

Predicting Atmospheric Rivers

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CLIVAR Workshop
9 August 2017

*California Central valley in flood on
21 January 2017 near Sacramento*



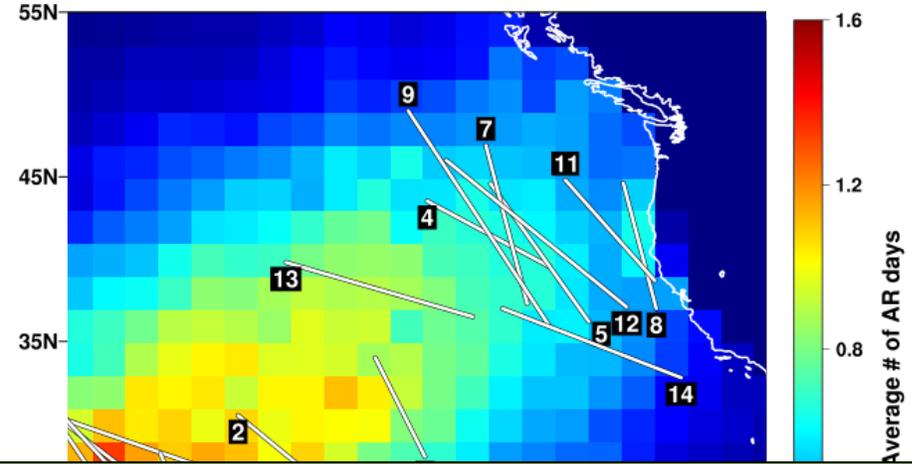
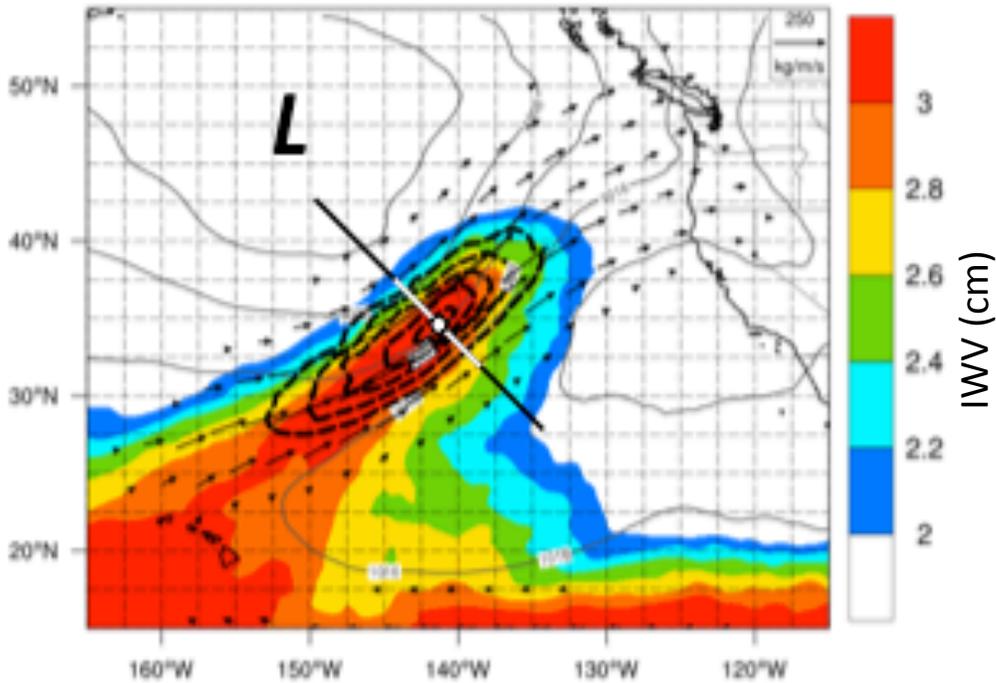
*Photo courtesy of
John Nielson-Gammon*



Observations of Water Vapor Transport by North Pacific Atmospheric Rivers

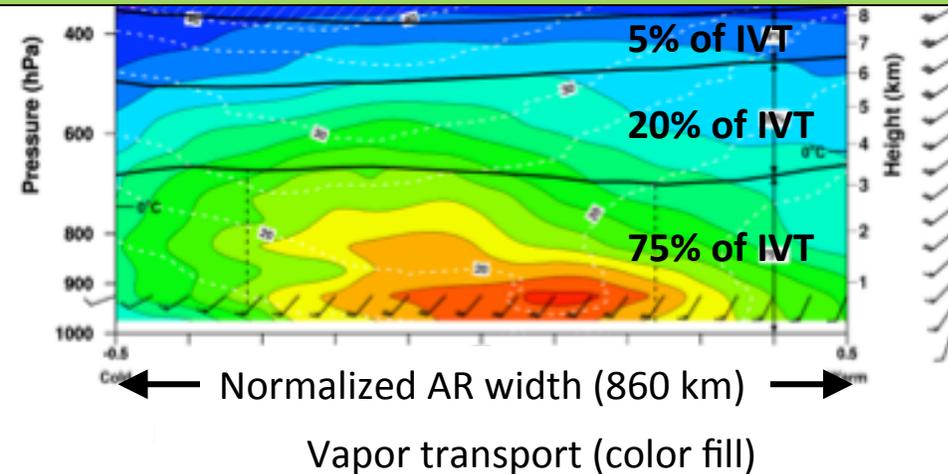
F.M. Ralph, S. Iacobellus, P.J. Neiman, J. Cordeira, J.R. Spackman, D. Waliser, G. Wick, A.B. White, C. Fairall
JHM 2017, in press

Composite AR Plan View (Color fill IWV; dashed lines IVT)



An average AR transports (as water vapor) the equivalent of

- 25 times the average discharge of the Mississippi River (as liquid), or
- 25 M acre feet/day



ATMOSPHERIC RIVER (Definition for Glossary of Meteorology; added May 2017)

- A long, narrow and transient corridor of strong horizontal water vapor transport that is typically associated with a low-level jet stream ahead of the cold front of an extratropical cyclone. The water vapor in atmospheric rivers is supplied by tropical and/or extratropical moisture sources. Atmospheric rivers frequently lead to heavy precipitation where they are forced upward, e.g., by mountains or by ascent in the warm-conveyor-belt. Horizontal water vapor transport in the mid-latitudes occurs primarily in atmospheric rivers and is focused in the lower troposphere.

