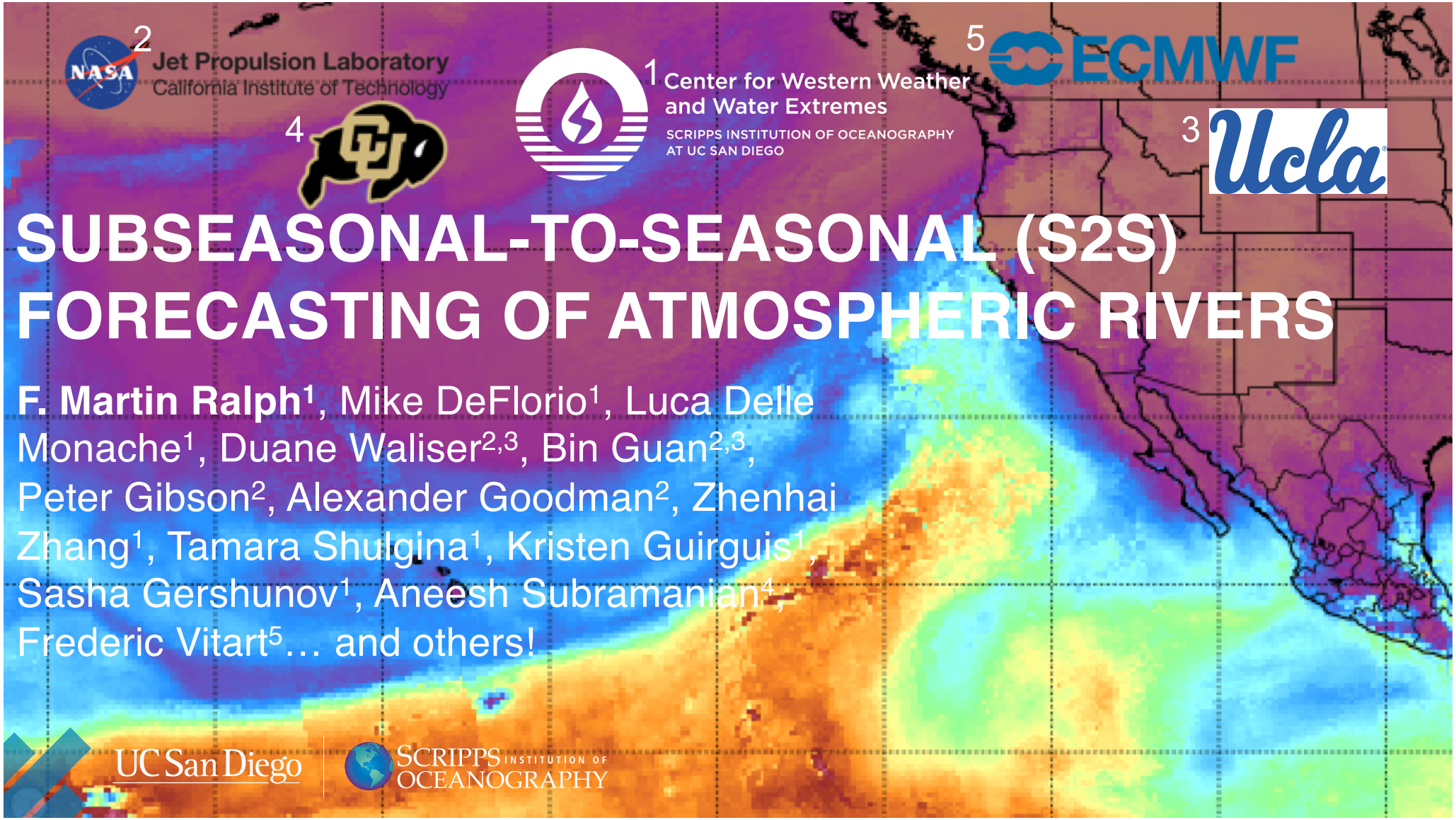
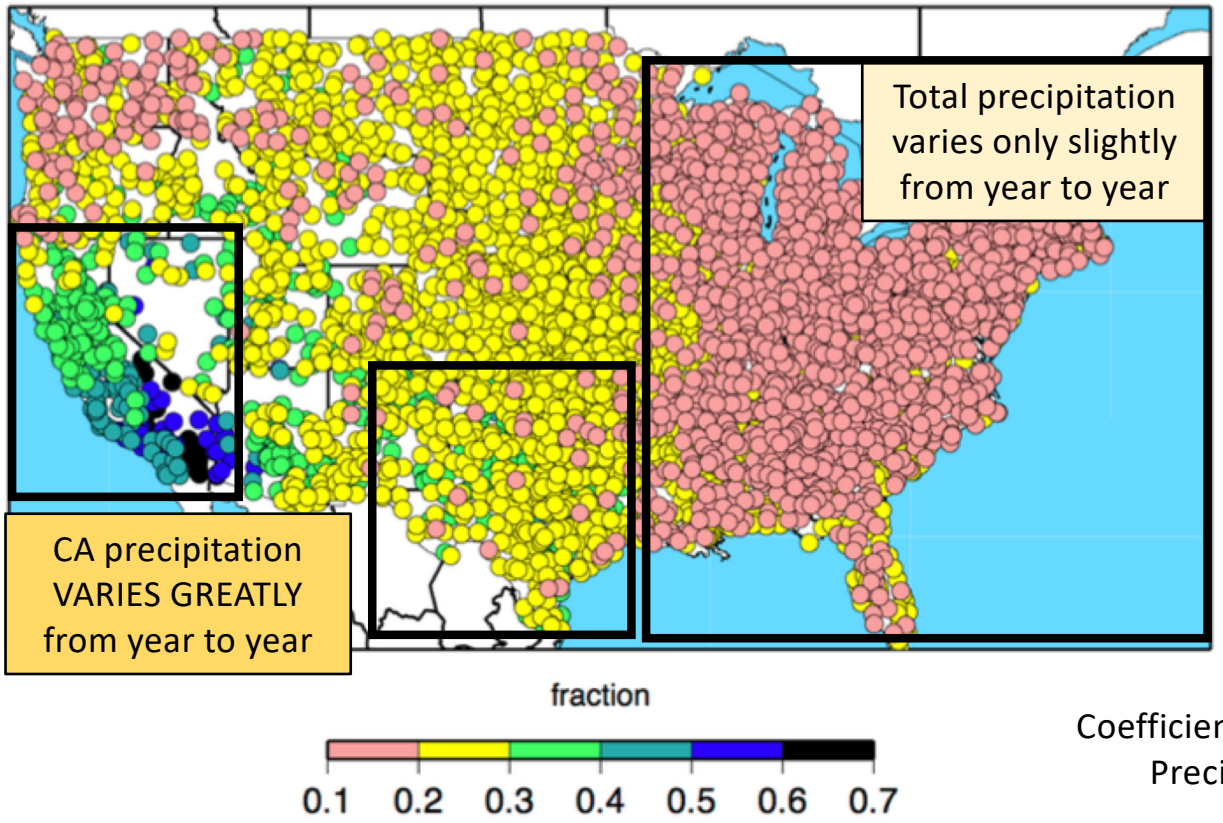

