Experimental Short-term Forecasting of Atmospheric Rivers

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Water Year 2019: Feast or Famine? Workshop; Irvine, CA

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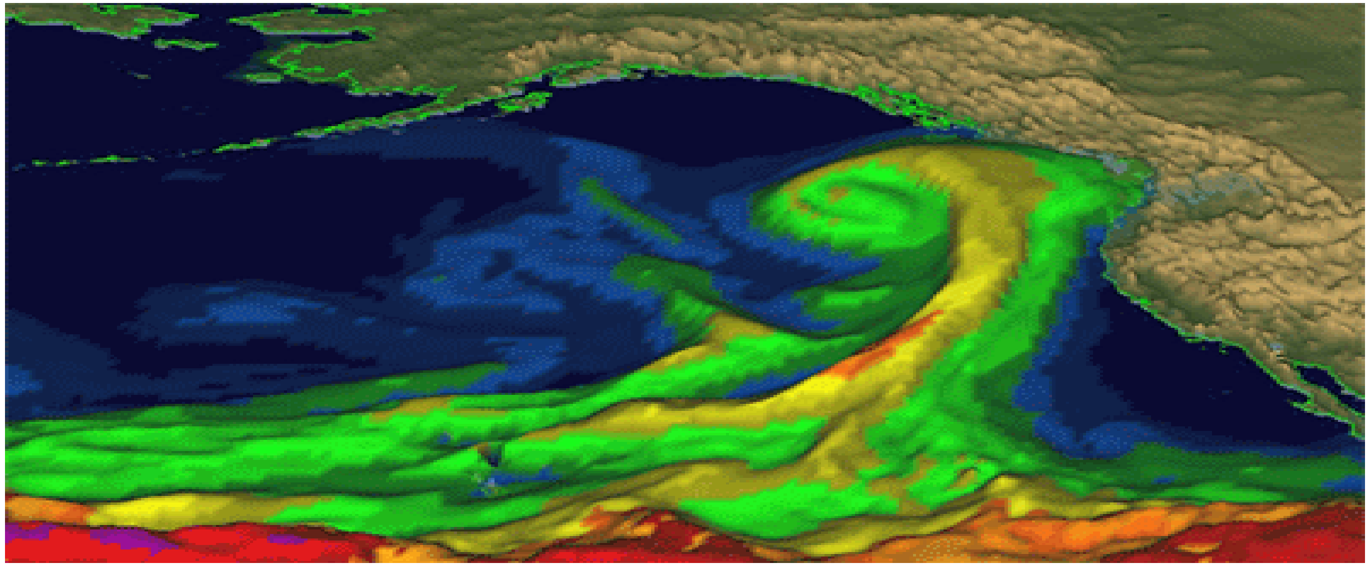
A multi-institutional research effort sponsored by California DWR

Atmospheric rivers and their associated flood and hazard risks occur globally and influence climate and water extremes.

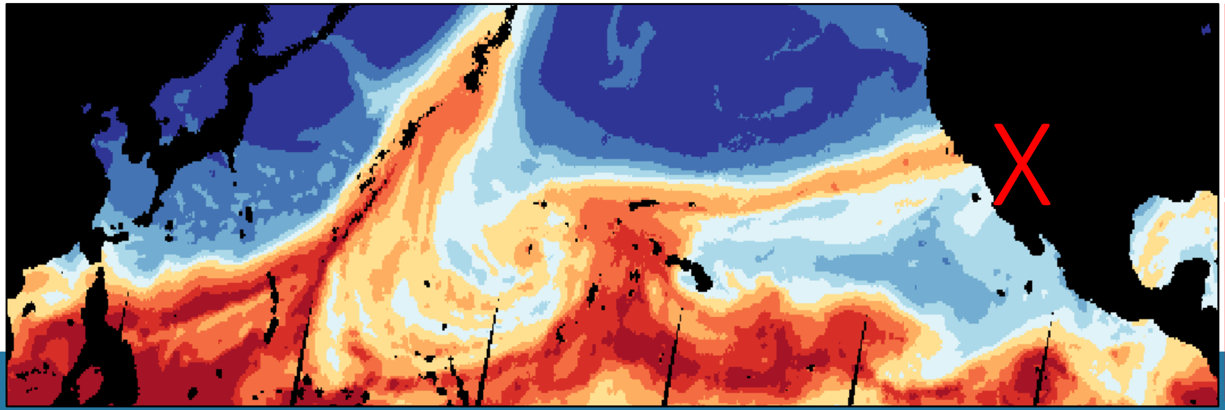


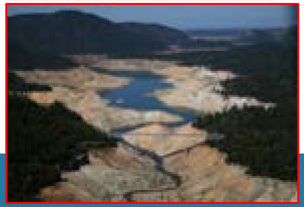
NOAA ESRL

Over 90% of poleward moisture transport at midlatitudes is by ARs that take up only ~10% of the zonal circumference.