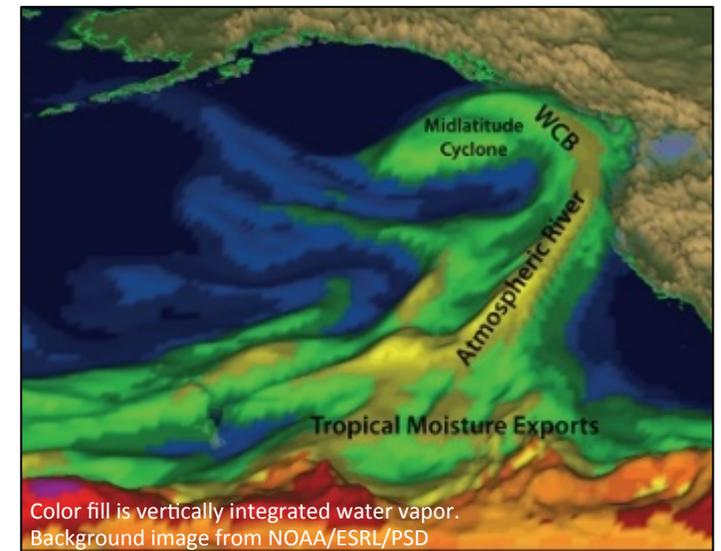
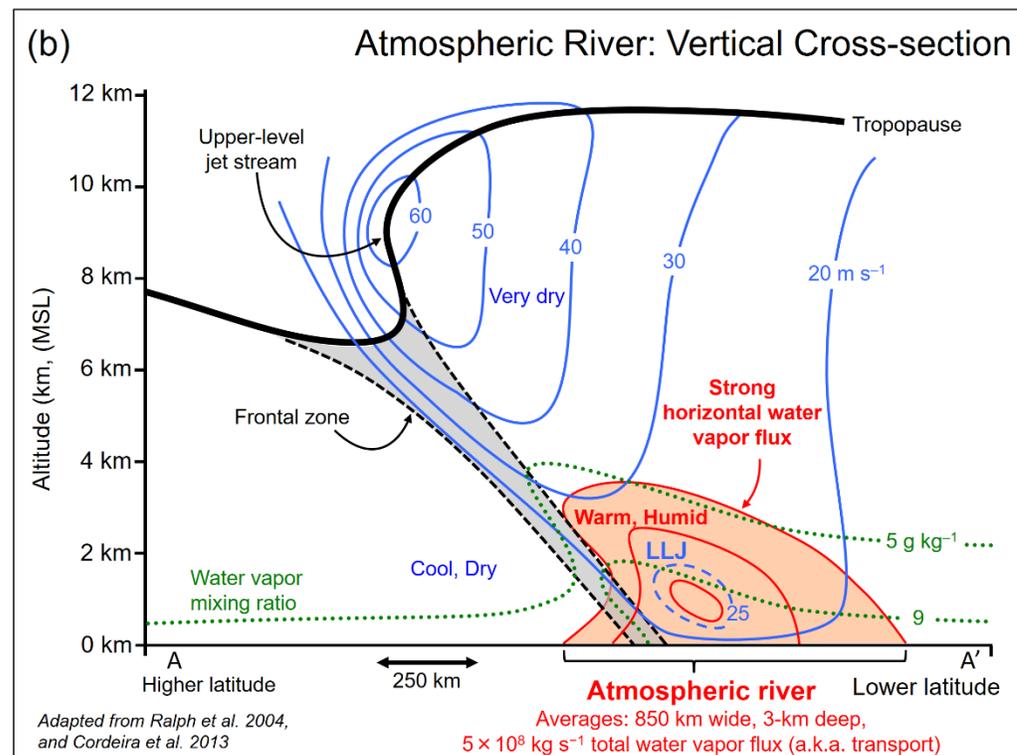
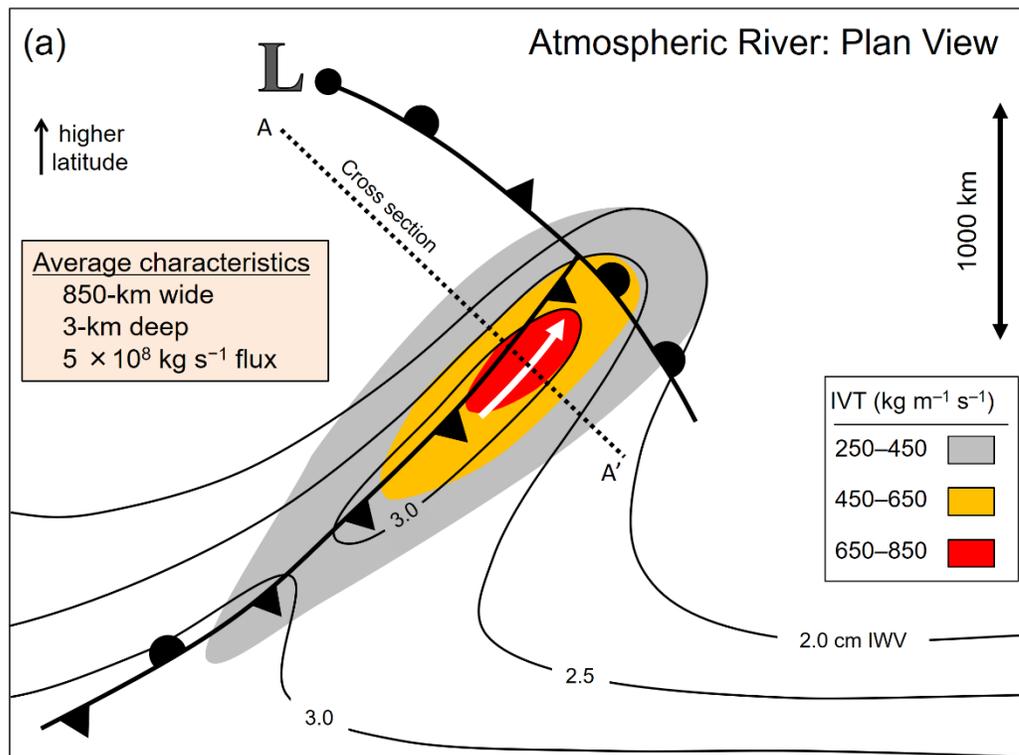


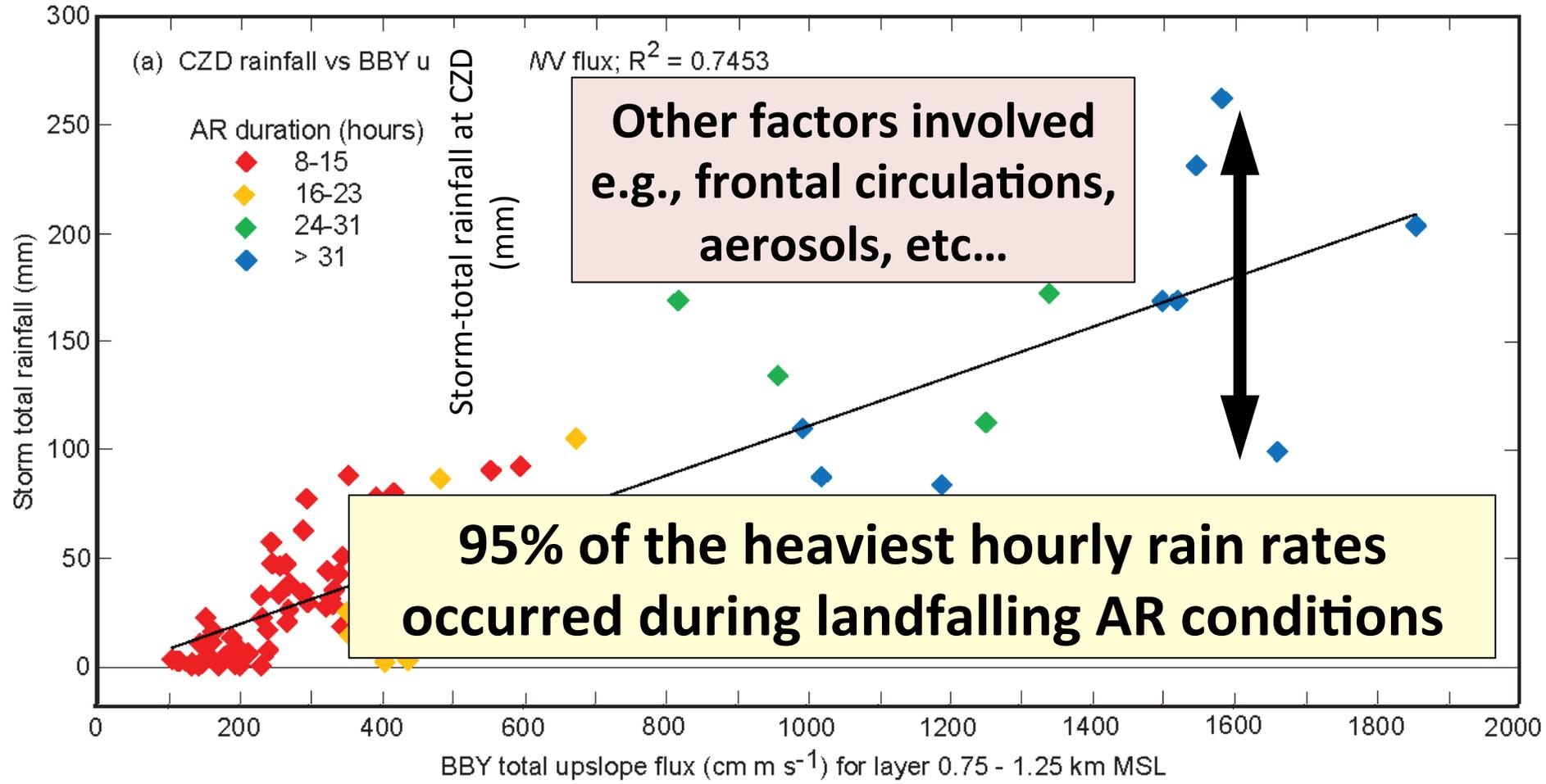
Fig. from Dettinger, Ralph, Lavers, EOS 2015