2 Jet Propulsion Laboratory
California Institute of Technology
1 Center for Western Weather
and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY
AT UC SAN DIEGO
5 ECMWF
4
3 Ucla
SUBSEASONAL-TO-SEASONAL (S2S)
FORECASTING OF ATMOSPHERIC RIVERS
F. Martin Ralph[1], Mike DeFlorio[1], Luca Delle
Monache[1], Duane Waliser[2,3], Bin Guan[2,3],
Peter Gibson[2], Alexander Goodman[2], Zhenhai
Zhang[1], Tamara Shulgina[1], Kristen Guirguis[1],
Sasha Gershunov[1], Aneesh Subramanian[4],
Frederic Vitart[5]… and others!
UC San Diego
SCRIPPS INSTITUTION OF
OCEANOGRAPHY

CALIFORNIA HAS GREATEST VARIABILITY OF ANNUAL PRECIPITATION IN THE U.S.



Coefficient of variation for annual Precipitation, 1950-2008

UC San Diego | SCRIPPS INSTITUTION OF OCEANOGRAPHY | Center for Western Weather and Water Extremes

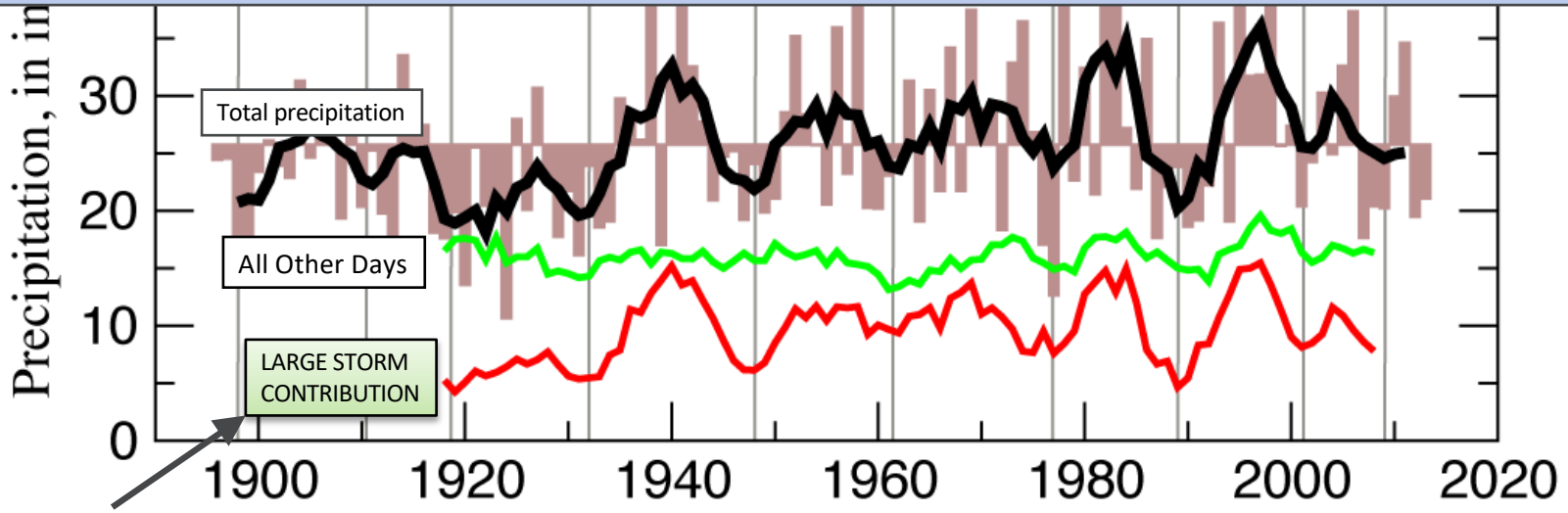
Dettinger, M.D., Ralph, F.M., Das, T., Neiman, P.J., and Cayan, D., 2011: **Atmospheric rivers, floods, and the water resources of California**. *Water*, **3**, 455-478.