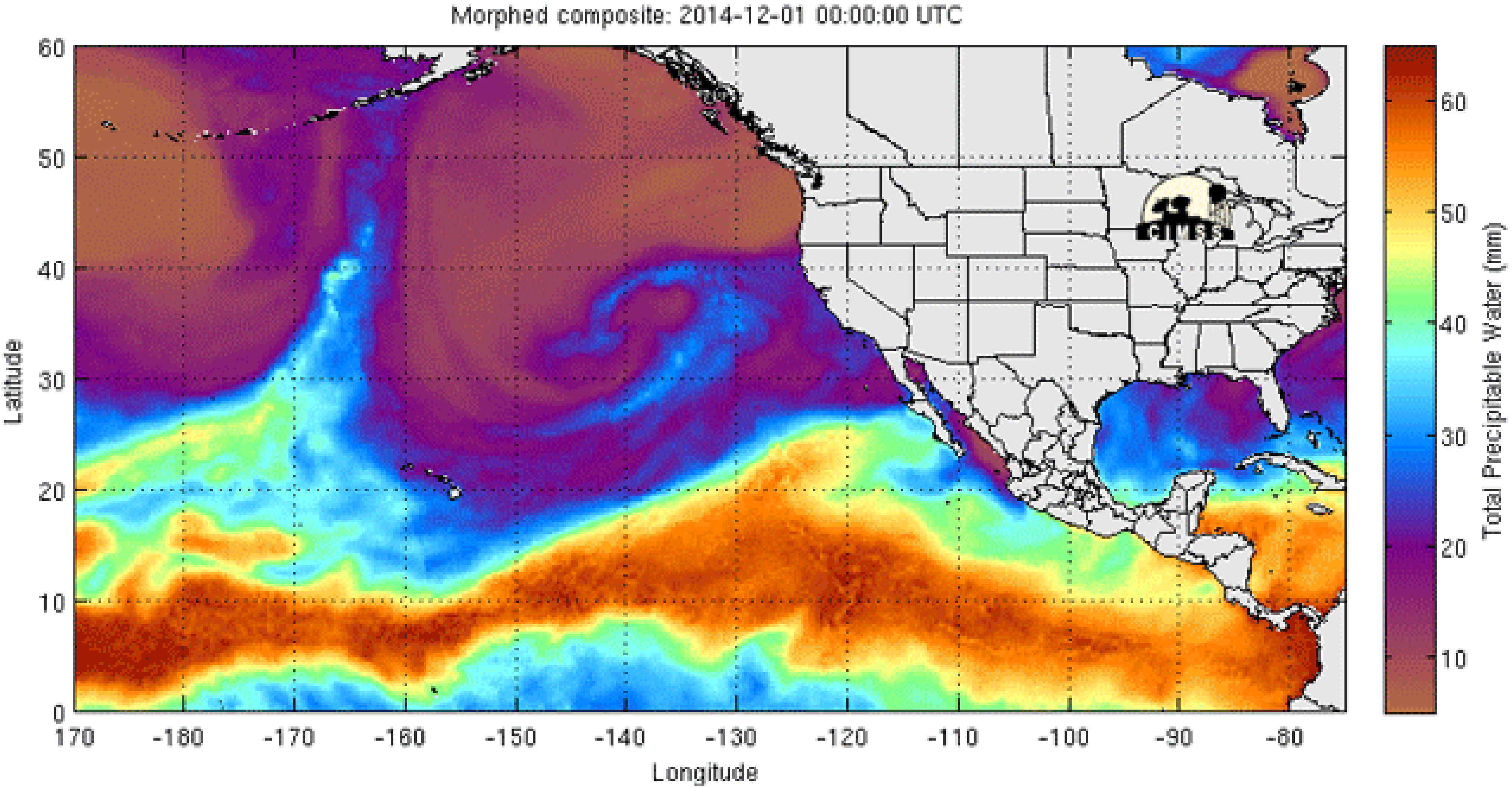
Zhu and Newell 1998
Ralph et al. 2004

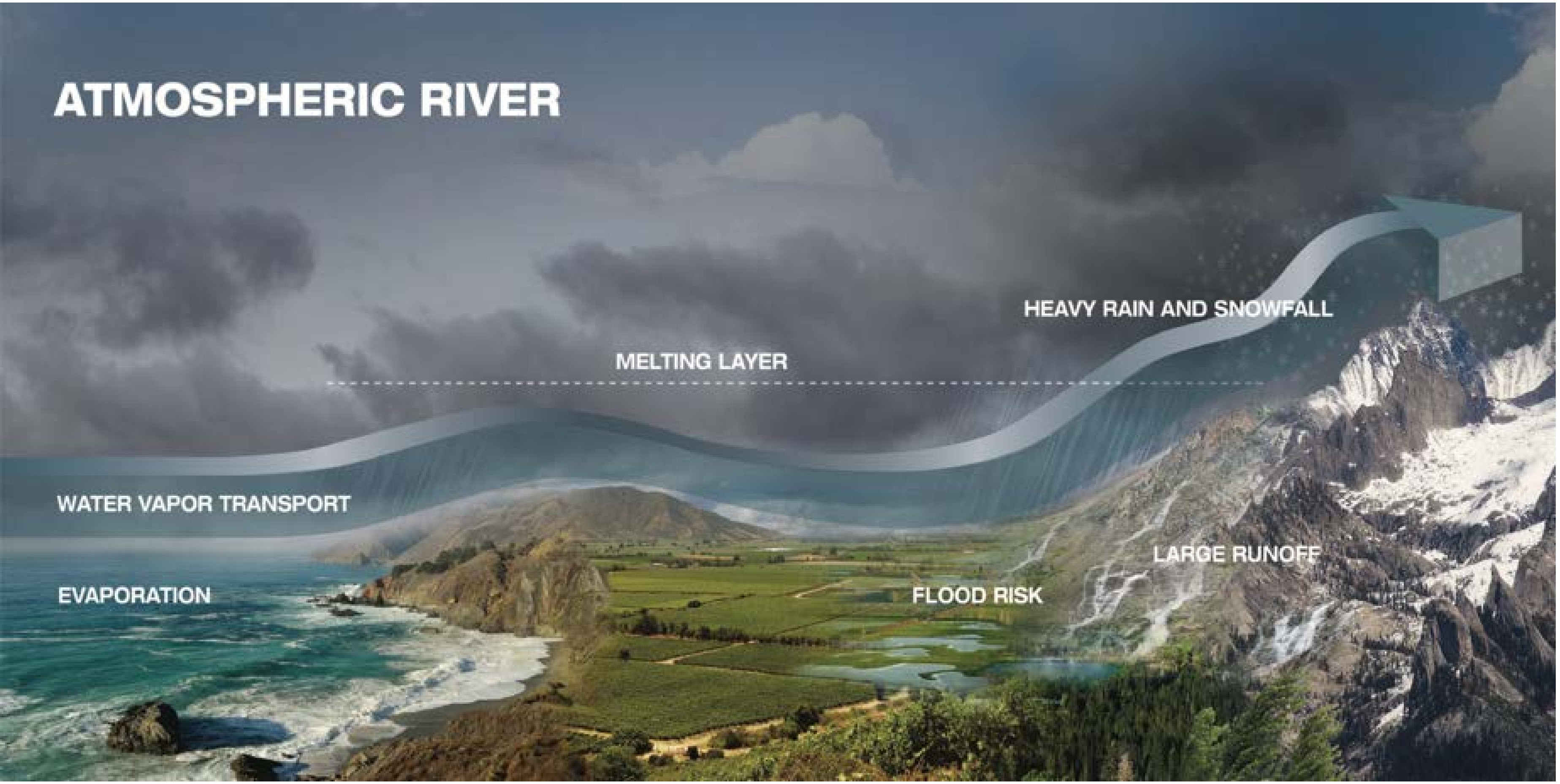
In the west, ARs account for ~40% of annual precipitation and most floods.





What does an Atmospheric River look like from space?