Figures from Ralph et al. 2017 (JHM; in press).

Observed impacts of duration and seasonality of atmospheric-river landfalls on soil moisture and runoff in coastal northern California

Ralph, F. M., T. Coleman, P.J. Neiman, R. Zamora, and M.D. Dettinger, *J. Hydrometeorology*, 2013



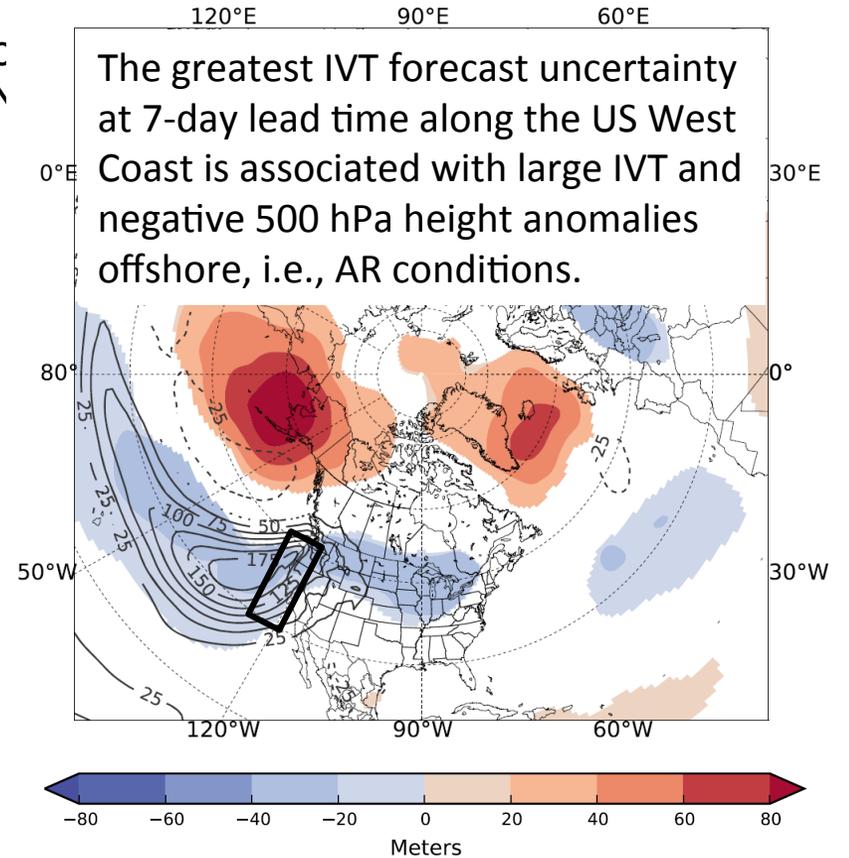
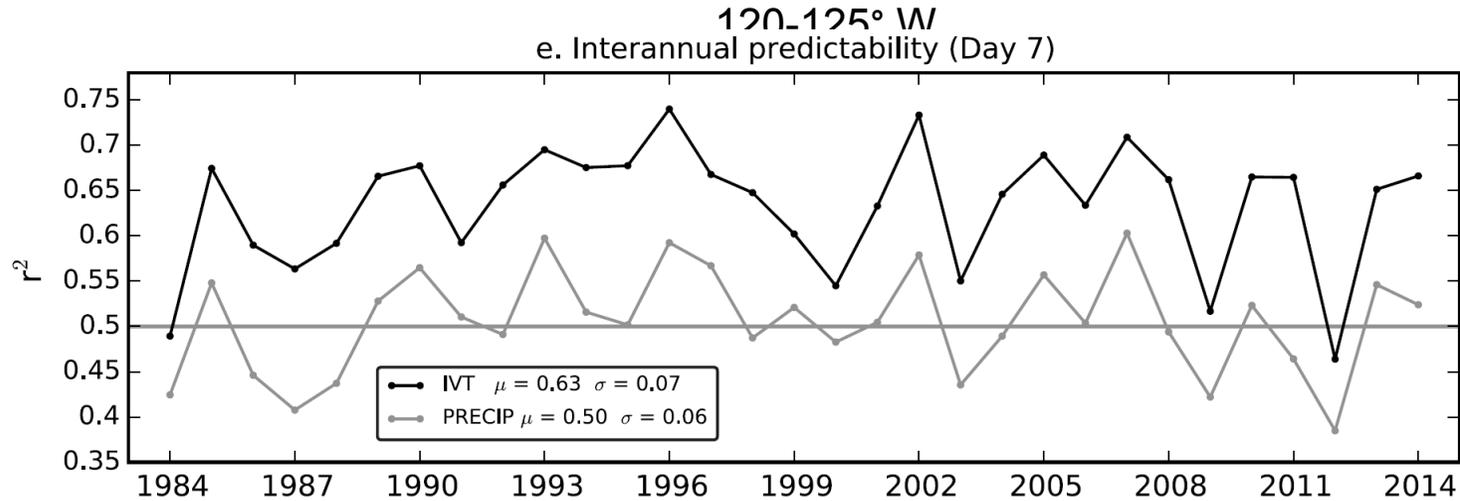
The greater the AR strength and duration

The greater the precipitation

Predictability of horizontal water vapor transport relative to precipitation: Enhancing situational awareness for forecasting western U.S. extreme precipitation and flooding