A few large storms (or their absence)

account for a disproportionate amount of California's precipitation variability

a) Water-Year Precipitation, Delta Catchment

WHETHER A YEAR WILL BE WET OR DRY IN CALIFORNIA IS MOSTLY DETERMINED BY THE NUMBER AND STRENGTH OF ATMOSPHERIC RIVERS STRIKING THE STATE.



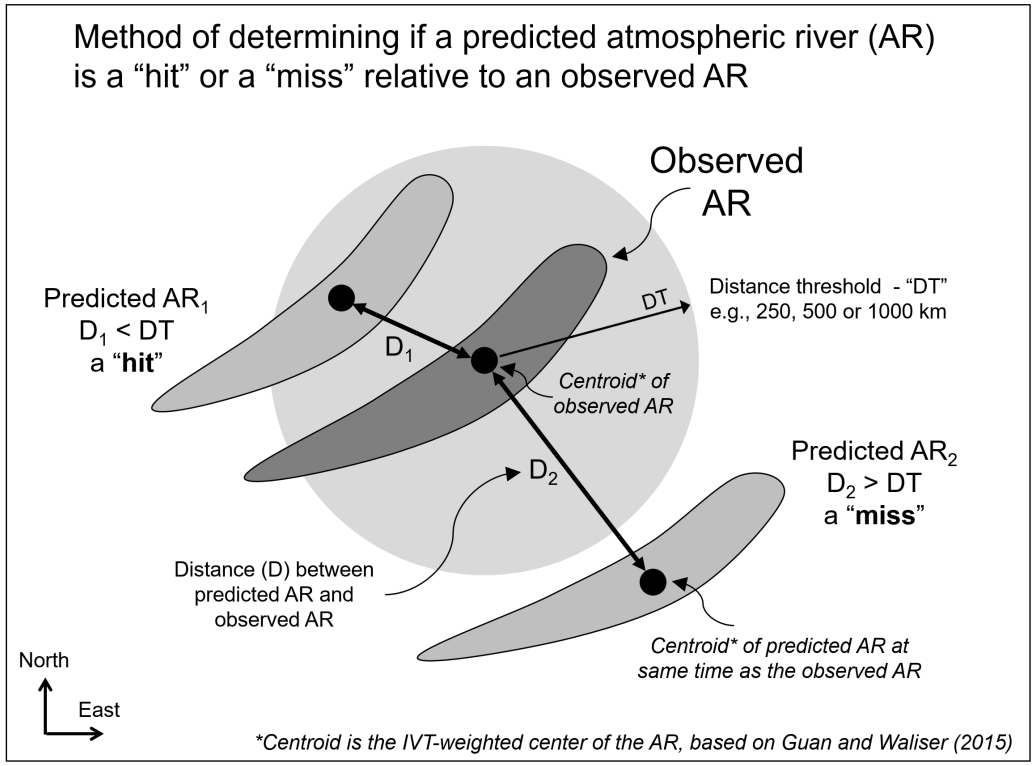
- 85% of interannual variability results from how wet the 5% wettest days are each year.
- These days are mostly atmospheric river events.

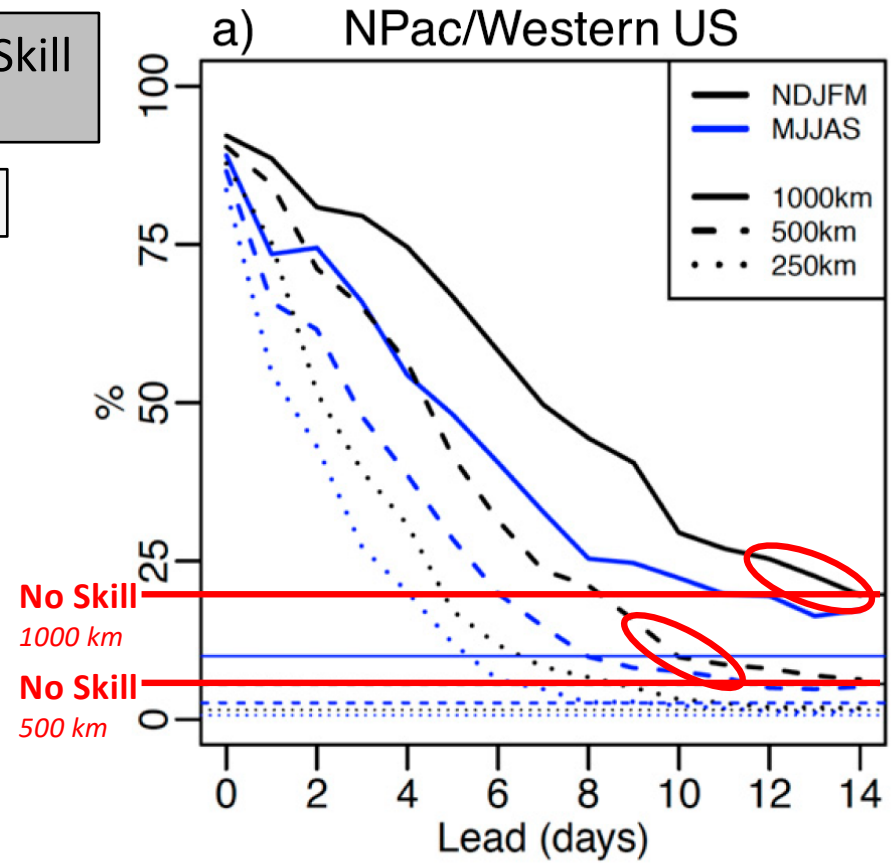
Dettinger and Cayan **Drought and the Delta—A Matter of Extremes**
San Francisco Estuary and Watershed Science, April 2014