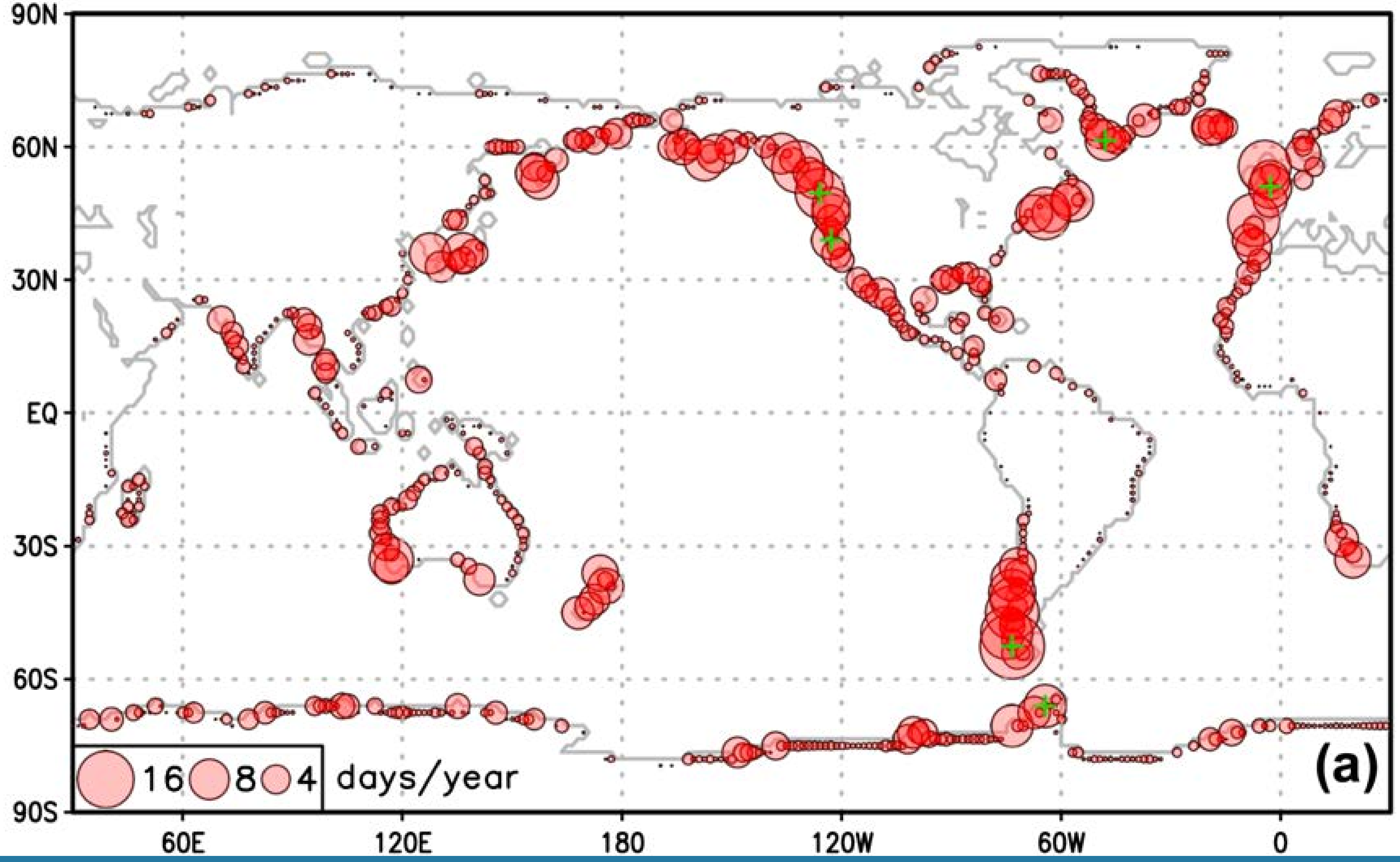


Source: CA DWR

Atmospheric rivers:

- can carry as much as water as 25 Mississippi Rivers, and can provide up to 50% of West Coast precipitation
- are about 500 miles wide (Ralph et al. 2017, Guan et al. 2018) and are located above the lowest mile of the atmosphere
- sometimes tap tropical moisture near Hawaii, transporting concentrated water vapor for thousands of miles

Where do atmospheric rivers make landfall most often?

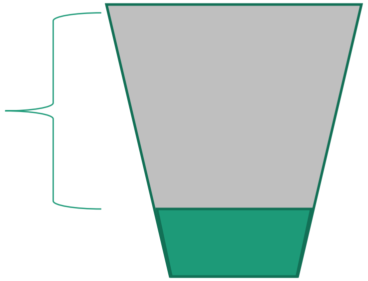


Guan and Waliser 2015

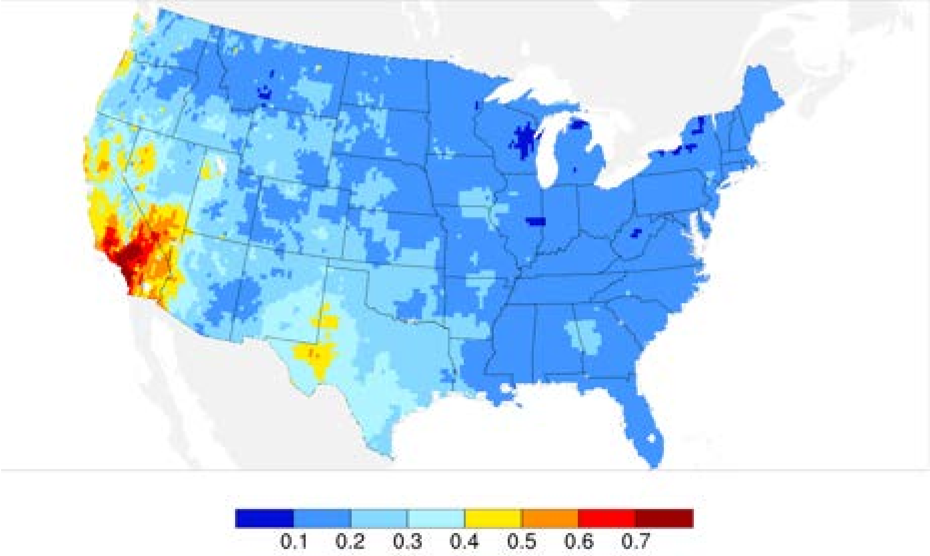
Why are our water challenges so unique in California?

Ratio of Year-to-Year Variation in Precipitation over Average Precipitation

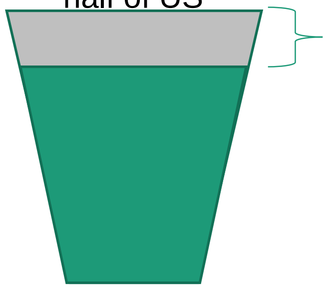
Annual precipitation "bucket" for southern California



Year-to-year variations ~70%

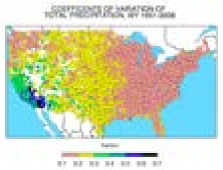


Annual precipitation "bucket" for eastern half of US



Year-to-year variations ~20%

Caption: Map shows the ratio of the year-to-year variability in precipitation divided by the long-term mean precipitation (based on TRMM, 1998-2016). Thus, the eastern half of the country vary rarely experiences a significant variation from their typical precipitation totals (~1-1.5m), about +/- 20% of the mean. Uniquely, in southern California, the year-to-year variations are nearly as big as the total annual precipitation (~0.2-0.3m), i.e. +/- 70% of the mean.