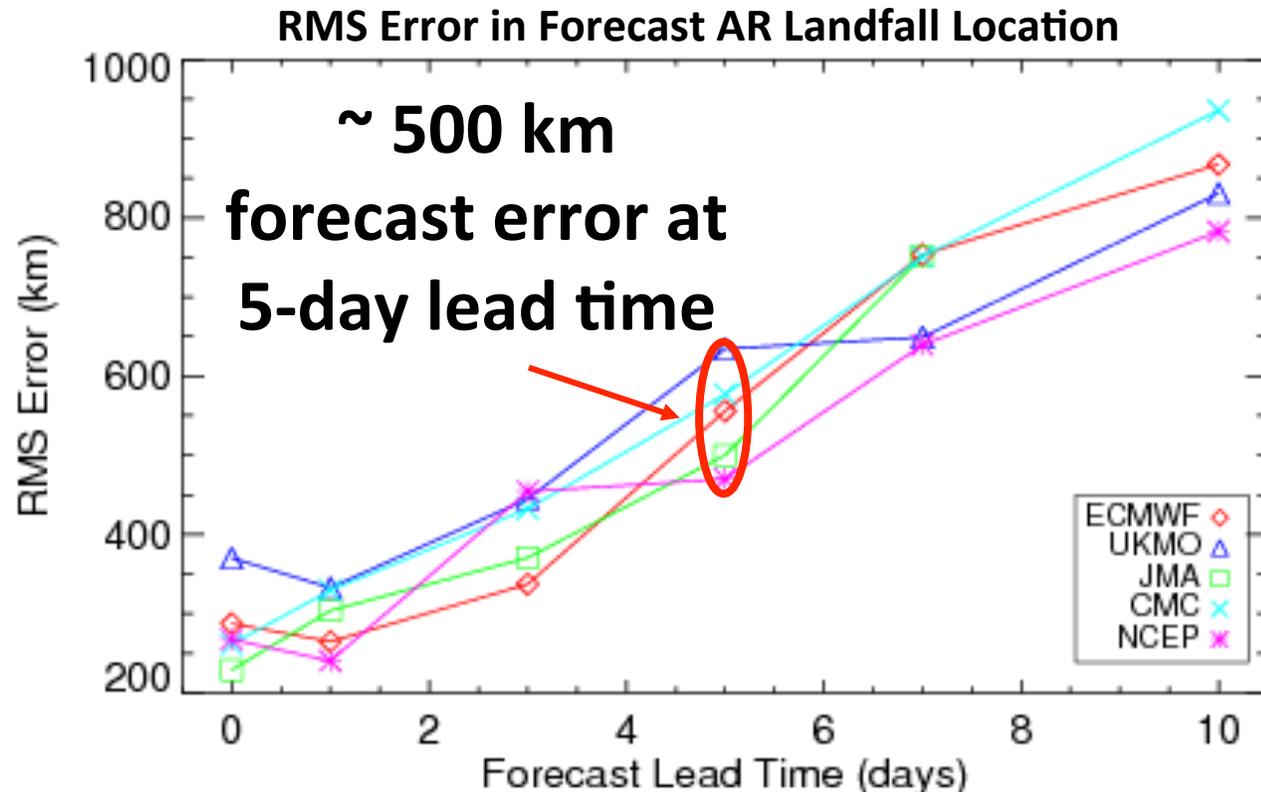
David A. Lavers, Duane E. Waliser, F. Martin Ralph, Michael D. Dettinger, *Geophys. Res. Lett.* 2016

Applying the potential predictability concept to NCEP global ensemble reforecasts, across 31 winters, IVT is found to be more predictable than precipitation in the region 30-50°N



AR Landfall Position Forecast Errors Quantified

While overall occurrence well forecast out to 10 days, landfall is less well predicted and the location is subject to significant errors, especially at longer lead times



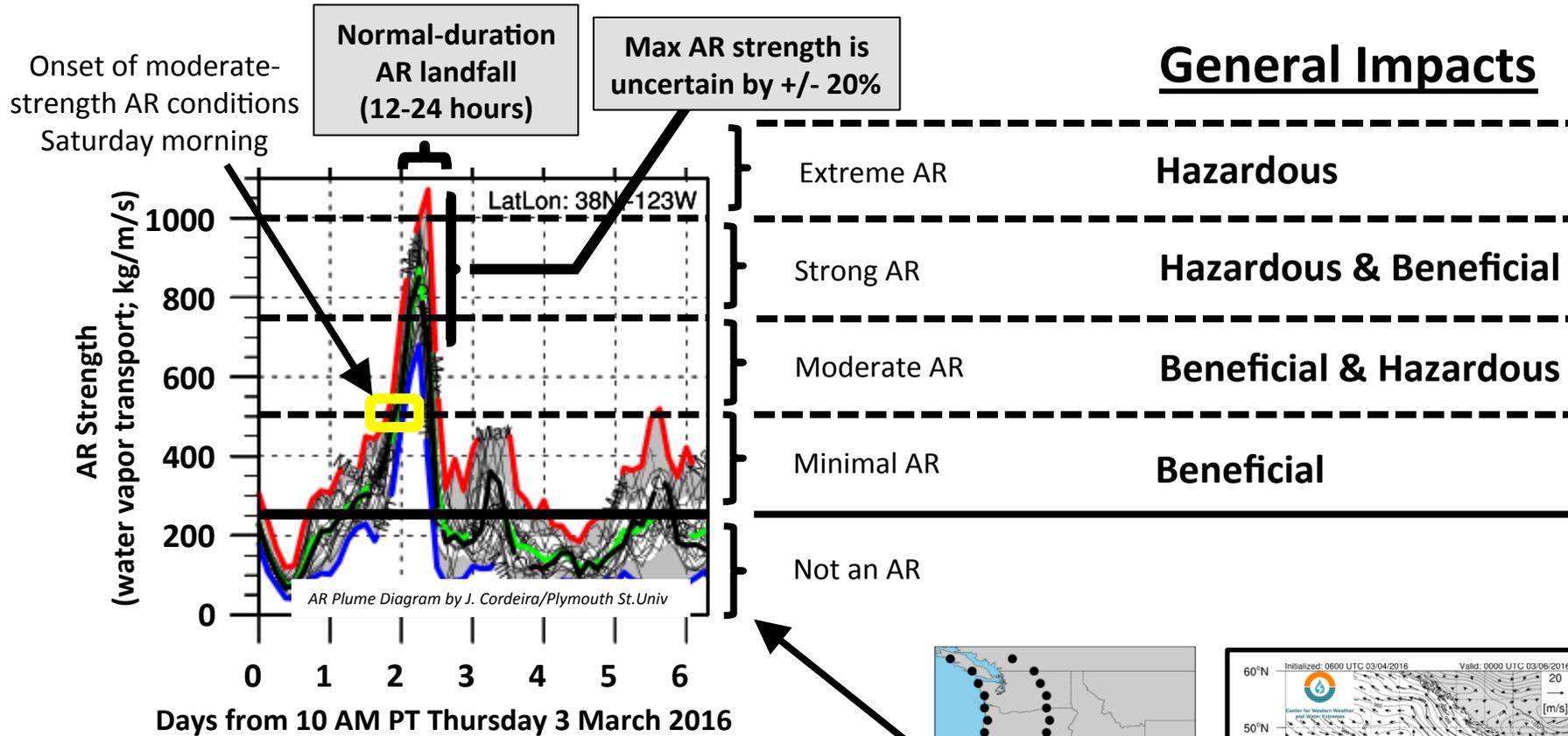
- Errors in location increase to over 800 km at 10-day lead
- Errors in 3-5 day forecasts comparable with current hurricane track errors
- Model resolution a key factor

From Wick et al., 2013 (Weather and Forecasting)