Global Assessment of Atmospheric River Prediction Skill

DeFlorio, Waliser, Guan, Lavers and Ralph (*JHM 2018)*

Uses ECMWF forecasts and Guan and Waliser (2015) AR Catalog





In Cool Season, analysis shows there is some skill for 500 km range out to 10 days and for 1000 km range out to 12 days

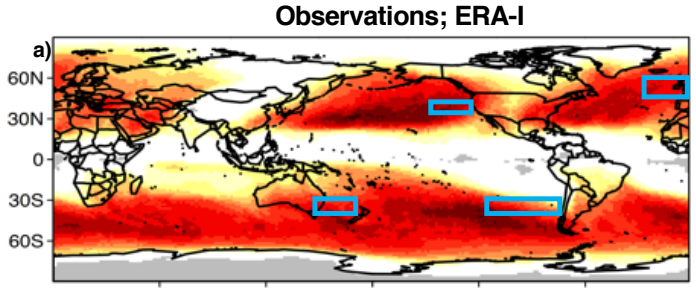
Global Evaluation of Atmospheric River Subseasonal Prediction Skill

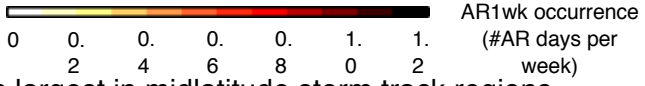
Michael J. DeFlorio[1], Duane E. Waliser[1], Bin Guan[1,2], F. Martin Ralph[3], and Frederic Vitart[4]; (*Climate Dynamics* 2018)
[1]NASA Jet Propulsion Lab., [2]UCLA, [3]UCSD/SIO/CW3E, ECMWF[4]

Purpose of Study

- Evaluate global ECMWF hindcast prediction skill of 1-week AR occurrence (AR1wk; number of AR days per week) at 1-week to 1-month lead times
- Quantify interannual variability of AR1wk magnitude, and identify conditions of climate variability which exhibit higher/lower AR1wk prediction skill

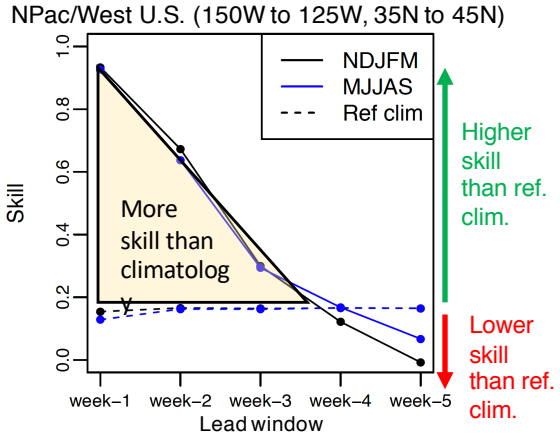
Global climatology of wintertime AR1wk, 1996-2015





- AR1wk is largest in midlatitude storm track regions

Does ECMWF AR1wk skill exceed climatological skill?
Is AR1wk skill modulated by large-scale climate mode activity?



- (left) ECMWF AR1wk occurrence forecast skill outperforms a reference forecast based on monthly climatology of AR1wk occurrence at week-3 (14d-20d) lead over the North

Assessment of Numerical Weather Prediction Model Reforecasts of the Occurrence, Intensity, and Location of Atmospheric Rivers along the West Coast of North America

K. Nardi, E. Barnes, F. M. Ralph, Mon. Wea. Rev,., 2018

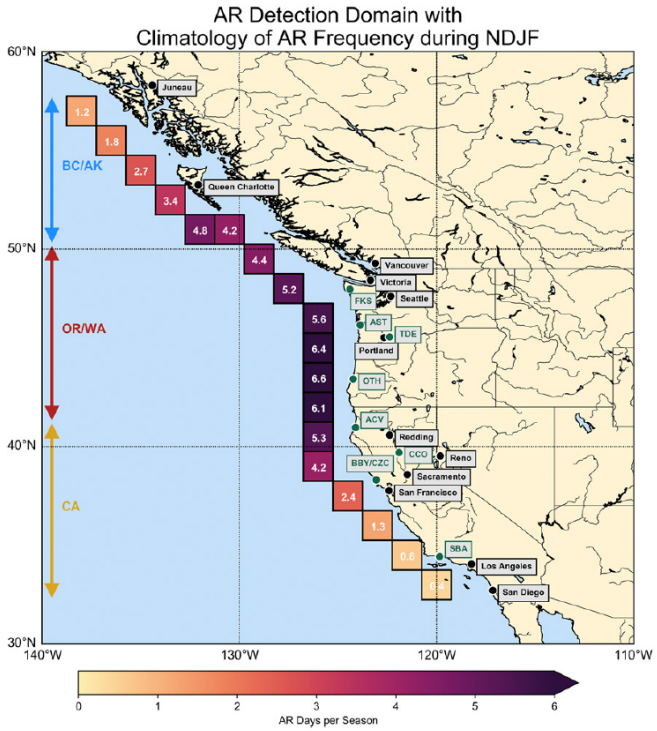


FIG. 2. The domain used for analysis of reforecasts of AR occurrence. The colored arrows refer to three subregions chosen for the analysis. Shading denotes the climatological number of AR days per NDJF season based on ERA-Interim reanalysis from 1979 to 2016. Black circles highlight the locations of several important population centers along the western coast of North America, while the green circles indicate locations of AR observatories (AROs).

