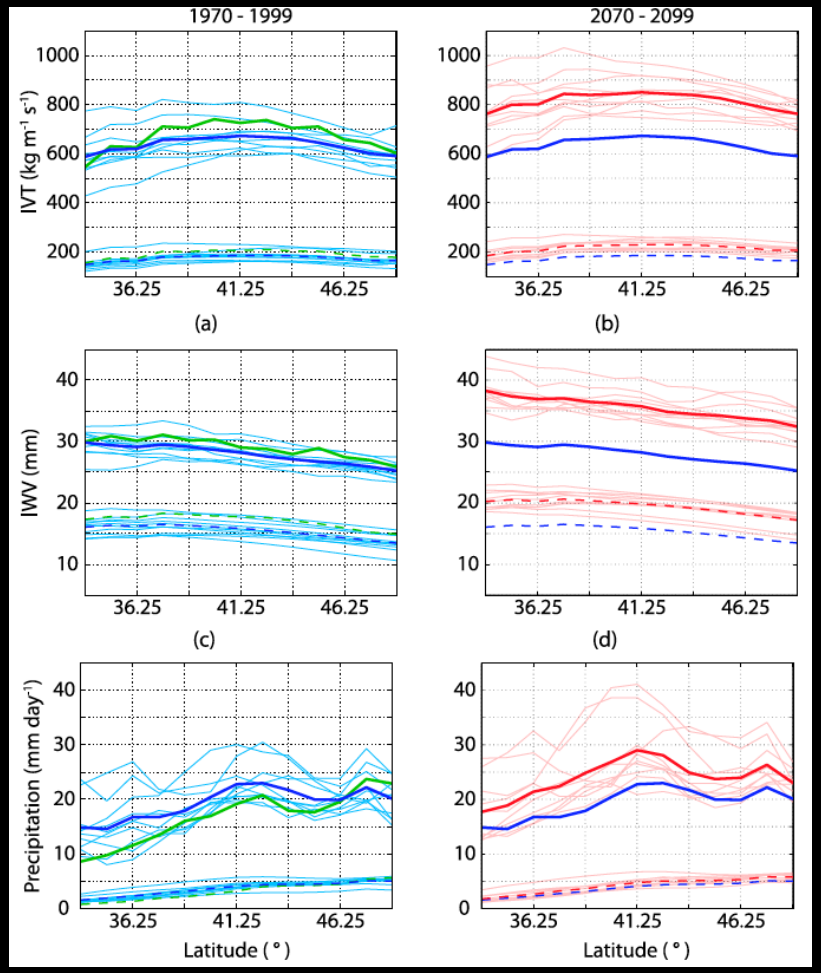


Guan and Waliser (In Prep)

Significant Variation in Model Fidelity in Spatial Patterns of AR Frequency

Other metrics include IVT, width, length, water vapor budgets, climate variations, global model evaluation toolbox

Global Change & Regional AR Impacts



Dettenger (2010)

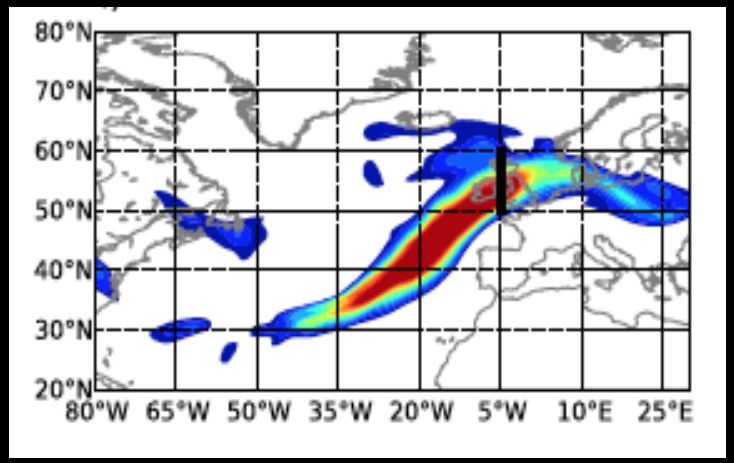
- Landfalling ARs in California
- 7 CMIP3 models
- IWV & 925 hpa wind at 1 pt

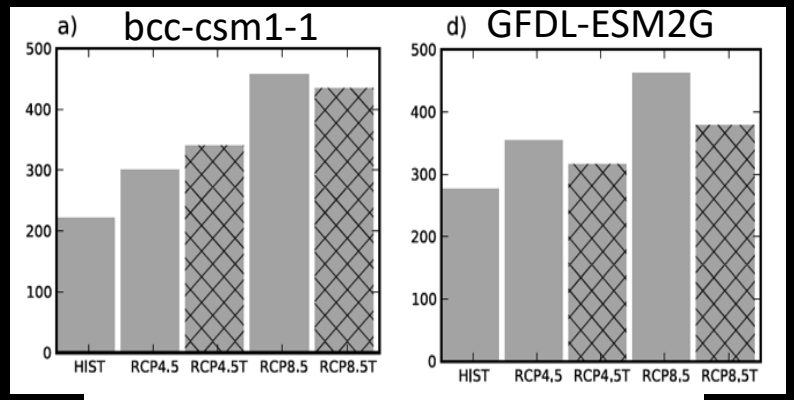
- Little change in AR frequency
- 5-10% increase in intensity
- ~ 2°C increase in AR temp

Warner et al. (2010)

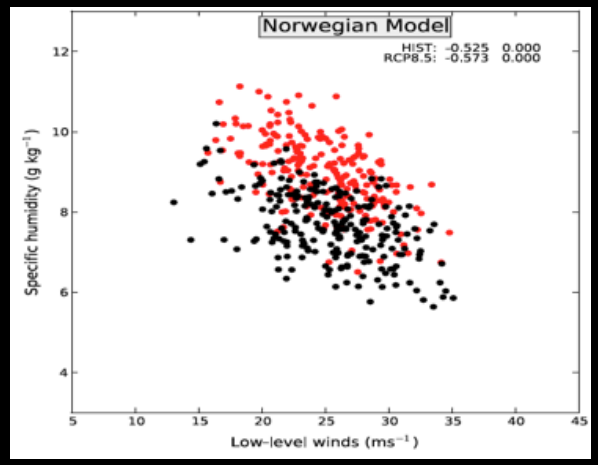
- US west coast; 10 CMIP5 models
- IVT approach to AR detection
- 20thC model representation good
- Significant changes in IVT, IWV, P
- Little change in wind

Global Change & Regional AR Impacts





Number of AR landfalls in 25 Yrs



Lavers et al. (2013)

- Landfalling ARs in UK
- 5 CMIP5 models
- IVT approach to AR detection

- Strong and more frequent
- Almost x2 frequency for RCP8.5
- Thermodynamic effects dominate

Gao et al. (2016)

- 24 CMIP5 models; Western Europe
- Biases: # AR days ~ Westerly Jet Position
- 130-280% increase by end of 21stC
- Illustrated modest impact from dynamics – change in Jet Position

Future Areas of Research

- Weather Forecasting – mesoscale and topography representation, improved observations for process evaluation & improvement, paired prediction skill + predictability studies, long-lead S2S, global perspective, ensemble / probabilistic approaches, QPF, R2O/applications (e.g., FIRO), etc.
- Climate Simulations – process diagnostics, evaluation & improvement (e.g. hydrology, aerosol-cloud, air-sea), finer resolutions for topography & mesoscale features, climate variability modulations, etc.
- Climate Change Projections – more comprehensive impacts assessments – and with finer scales, global perspective, continued work on model performance measures for characterizing uncertainties, etc.