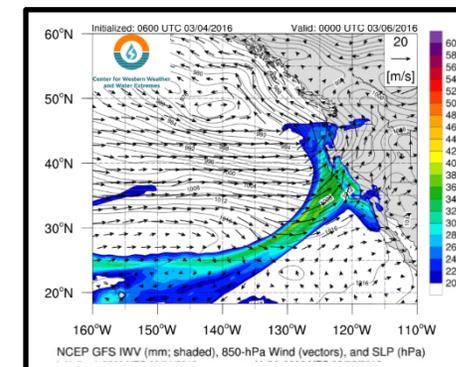
- Models provide useful heads-up for AR impact and IWV content, but location highly uncertain
- Location uncertainty highlights limitations in ability to predict extreme precipitation and flooding
- Improvements in predictions clearly desirable

A Scaling for Atmospheric River Intensity

Example is from a CW3E "AR Outlook" posted 4 March 2016 for Pt Reyes, CA area, including the Russian River



General Impacts



Center for Western Weather and Water Extremes

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AT UC SAN DIEGO

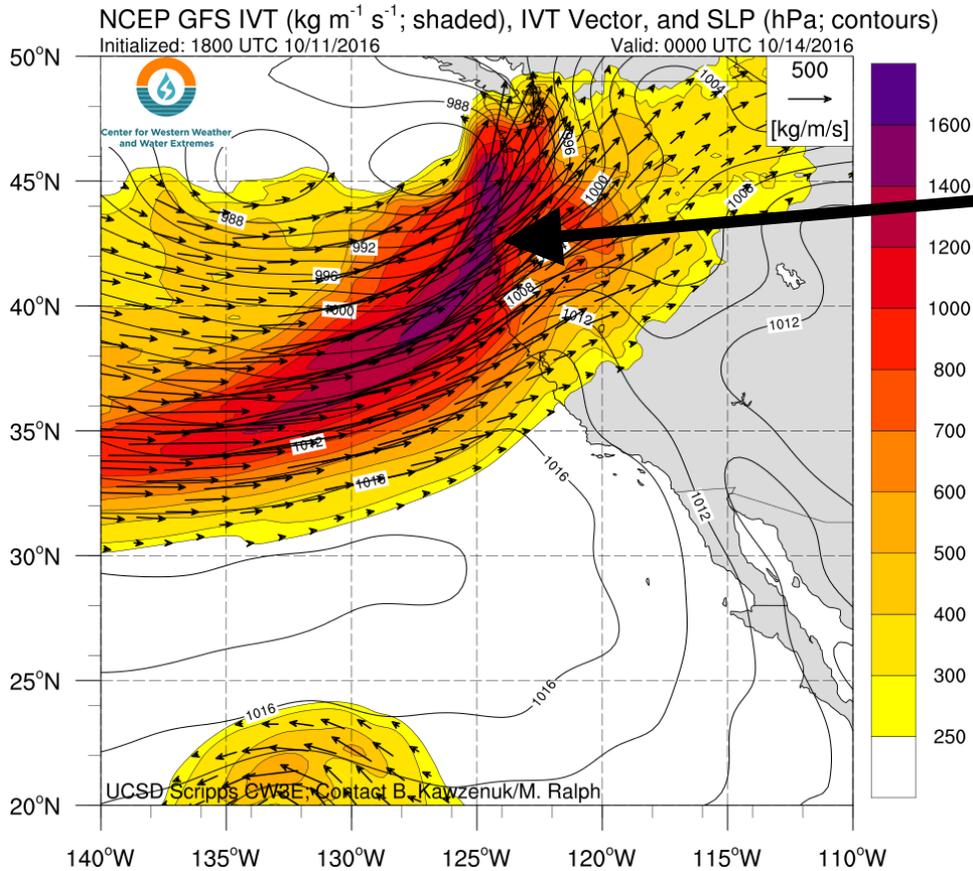
By F. Martin Ralph 2016

CW3E Atmospheric River Update – Outlook



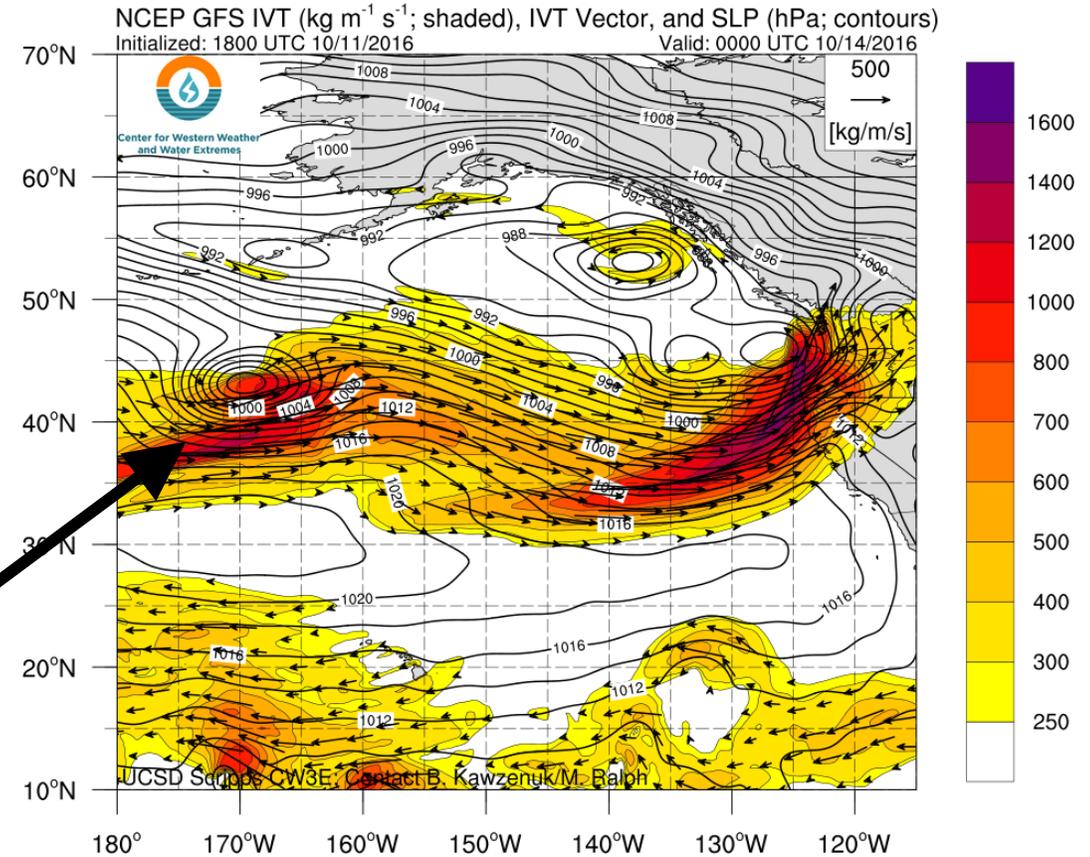
Center for Western Weather
and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY
AT UC SAN DIEGO

First strong landfalling Atmospheric River this water year to hit NW US, including N. CA



First AR has very strong water vapor transport at landfall on 13 Oct. High confidence.

Second AR is seen farther west. Likely to hit shore on 15 Oct. Moderate confidence.