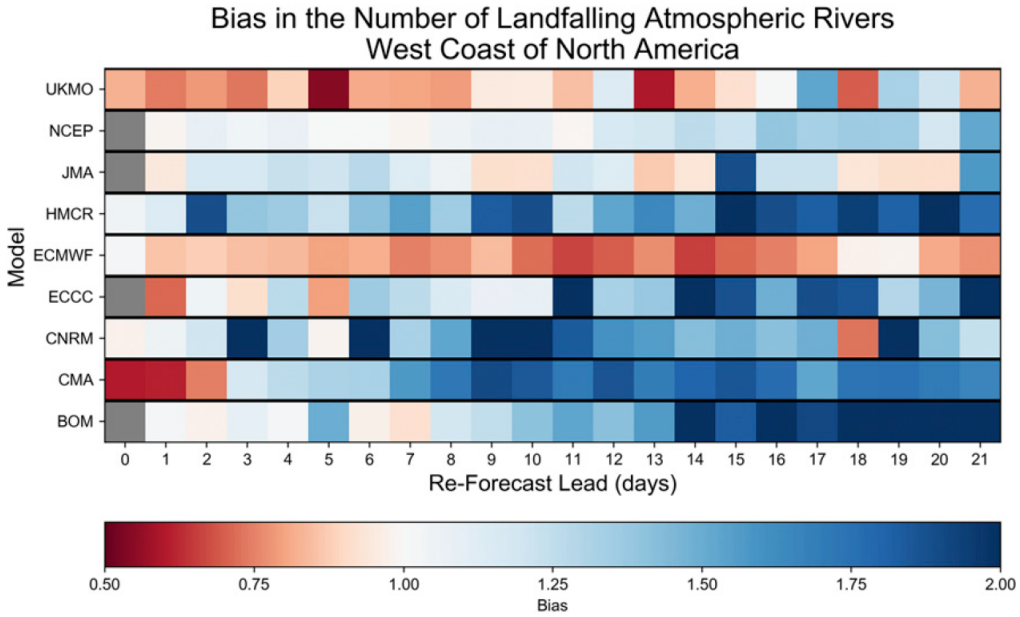


FIG. 3. Model bias (ratio of AR occurrence reforecasts to AR observations) plotted as a function of model and reforecast lead time (in days). Reforecast leads for which there are no data are shaded gray. Red colors indicate fewer AR occurrences reforecast than observed in reanalysis data, and blue colors indicate more AR occurrences reforecast than observed in reanalysis data.

Overview of Western Water S2S AR/Ridging Team

Research and development → **S2S Advisory Panel** ← Research and development

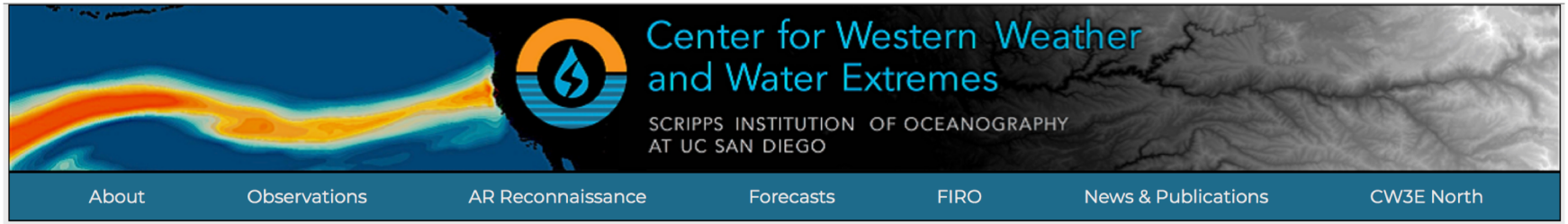
Center for Western Weather and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO

Jet Propulsion Laboratory
California Institute of Technology

Co-chairs: F. Martin Ralph (CW3E) & Duane Waliser (JPL)

Members
- Dan Cayan
- Bruce Cornuelle
- Art Miller

Assessment of S2S tools and forecast metrics evaluated in peer-reviewed literature framework