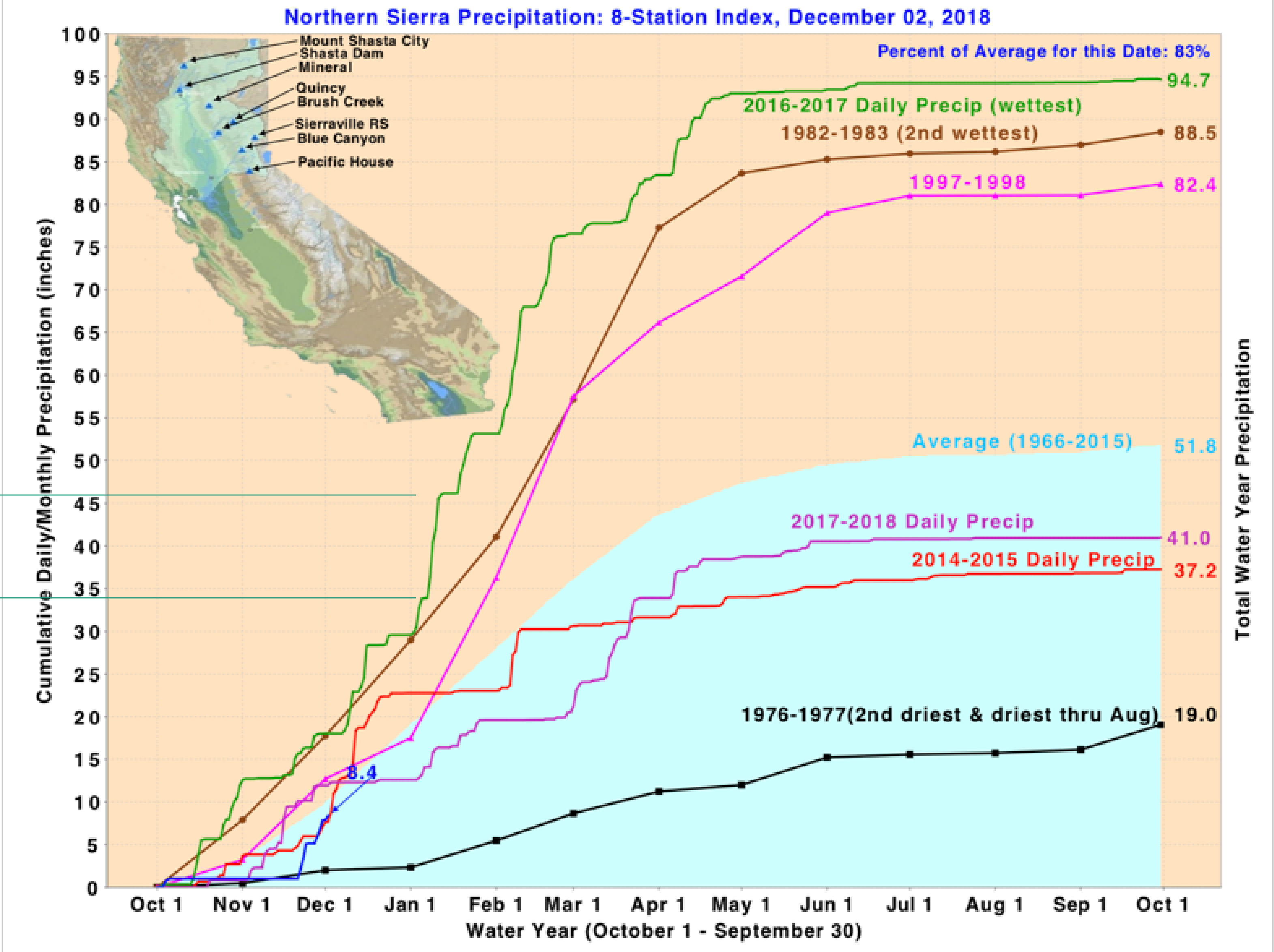


Calculation using Tropical Rainfall Measuring Mission (TRMM) data, as originally performed by Dettinger et al. 2011 with station data

Relative to the rest of the U.S., southern California experiences the largest year to year swings in annual precipitation totals relative to its average values.

Dettinger et al. 2011

- ~ 14% of total Water Year precip in 2016-2017 fell in a ~10-day period in early January (13'' of total 94.7'')



Source: CA DWR

Our team at CW3E (UCSD-Scripps), NASA JPL, UCLA, and ECMWF is focused on improving forecasts of atmospheric rivers 3 weeks or more into the future.

A forecast this far into the future differs from a traditional weather forecast.

Key Research Question

Center for Western Weather and Water Extremes

What is the limit of global subseasonal (1-week to 1-month) prediction skill of atmospheric river occurrence, and how does it vary as a function of season, region, and certain large-scale climate conditions?

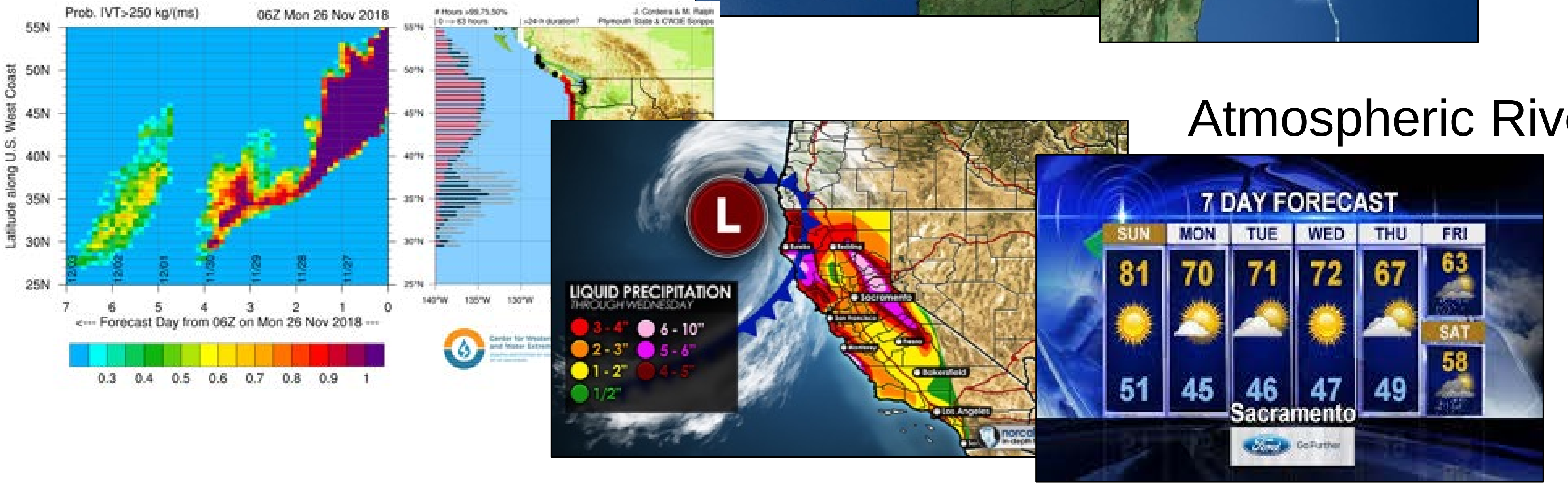
Key Applications Question

Can present-day subseasonal-to-seasonal (S2S) forecast systems provide benefit to CA water resource management decision makers?