For California DWR's AR Program

Summary by F.M. Ralph 11 PM PT Tue 11 Oct 2016

AR Update: 4 April 2017

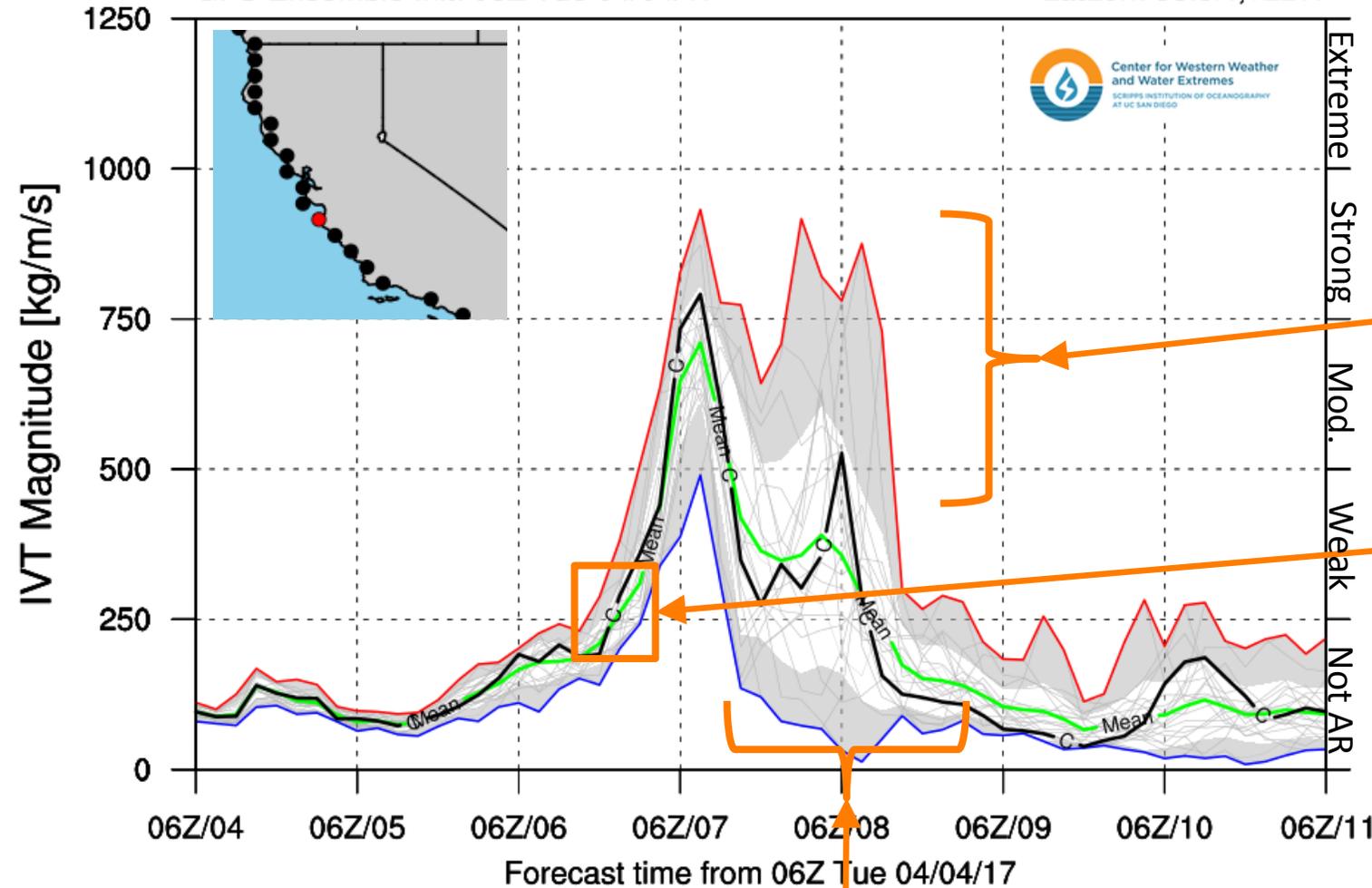
For California DWR's AR Program



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AT UC SAN DIEGO

GFS Ensemble Init: 06Z Tue 04/04/17

LatLon: 36.5N;122W



Monterey, CA could experience strong AR conditions $IVT > 750 \text{ kg m}^{-1} \text{ s}^{-1}$

Magnitude of AR over Monterey

- Maximum possible IVT $\sim 900 \text{ kg m}^{-1} \text{ s}^{-1}$
- Mean IVT $\sim 800 \text{ kg m}^{-1} \text{ s}^{-1}$
- Uncertainty $\sim \pm 12\%$

High Confidence in onset of AR conditions:

- 1 PM PT Thursday 06 April $\pm 4 \text{ h}$

Duration of AR conditions

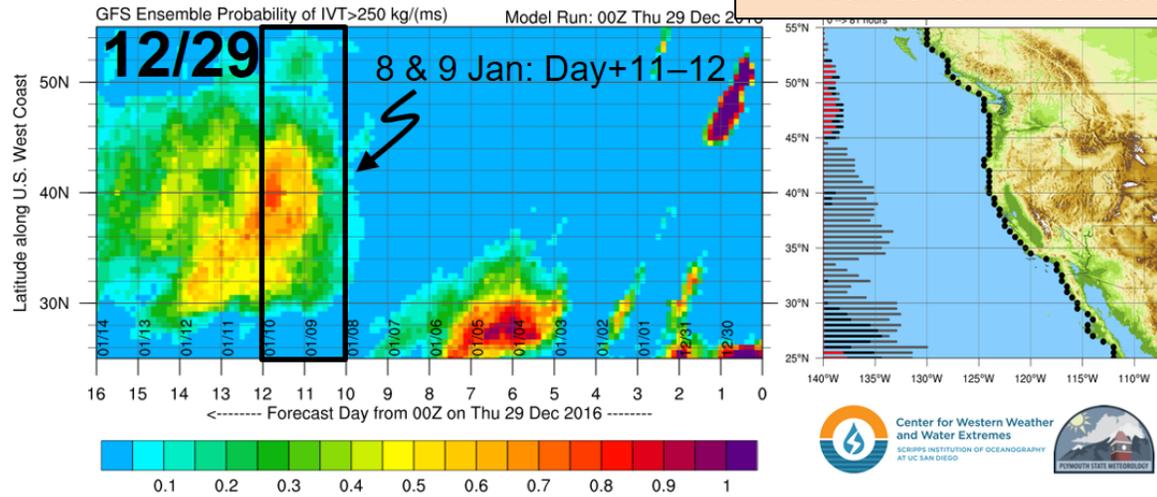
- Weak: $\sim 36 \text{ hours} \pm 20 \text{ h}$
- Moderate: $\sim 10 \text{ hours} \pm 20 \text{ h}$
- Strong $\sim 3 \text{ hours} \pm 3 \text{ h}$

There is more uncertainty in IVT magnitude associated with the development of the mesoscale frontal wave, which creates large uncertainty in the duration of AR conditions over Monterey

Time (right-to-left)–Latitude

Take-Away:

- AR Landfall Tool gave heads up probability of at least weak landfalling AR 11–12 days in advance
- Run-to-run inconsistencies limited confidence in location/duration until 4–5 days in advance