CW3E S2S Experimental AR Outlooks

Dissemination of experimental products onto CW3E website

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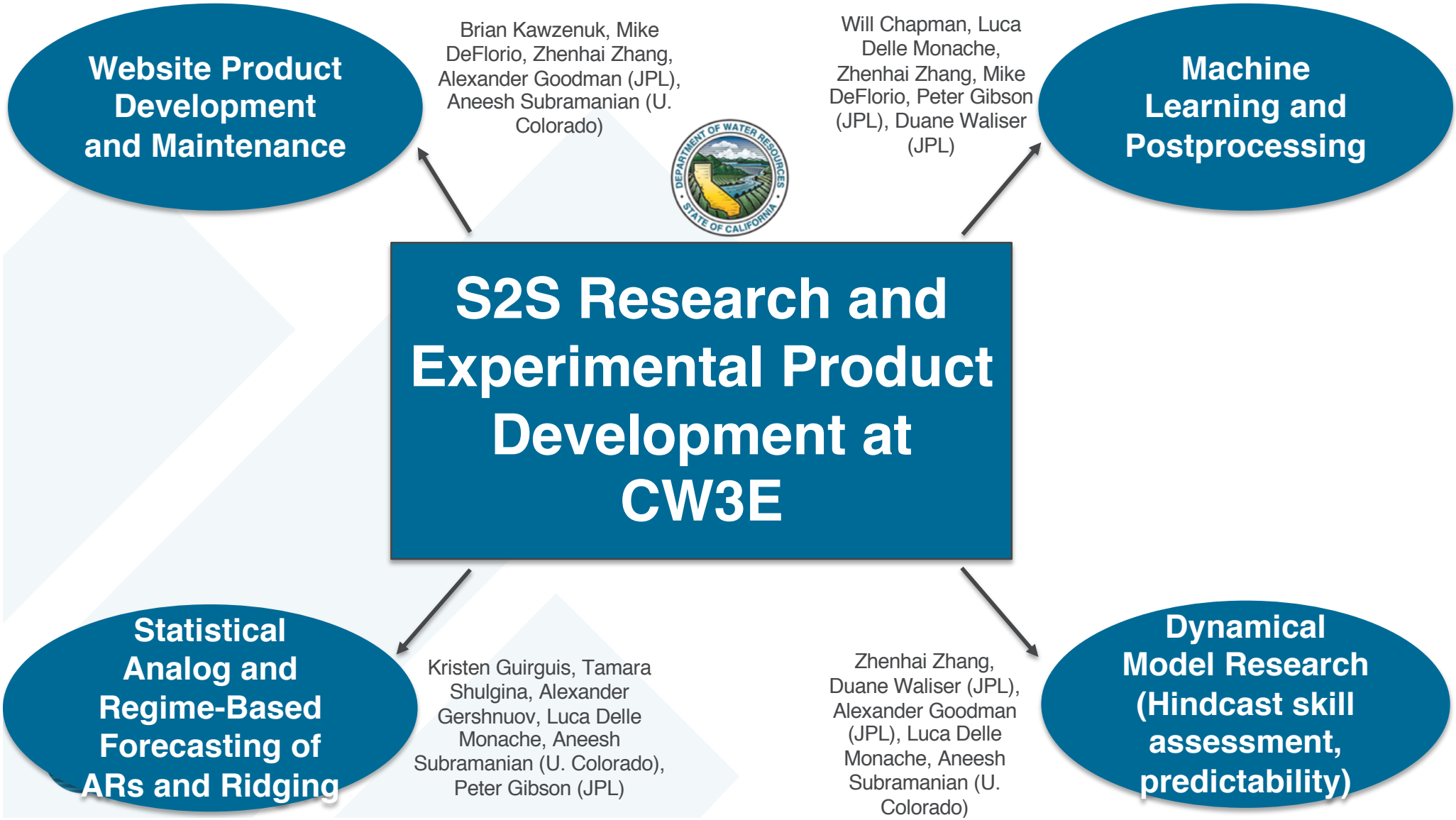
Website Product Development and Maintenance
Brian Kawzenuk, Mike DeFlorio, Zhenhai Zhang, Alexander Goodman (JPL), Aneesh Subramanian (U. Colorado)
Will Chapman, Luca Delle Monache, Zhenhai Zhang, Mike DeFlorio, Peter Gibson (JPL), Duane Waliser (JPL)
Machine Learning and Postprocessing
S2S Research and Experimental Product Development at CW3E
Statistical Analog and Regime-Based Forecasting of ARs and Ridging
Kristen Guirguis, Tamara Shulgina, Alexander Gershnuov, Luca Delle Monache, Aneesh Subramanian (U. Colorado), Peter Gibson (JPL)
Zhenhai Zhang, Duane Waliser (JPL), Alexander Goodman (JPL), Luca Delle Monache, Aneesh Subramanian (U. Colorado)
Dynamical Model Research (Hindcast skill assessment, predictability)

Overview of S2S AR Team

S2S Advisory Panel

*F. Martin Ralph[1] (Chair), *Duane Waliser[2], Dan Cayan[1], Bruce Cornuelle[1], Art Miller[1]

denotes DWR co-PI

S2S AR Prediction Team

Mike DeFlorio (lead researcher)[1], William Chapman[1], Jason Cordeira[3], Luca Delle Monache[1], Alexander Gershunov[1], Peter Gibson[2], Alexander Goodman[2], Bin Guan[2], Kristen Guirguis[1], Brian Kawzenuk[1], Arun Kumar[5], Hai Lin[6], Tamara Shulgina[1], Aneesh Subramanian[4], Rui Sun[1], Frederic Vitart[7], Anna Wilson[1], Zhenhai Zhang[1]

Affiliations: [1]CW3E, SIO-UCSD; [2]NASA JPL/CalTech; [3]Plymouth State University, [4]University of Colorado Boulder; [5]NCEP; [6]ECCC; [7]ECMWF

Experimental Multi-Model Atmospheric River Forecast*

Week-3: issued on February 7, 2019; Week-2: issued on February 14, 2019; Week-1: issued on February 21, 2019

Contents:

"Week-3 forecast" - US west coast weather/precipitation forecast for week 3 considering the number of atmospheric river days predicted to occur in the given forecast week.
Novelty – an S2S forecast presented only in terms of AR likelihood - specifically for week 3, an extended/long-range or "subseasonal" prediction