Weather Forecasts (0-14 Days)

Hurricanes

Atmospheric Rivers



… cold spells, heat waves, thunderstorms/tornados, nor’easters, santa ana winds, etc

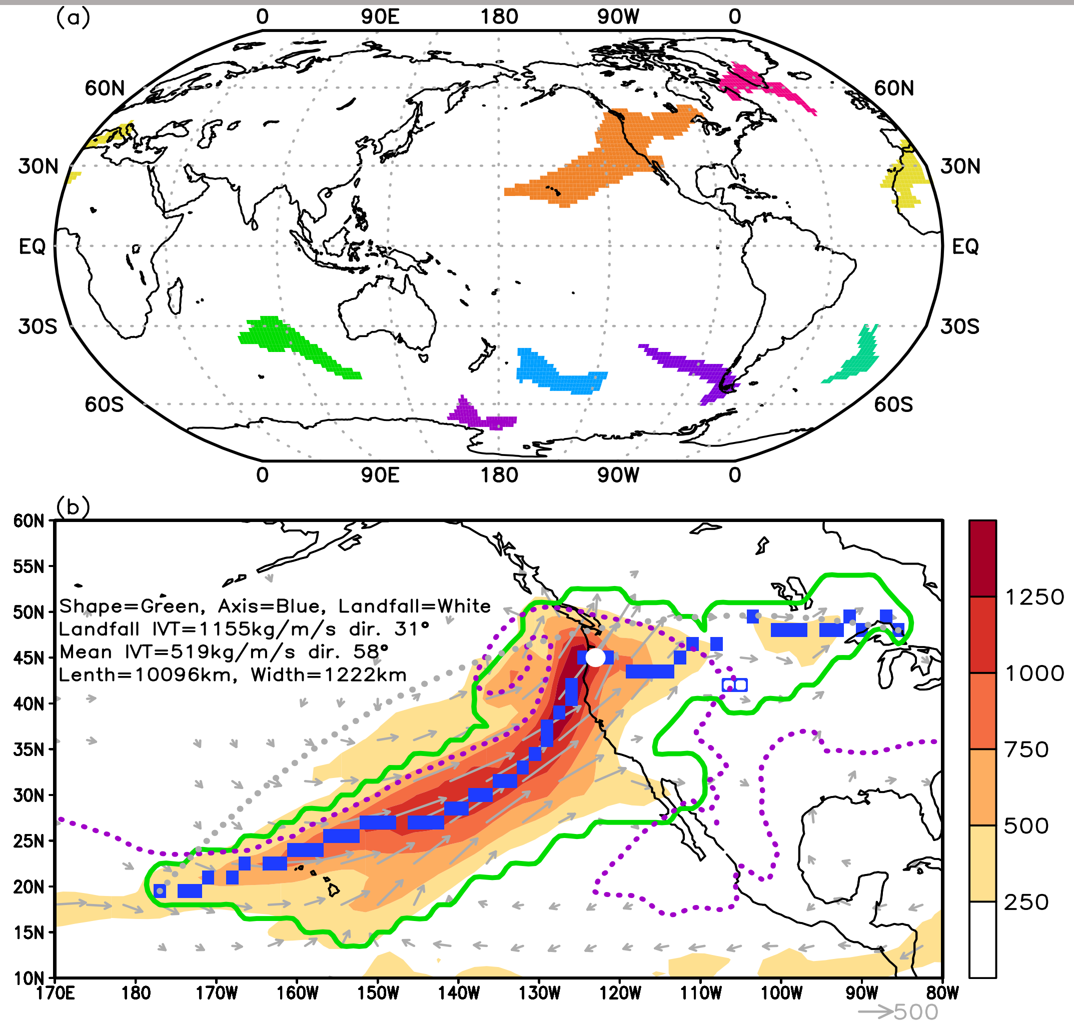
“Short term” (S2S) Forecasts: Atmospheric Rivers (3-4 weeks)

Atmospheric Rivers

- How can we predict atmospheric rivers 3-4 weeks in the future?
- Rather than try to predict the occurrence or evolution of a single atmospheric river at such long leads, can we predict the likelihood of an atmospheric river or expected frequency of atmospheric rivers?

A global, objective algorithm for AR identification

(Guan and Waliser 2015)



- Based on Integrated Vapor Transport (IVT) fields and a number of common AR criteria (e.g. Ralph et al. 2004)
- Applied to global hindcast/forecast systems and reanalysis datasets
- Code and databases available at: https://ucla.box.com/ARcatalog
- Databases include AR Date, $IVT_{x,y}$, Shape, Axis, Landfall Location, etc.
- Used for GCM evaluation (Guan and Waliser 2017), climate change projections (Espinoza et al. 2018), & forecast skill assessment (DeFlorio et al. 2018a and 2018b)

Experimental S2S AR Forecasting for Winter 2017-18 and 2018-19

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Experimental Multi-Model Atmospheric River Forecast*

Issued on Thursday, November 29, 2018

Contents:

Slide 1-2: “Weather” - Typical presentation of US west coast weather/precipitation forecast over lead times of 1 to 14 days considering only the likelihood of an atmospheric river (AR) occurring on a given forecast day. *Novelty – a weather forecast presented only in terms of AR likelihood.*