NCEP GEFS dProg/dt Example from January 2017

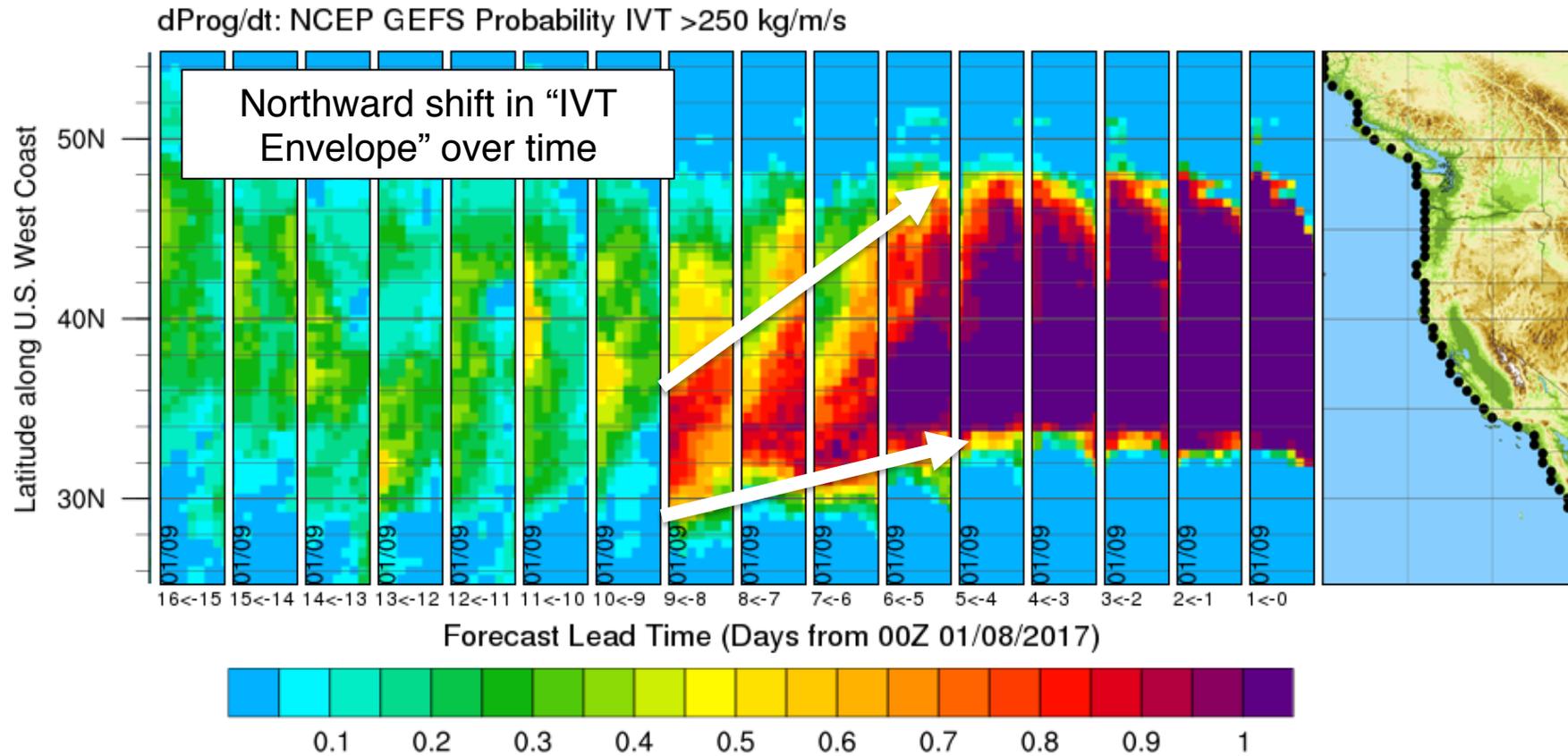


Image Description: Shading represents the NCEP GEFS probability that IVT will exceed $250 \text{ kg m}^{-1} \text{ s}^{-1}$ at 0.5-degree grid locations along the U.S. West Coast (dots). Each panel represents a 24-h forecast that verifies during the 24-h period starting at the time listed above the color bar. The lead time of that forecast period increases from right-to-left. For example, the left-most panel is a 15-to-16-day forecast whereas the right-most panel is the 0-to-1-day forecast.

Distribution of Landfalling Atmospheric Rivers on the U.S. West Coast (From 1 Oct 2016 to 1 May 2017)

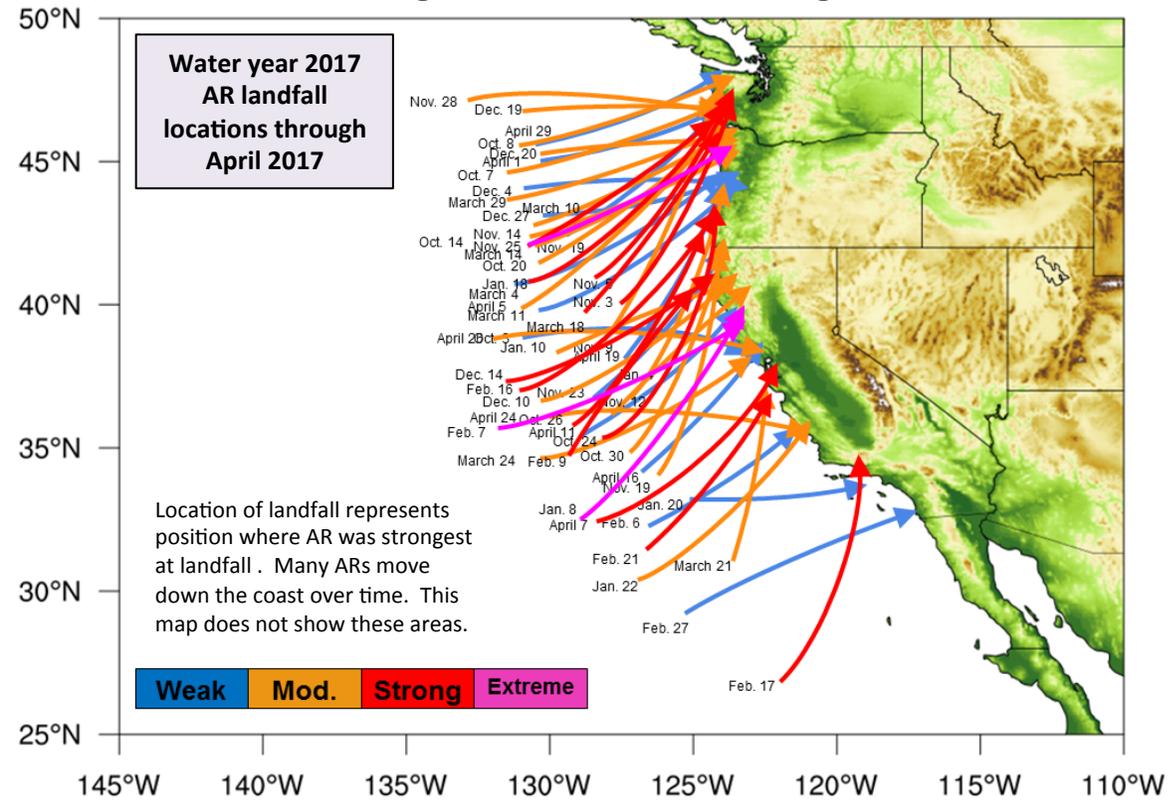
AR Strength	AR Count*
Weak	15
Moderate	23
Strong	13
Extreme	3

Ralph/CW3E AR Strength Scale

- Weak: $IVT=250-500 \text{ kg m}^{-1} \text{ s}^{-1}$
- Moderate: $IVT=500-750 \text{ kg m}^{-1} \text{ s}^{-1}$
- Strong: $IVT=750-1000 \text{ kg m}^{-1} \text{ s}^{-1}$
- Extreme: $IVT>1000 \text{ kg m}^{-1} \text{ s}^{-1}$