Ensemble Forecast Systems Used

ECMWF (European Centre for Medium-Range Weather Forecasts) forecast system
NCEP (National Centers for Environmental Systems) forecast system
ECCC (Environment and Climate Change Canada) forecast system

**This is an experimental activity for the 2017-18 and 2018-19 winters. Methodologies and hindcast skill are documented in DeFlorio et al. (2018,2019a,2019b). Further validation of the real-time forecast results is required and underway. This phase of the research includes gathering stakeholder input on the presentation of information – feedback is welcome.*

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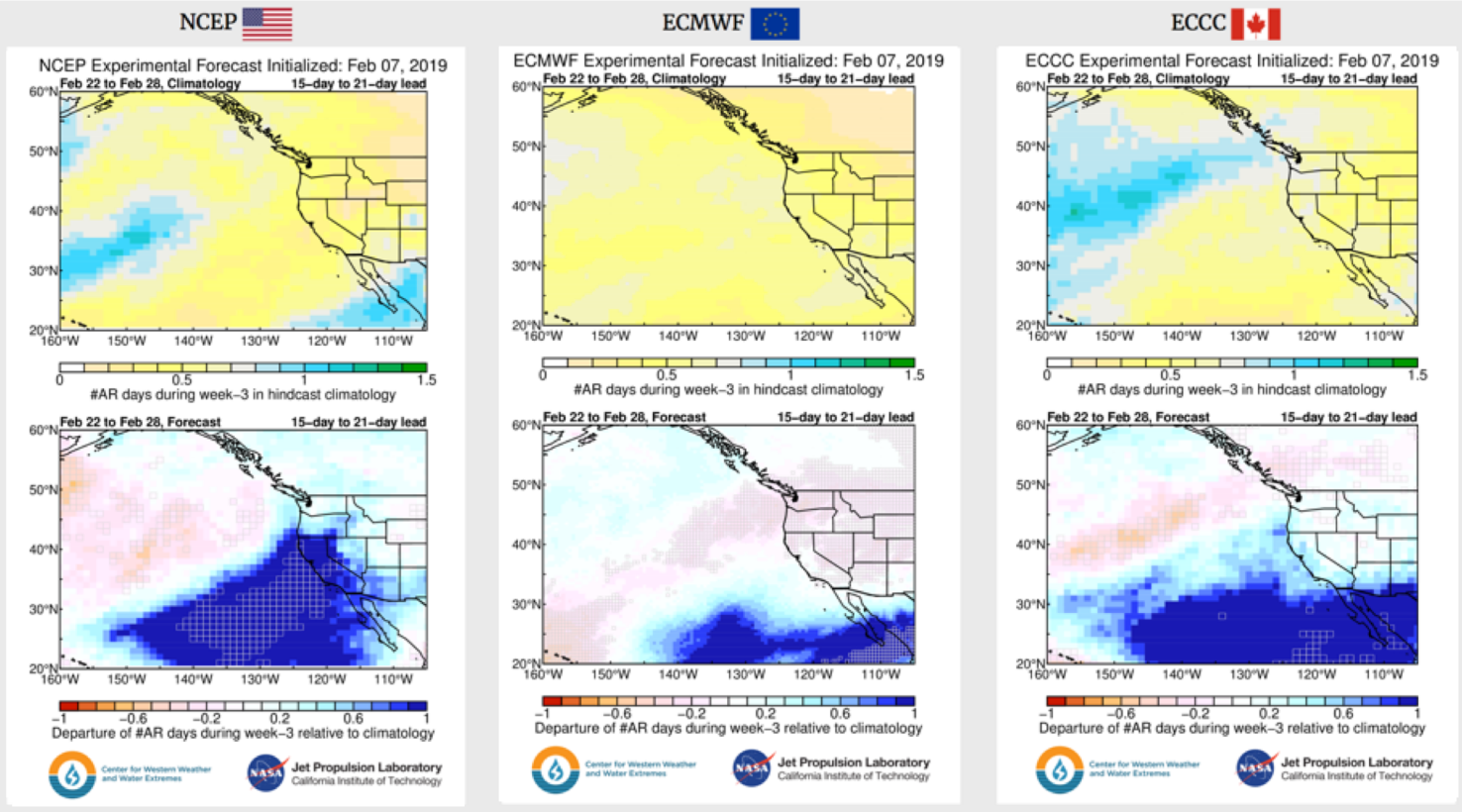
EXPERIMENTAL AR FORECAST

Week-3 (15-day to 21-day lead)

Hindcast Climatology

Forecast Minus Climatology



Experimental AR forecast issued on Thursday, February 7, 2019 by M. DeFlorio, D. Waliser, M. Ralph, A. Goodman, B. Guan, A. Subramanian, and Z. Zhang for an Experimental AR Forecasting Research Activity sponsored by California DWR

Contact: Mike DeFlorio (mdeflorio@ucsd.edu)

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EXPERIMENTAL SEASONAL FORECAST OF JANUARY-MARCH 2019 PRECIPITATION ANOMALIES OVER THE WESTERN US VIA DECEMBER 2018 SST