Slide 3-5: “week-3” - 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

Slides 1-3: ECMWF (European Centre for Medium-Range Weather Forecasts) forecast system
Slide 4: NCEP (National Centers for Environmental Systems) forecast system
Slide 5: 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. (2018a,b). 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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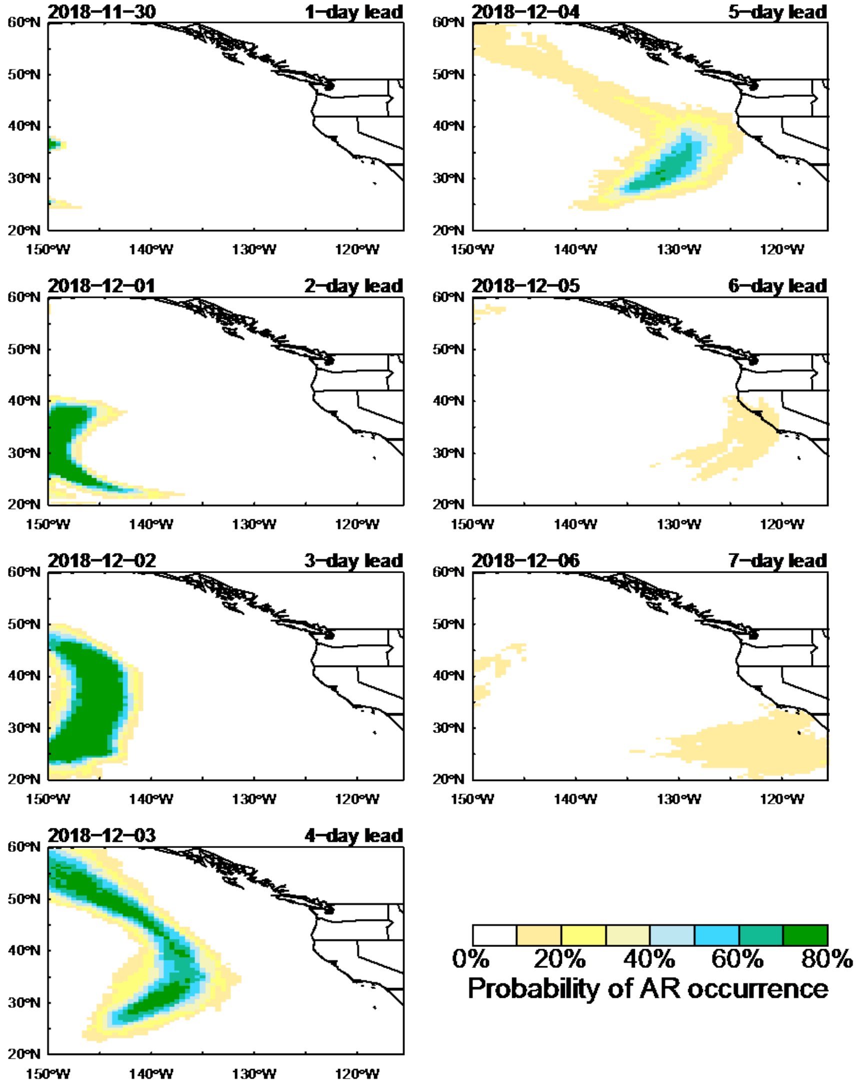
EXPERIMENTAL AR FORECAST

ECMWF Forecast Initialized: Nov 29, 2018



ECMWF

Week-1

(1-day to 7-day lead)

Experimental AR forecast issued on Thursday, November 29, 2018 by M. DeFlorio, D. Waliser, A. Goodman, B. Guan, A. Subramanian, Z. Zhang, and M. Ralph using 51-member real-time ECMWF data for an Experimental AR Forecasting Research Activity sponsored by California DWR

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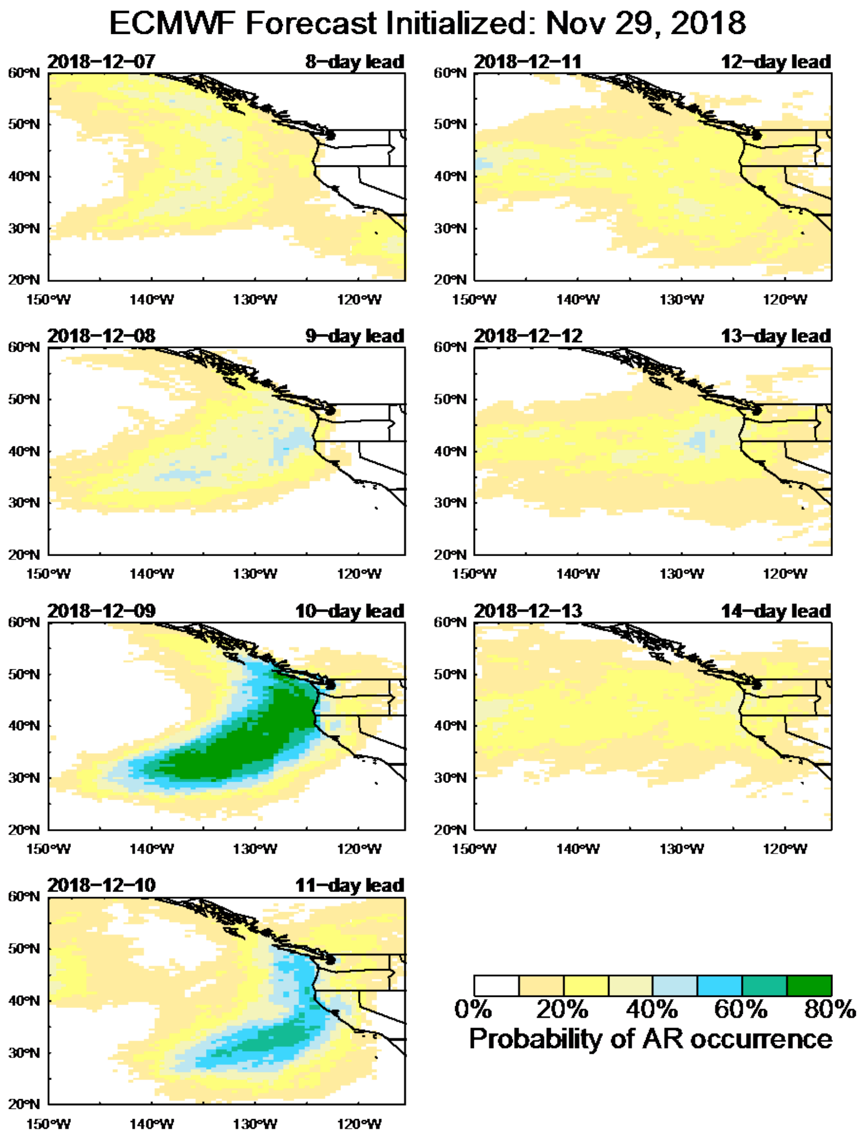
EXPERIMENTAL AR FORECAST



ECMWF

Week-2

(8-day to 14-day lead)