*Radiosondes at Bodega Bay, CA indicated the 10–11 Jan AR was strong (noted as moderate based on GFS analysis data) and 7–8 Feb AR was extreme (noted as strong)

- 54 Atmospheric Rivers have made landfall on the West Coast thus far during the 2017 water year (1 Oct. – 12 April 2017)
- This is much greater than normal
- 1/3 of the landfalling ARs have been “strong” or “extreme”



New Post-Doc Positions Open at CW3E

- Synoptic and Mesoscale Dimensions of Atmospheric Rivers
- Aerosol Science and Incorporation Into West-WRF Model
- Hydrology and Decision Support System Development
- Weather, Climate and Crustal Deformation Dimensions of California Precipitation

- Preferred starting dates: 1 Sept – 1 Dec 2017
- Points of Contact:
 - Marty Ralph – CW3E Director (mralth@ucsd.edu)
 - Julie Kalansky – CW3E Operations manager (jkalansky@ucsd.edu)



AR Forecast Tools

Extreme Event Summaries

Lake Mendocino FIRO summary information

Are available at

CW3E.UCSD.EDU

Contact: mralth@ucsd.edu



The mission of CW3E is to provide 21st Century water cycle science, technology and outreach to support effective policies and practices that address the impacts of extreme weather and water events on the environment, people and the economy of Western North America.



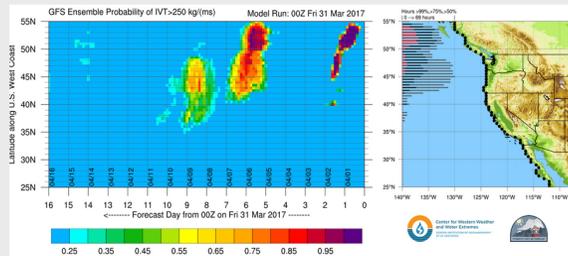
AR Observations

Precipitation Observations

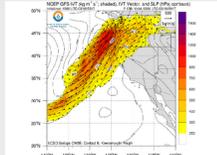
Model Forecasts

West-WRF Forecasts

Atmospheric River Forecasts

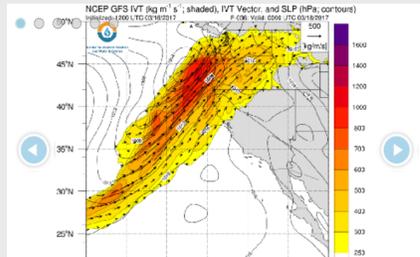


Latest News



CW3E AR Update: 16 March Outlook

CW3E News



CW3E AR Update: 16 March 2017 Outlook

- Mar. 16: [CW3E AR Update: 16 March 2017 Outlook](#)
- Mar. 9: [Weather on Steroids: The Art of Climate Change Science](#)
- Mar. 8: [CW3E Launches New Website](#)
- Mar. 8: [Odds of Reaching 100% Water Year Precipitation – Mar Update](#)
- Mar. 7: [Director of CW3E to Present at Birch Aquarium](#)
- Mar. 7: [Current Winter Setting a New California-Wide Record Precipitation Accumulation](#)

"Atmospheric River" drink created for season at Harrah's and Harveys

Submitted by paula on Wed, 02/22/2017 - 1:55pm



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Rivers have flooded, the lake is filling and snow is covering the slopes because of the several atmospheric rivers to hit Lake Tahoe this winter. To celebrate the epic season, the Beverage Department team at Harrah's and Harveys Lake Tahoe concocted a cocktail to honor and celebrate the winter.

The "Atmospheric River" drink "blends the frosty peaks of the Sierra Nevada with the stunning shades of blue found only at Lake Tahoe," said John Packer of Harrah's and Harveys Lake Tahoe.

Named for the climatic condition that has held sway in northern California and Nevada for the past few months, the "Atmospheric River" combines fruit juices, vodka, cognac and other ingredients to produce one of the most refreshing adult beverages of the season.

The festive cocktail is available exclusively at the two California Bars, located on the main floor of both casinos in Stateline, Nevada.

Their master mixologists combine Grey Goose Vodka, Hpnotiq Liqueur, Cointreau, Curacao, Sweet and Sour with Seven-Up, blend it with ice and serve it up in a chilled, sugar-rimmed martini glass.

It's a "drought-busting libation."



Tweets

Tweets & replies

Media



South Tahoe Now @SouthTahoeNow · 10m
Atmospheric River cocktail created @HarrahsTahoe and @harveystahoe to celebrate extra wet & snowy season #LakeTahoe southtahoenow.com/story/02/22/20...



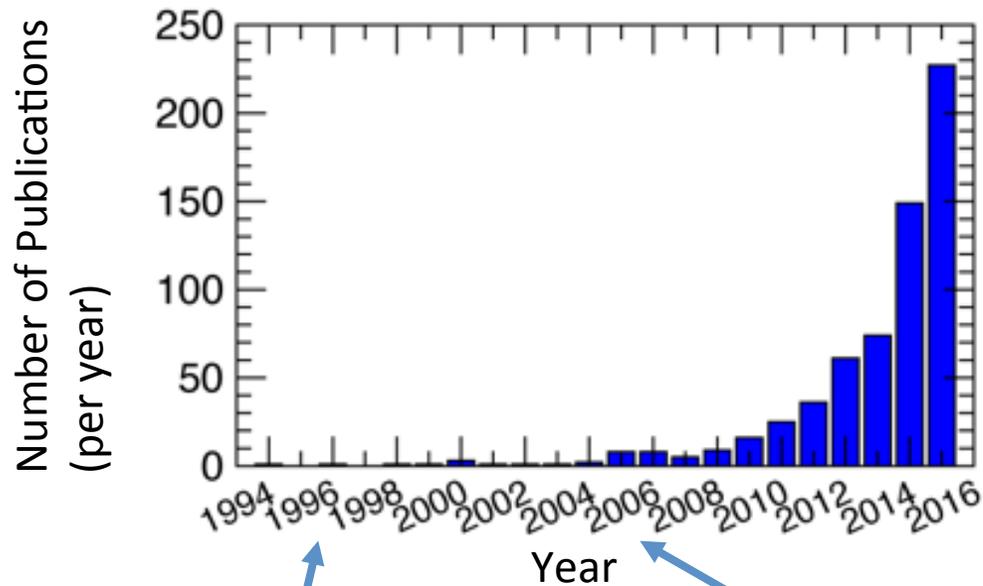
1 oz Grey Goose Vodka + 1 oz Hpnotiq Liqueur + 1 oz Cointreau, top off with Sweet and Sour with 7-Up; blend with ice and serve in sugar-rimmed, chilled martini glass.

Atmospheric Rivers Emerge as a Global Science and Applications Focus

Summary of the 1st International Atmospheric Rivers Conference in 2016

F. M. Ralph, M. Dettinger, D. Lavers, I. V. Gorodetskaya, A. Martin, M. Viale, A. B. White, N. Oaklev, J. Rutz, J. R. Spang, M. Wernli, and M. A. Cordeira, et al.

a) Scientific literature discussing ARs



Term "atmospheric river" coined in mid '90s.
Key paper by Zhu and Newell (1998).

First study to combine aircraft and satellite data
Also identified role in western water (Ralph et al. 2004).

Led to numerous studies and
results for Western U.S. and globe