Atmospheric Rivers have been shown to produce on average 25-50% of annual precipitation in key areas of the Western United States. They are responsible for most of the extreme precipitation and flooding events in California, and produce much of the snowpack and water supply.
About CW3E

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

Forecast-Informed Reservoir Operations

Tools for California Water Extremes

“West-WRF” Weather Model

Climate Science

Subseasonal-to-Seasonal Outlooks

Marty Ralph, PhD
CW3E Director
Atmospheric Rivers (ARs)

WHAT IS AN ATMOSPHERIC RIVER?
AR Climatology

Source: Ralph et al., *Atmospheric Rivers*, 2020; Updated from Guan and Waliser 2015)
While the West Coast gets most of its precipitation from ARs, the relative frequency of AR precipitation is higher in the Southwest.
AR Climatology

Fig. 6. Month of maximum AR frequency based on IVT$_{250}$. Histograms of IVT$_{250}$ AR frequency by month at selected (left) coastal and (right) interior locations.

Source: Rutz et al. 2014

Mean Daily IVT Upper Salt Basin (ERA5, 1959-2023)

90th Percentile
Notable Events (Max IVT)

Credit: P. Iñiguez, UCSD/SIO/CW3E
Significant AZ ARs - 22 Jan 2010 (#3)

Source: Neiman et al. 2013
Significant AZ ARs - 15 Feb 2019 (#1)

[Graph showing atmospheric conditions]

Integrated Vapor Transport (kg/ms; shaded according to scale) with IVT vectors according to reference vector. Imagery supports FIFC and California AR Programs at CW3E. For use please cite CW3E. Data source: ECMWF ERA5
Significant AZ ARs - 24 Dec 2021 (#5)

Max IVT: 952 kg ms^{-1} from 210 deg | Event duration: 49h | Event Start: 22Z 12/20/2021 | Event End: 18Z 12/24/2021

Integrated Vapor Transport (kg/ms; shaded according to scale) with IVT vectors according to reference vector.

Imagery supports FIPRC and California AR Programs at CW3E. For use please cite CW3E. Data source: ECMWF ERA5

UC San Diego | Scripps Institution of Oceanography
WY2023 Landfalling ARs

<table>
<thead>
<tr>
<th>AR Strength</th>
<th>AR Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak</td>
<td>12</td>
</tr>
<tr>
<td>Moderate</td>
<td>22</td>
</tr>
<tr>
<td>Strong</td>
<td>9</td>
</tr>
<tr>
<td>Extreme</td>
<td>2</td>
</tr>
<tr>
<td>Exceptional</td>
<td>1</td>
</tr>
</tbody>
</table>

46 atmospheric rivers made landfall over the U.S. West Coast during Water Year 2023

**Regions Impacted by Each AR**

<table>
<thead>
<tr>
<th>State/Region</th>
<th>AR Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washington</td>
<td>34</td>
</tr>
<tr>
<td>Oregon</td>
<td>37</td>
</tr>
<tr>
<td>Northern CA</td>
<td>32</td>
</tr>
<tr>
<td>Central CA</td>
<td>21</td>
</tr>
<tr>
<td>Southern CA</td>
<td>17</td>
</tr>
</tbody>
</table>
Tools to Forecast ARs

Atmospheric River Forecast Products

The products are provided "as is" and are intended for research purposes only (disclaimer).

This page contains graphics designed to forecast the presence and strength of Atmospheric Rivers using data from the NCEP Global Forecast System (GFS), North American Mesoscale Forecast System (NAM), Global Ensemble Forecast System (GEFS ~ v12) and the European Centre for Medium-Range Weather Forecasts (ECMWF) models. The Ensemble based products are produced by Dr. Jason Cordeira at Plymouth State University as a cooperative effort with CW3E. For more information on ARs visit the AR FAQs or watch this informational video about ARs.


Deterministic Model Forecasts

IWV, IVT, and Time-Integrated IVT Click on an image to see forecasts out to 180 hours from the GFS, ECMWF, and NAM.

IWV

IVT
Tools to Forecast ARs

NCEP GFS IVT (kg m$^{-1}$ s$^{-1}$; shaded), IVT Vector, and SLP (hPa; contours)
Initialized: 1200 UTC 11/19/2023
Valid: 0000 UTC 11/19/2023

ECMWF, GEFS, & West-WRF Ensemble Member IVT Forecast (kg m$^{-1}$ s$^{-1}$)

Forecast Initialized at 00Z Wed 11/15/23
Tools to Forecast ARs

Model Run: 06Z Tue 14 Nov 2023

---------- Forecast Day from 06Z on Tue 14 Nov 2023 -------

Probability of IVT $\geq$ 150 kg m$^{-1}$ s$^{-1}$

Forecasts support FIRO/CA-AR Program and NSF #2052972 | Intended for research purposes only
Tools to Forecast ARs

West-WRF High-Resolution Model & 200 Member Ensemble
ATMOSPHERIC RIVER RECONNAISSANCE
Filling Gaps in Pacific Weather Observations

Winter 2023-2024
Mather, CA
Honolulu, HI
Guam
Atmosphere-ocean feedbacks during El Niño-Southern Oscillation

Neutral

Australia

equator

South America

warmer

colder

thermocline

NOAA Climate.gov
ENSO Impacts

El Niño winters

- warmer
- drier
- wetter
- extended Pacific jet stream, amplified storm track

La Niña winters

- colder
- warmer
- wetter
- blocking high pressure
ENSO Impacts

How often have El Niño winters been drier than average vs. wetter than average?

How often have El Niño winters been cooler than average vs. warmer than average?
El Niño (La Niña) can increase (decrease) AR frequency across the N. Pacific but impact on precipitation across the Southwest is less robust. Other climate influences (MJO, PNA) must be considered.

Source: Huffman et al. 2001 (Updated from Guan and Waliser 2015)
CPC ENSO Forecast

Official NOAA CPC ENSO Probabilities (issued Nov. 2023)

Based on -0.5°C/+0.5°C thresholds in ERSSTv5 Niño-3.4 index

Percent Chance (%)

Season

La Niña
Neutral
El Niño

OND
NDJ
DJF
JFM
FMA
MAM
AMJ
MJJ
JJA
CPC Outlook

NOAA/CPC Seasonal Temperature Outlook - DJF 2023-2024

Probability of Each Climatological Category Occurring

Created: Nov 16, 2023
Credit: P. Miguez @ UCSD/SIO/CW3E
Data Source: NOAA

UC San Diego
Seasonal Temperature Outlooks for Phoenix, AZ

Created: Nov 16, 2023 | Credit: P. Irieguez @ UCSD/SIO/CW3E | Data Source: NOAA
Atmospheric Rivers have been shown to produce on average 25-50% of annual precipitation in key areas of the Western United States. They are responsible for most of the extreme precipitation and flooding events in California, and produce much of the snowpack and water supply.