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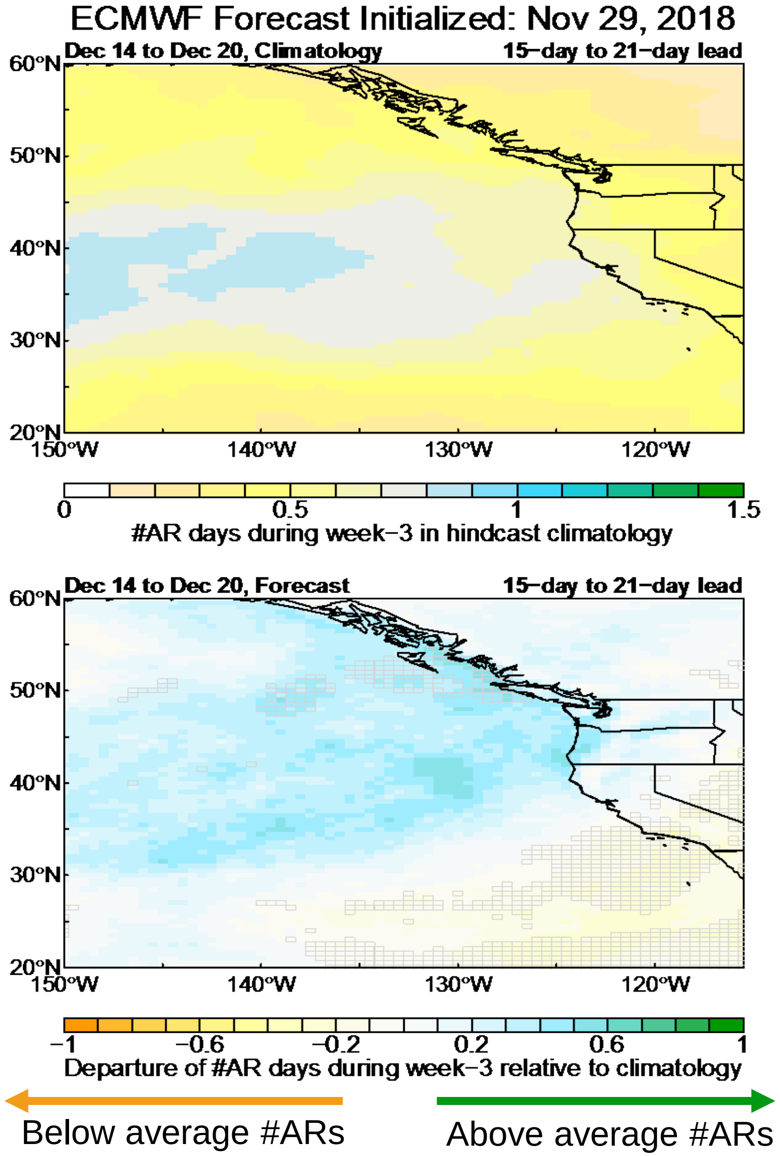
EXPERIMENTAL AR FORECAST



ECMWF

Week-3

(Combined 15-day to 21-day lead)

Top row: hindcast climatology (ECMWF 1996-2015 data)
Bottom row: real-time forecast minus climatology (ECMWF 51-member ensemble)

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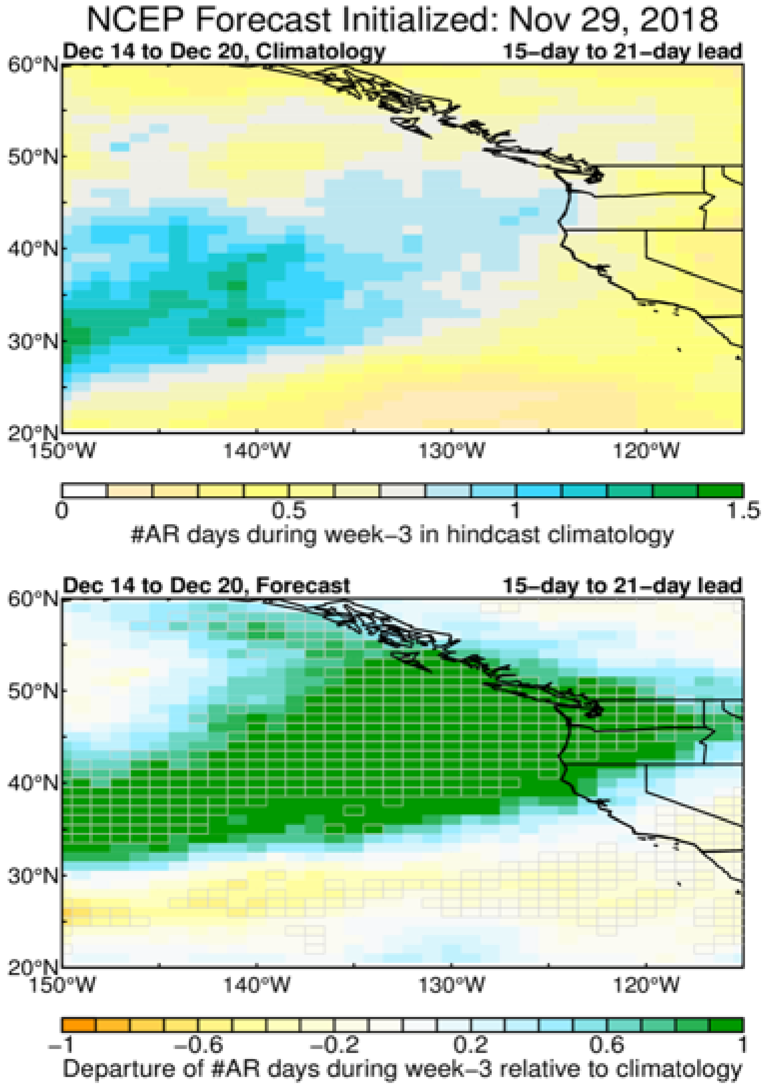
EXPERIMENTAL AR FORECAST



Below average #ARs

Above average #ARs

NCEP

Week-3

(Combined 15-day to 21-day lead)

Top row: hindcast climatology (NCEP 1999-2010 data)
Bottom row: real-time forecast (NCEP 16-member ensemble)

