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


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.

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

95% of the heaviest hourly rain rates occurred during landfalling AR conditions

The greater the AR strength and duration

Other factors involved e.g., frontal circulations, aerosols, etc...
Predictability of horizontal water vapor transport relative to precipitation: Enhancing situational awareness for forecasting western U.S. extreme precipitation and flooding


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, 120-125°W.

The greatest IVT forecast uncertainty at 7-day lead time along the US West Coast is associated with large IVT and negative 500 hPa height anomalies offshore, i.e., AR conditions.

Composite mean of the 500 hPa geopotential height anomalies at the analysis time (shading, in meters) and of the ensemble mean IVT forecast anomalies (contours, dashed where less than climatology) during the 140 largest ensemble spreads on forecast day 7. Colored and contoured regions indicate areas where the composite mean is different from zero at the 90% significance level.
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

RMS Error in Forecast AR Landfall Location

~ 500 km forecast error at 5-day lead time

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

Onset of moderate-strength AR conditions Saturday morning

Normal-duration AR landfall (12-24 hours)

Max AR strength is uncertain by +/- 20%

General Impacts

- Extreme AR: Hazardous
- Strong AR: Hazardous & Beneficial
- Moderate AR: Beneficial & Hazardous
- Minimal AR: Beneficial
- Not an AR

A Scaling for Atmospheric River Intensity

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

By F. Martin Ralph 2016
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
Monterey, CA could experience strong AR conditions IVT> 750 kg m\(^{-1}\) s\(^{-1}\)

**Magnitude of AR over Monterey**
- Maximum possible IVT \(\sim 900\) kg m\(^{-1}\) s\(^{-1}\)
- Mean IVT \(\sim 800\) kg m\(^{-1}\) s\(^{-1}\)
- Uncertainty \(\sim +/- 12\%\)

**High Confidence in onset of AR conditions:**
- 1 PM PT Thursday 06 April +/- 4 h

**Duration of AR conditions**
- Weak: \(\sim 36\) hours +/- 20 h
- Moderate: \(\sim 10\) hours +/- 20 h
- Strong: \(\sim 3\) hours +/- 3 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
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
Image Description: Shading represents the NCEP GEFS probability that IVT will exceed 250 kg m\(^{-1}\) 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)

<table>
<thead>
<tr>
<th>AR Strength</th>
<th>AR Count*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak</td>
<td>15</td>
</tr>
<tr>
<td>Moderate</td>
<td>23</td>
</tr>
<tr>
<td>Strong</td>
<td>13</td>
</tr>
<tr>
<td>Extreme</td>
<td>3</td>
</tr>
</tbody>
</table>

- 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”

Ralph/CW3E AR Strength Scale:
- Weak: IVT=250–500 kg m\(^{-1}\) s\(^{-1}\)
- Moderate: IVT=500–750 kg m\(^{-1}\) s\(^{-1}\)
- Strong: IVT=750–1000 kg m\(^{-1}\) s\(^{-1}\)
- Extreme: IVT>1000 kg m\(^{-1}\) s\(^{-1}\)

*Radio sondes 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)

By F.M. Ralph, B. Kawzenuk, C. Hecht, J. Kalansky
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 (mralph@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: mralph@ucsd.edu
"Atomspheric River" drink created for season at Harrah's and Harveys

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

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 "Atomspheric 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 "Atomspheric 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."
Atmospheric Rivers Emerge as a Global Science and Applications Focus
Summary of the 1st International Atmospheric Rivers Conference in 2016


a) Scientific literature discussing ARs


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