Key CW3E personnel: Tamara Shulgina, Alexander Gershunov, Kristen Guirgius

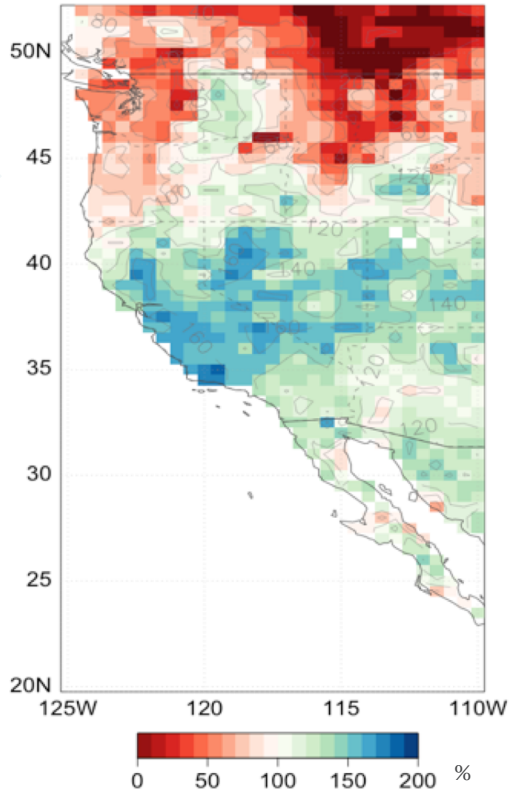
CCA prediction approach:

Predictor: December Pacific SST [20S – 65N]

Predictand: JFM precipitation anomalies (%)

Model training period: 1950 – 2012

Prediction of total precipitation anomalies, January-March, 2019



EXPERIMENTAL SEASONAL FORECAST IN DECEMBER 2018 OF JFM 2019 PRECIPITATION BASED ON PACIFIC SST

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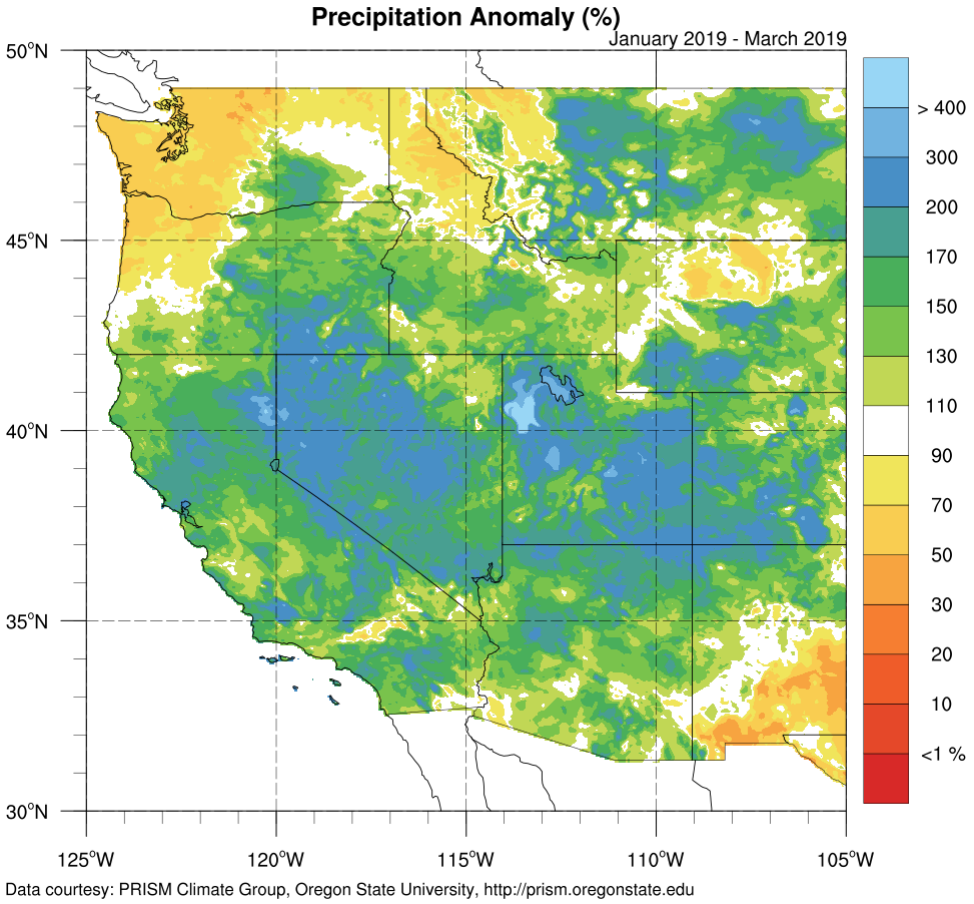
SUBSEQUENT OBSERVED PRECIPITATION ANOMALIES, JFM 2019



Good agreement with observations of spatial structure and magnitude of experimental seasonal precipitation forecast made on January 1, 2019 based on December 2018 Pacific basin SSTs

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California Institute of Technology

SUMMARY

- Atmospheric rivers occur globally and influence weather and water extremes.
- Total amount of annual California precipitation is uniquely variable from year to year and is strongly influenced by occurrence or absence of atmospheric rivers.
- S2S (2-12 week lead time) forecasting of atmospheric rivers represents a critical decision-making time window for water resource managers.
- Real-time experimental AR occurrence, AR intensity, ridging, and precipitation forecasting effort using ECMWF, NCEP, and ECCC data is ongoing (CW3E/JPL partnership), with engagement from NCEP and addition of NASA GMAO data forthcoming
    - Pilot S2S Project for Applications

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Thank you!
mralph@ucsd.edu
Center for Western Weather and Water Extremes
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cw3e.ucsd.edu