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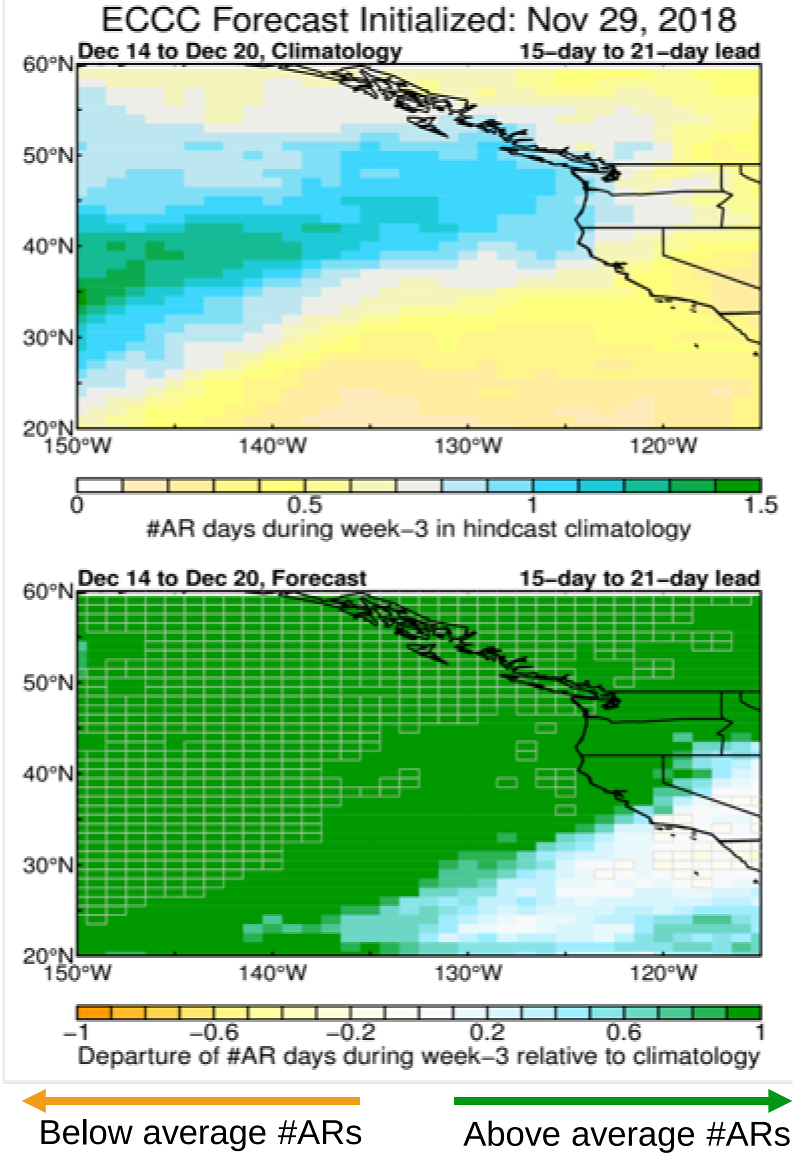
EXPERIMENTAL AR FORECAST



ECCC

Week-3

(Combined 15-day to 21-day lead)

Top row: hindcast climatology (ECCC 1995-2014 data)
Bottom row: real-time forecast (ECCC 21-member ensemble)

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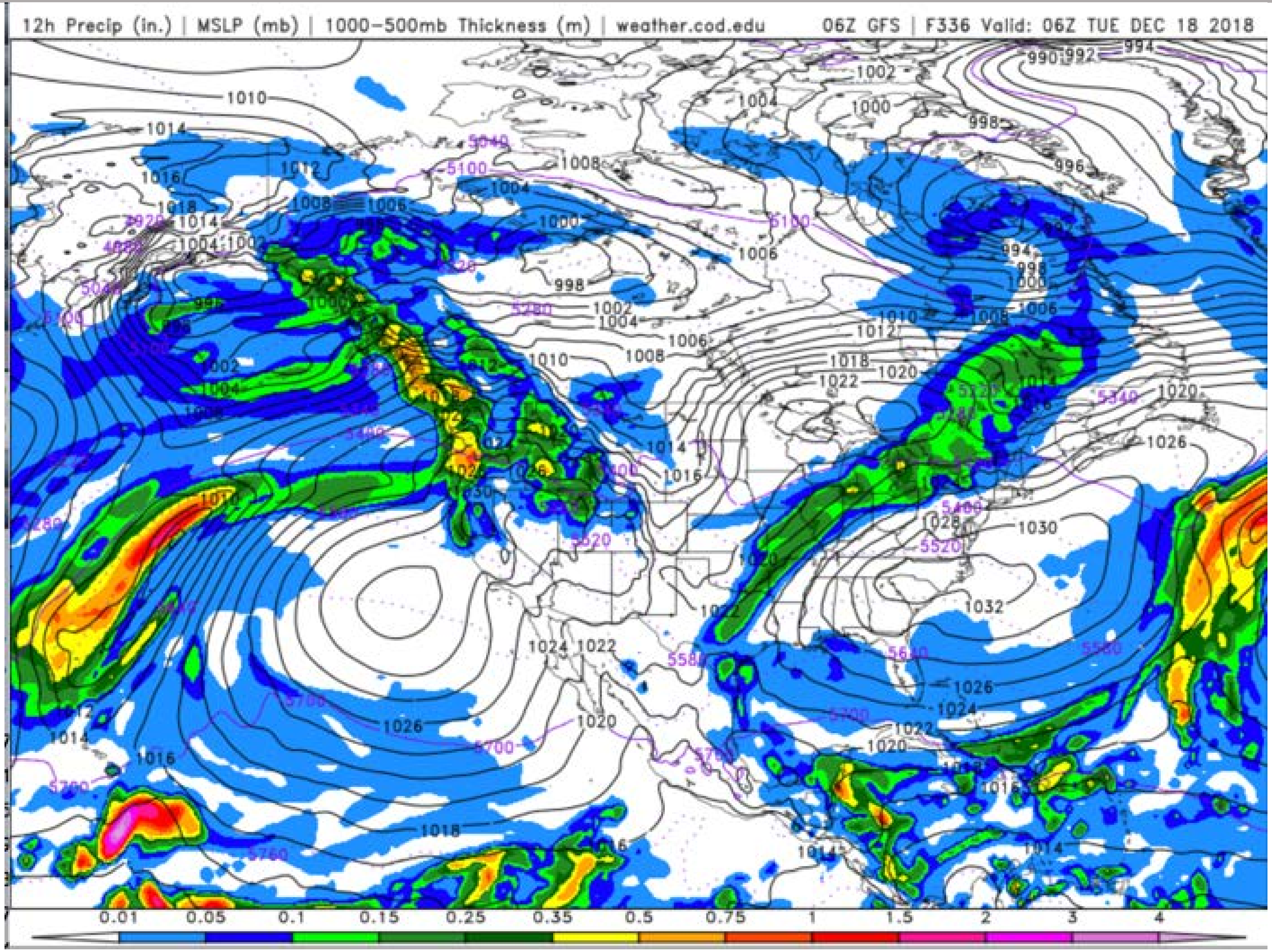
Multi-model agreement (>75% confidence) on dry conditions over Southern California between Dec 14-20 linked to forecasted ridging event



See next talk by
Peter Gibson
(NASA JPL/CalTech)

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.
- Short-term (i.e. ”S2S”, 3-4 week lead time) forecasting of atmospheric rivers represents a critical decision-making time window for water resource managers.
- Real-time experimental AR occurrence forecasting effort using ECMWF, NCEP, and ECCC data is ongoing (collaboration between CW3E and JPL), with engagement from NCEP.
- Verification of Winter 2017-2018 forecasts is nearly complete, and pending these results, week-3 products may be displayed on CW3E website in the future.
- Examining sources of increased prediction skill at longer lead times – e.g. atmospheric ridging events (Peter Gibson, JPL)