Congressional Research Service
Informing the legislative debate since 1914

INSIGHT

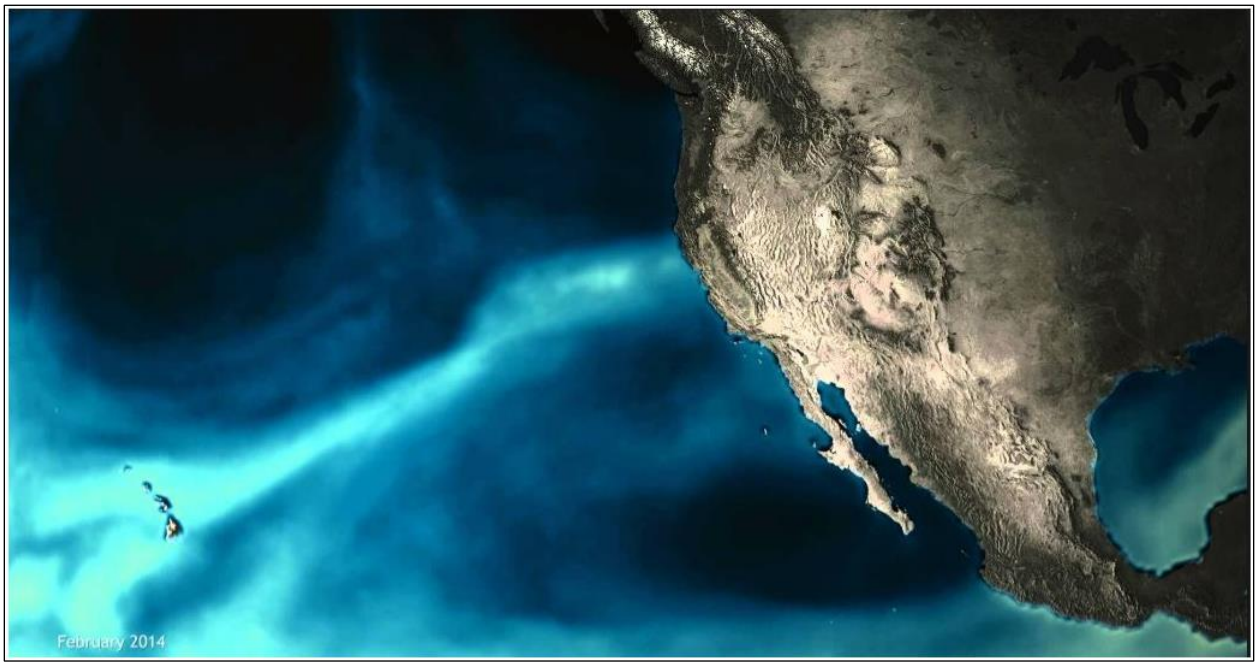
Atmospheric Rivers: Background and Forecasting

February 9, 2023

An *atmospheric river* (AR) consists of a long band of water vapor moving through the atmosphere, typically resulting in heavy precipitation over land (**Figure 1**). Improved AR observations and understanding (especially for large ARs) may facilitate flood preparedness and response and water supply management. This is especially true in some western snowpack-dominated watersheds. ARs significantly influence U.S. West Coast water conditions, producing on average 30%-50% of the region's annual precipitation, as illustrated by the December 2022-January 2023 series of ARs that affected the region, particularly California. ARs may have implications for other U.S. regions, as well. For instance, ARs from the Gulf of Mexico contributed to central U.S. flooding in 1983 and 2008 and southern U.S. flooding in 2016. Congress may influence AR research and the use of AR information through authorizations and appropriations for involved agencies, such as the National Oceanic and Atmospheric Administration (NOAA), which conducts and supports AR science, and the U.S. Army Corps of Engineers (USACE), which manages water resources and flood risks.

Congressional Research Service
https://crsreports.congress.gov
IN12094

Figure 1. Atmospheric River Extending From Hawaii to the U.S. West Coast, 2014

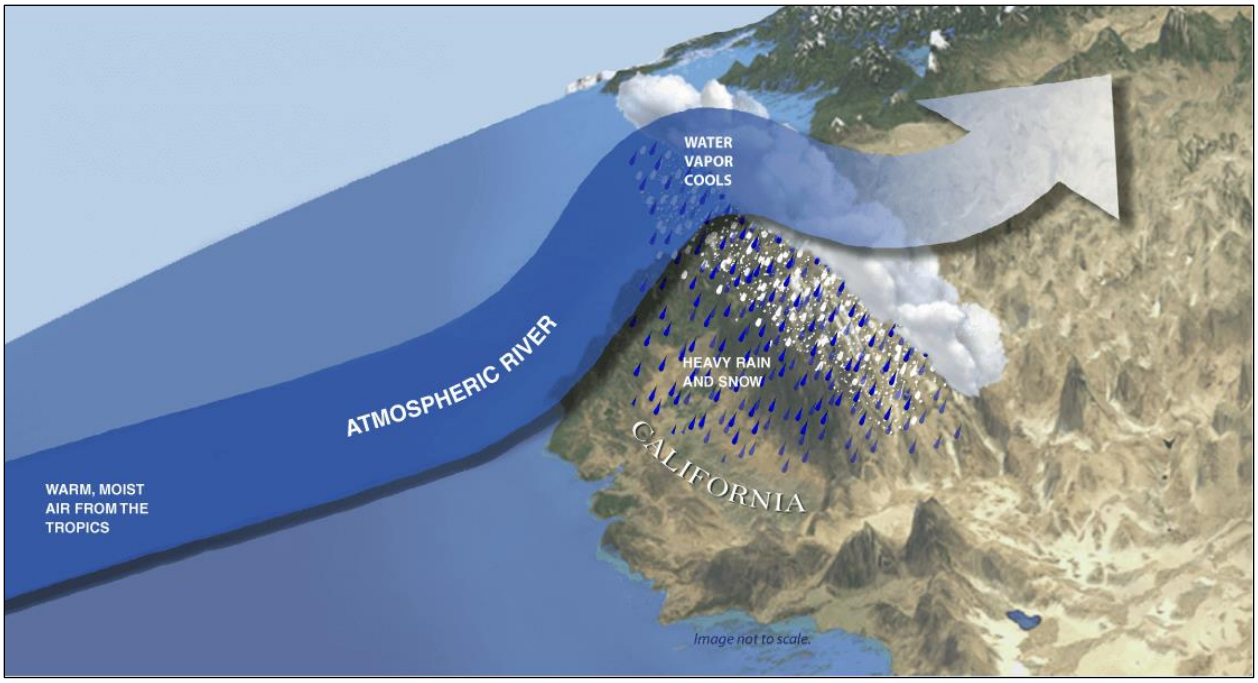


Source: NOAA, "Atmospheric Rivers."

Notes: The light blue area denotes a plume of water vapor. An AR originating in the tropics near Hawaii that brings water vapor to the U.S. West Coast is sometimes called a *Pineapple Express*.

ARs typically form in tropical regions when winds over the ocean draw water vapor into narrow bands. AR interactions with land features, such as mountain ranges (**Figure 2**), or certain atmospheric conditions cause the water vapor to move upward in the atmosphere and fall as heavy rain or snowfall. When ARs slow down over a particular area or occur in rapid succession, the resultant precipitation can lead to flooding, mudslides, landslides, and debris flows, especially in areas that have experienced wildfires in recent years. In some cases, ARs can help improve or "bust" drought conditions.

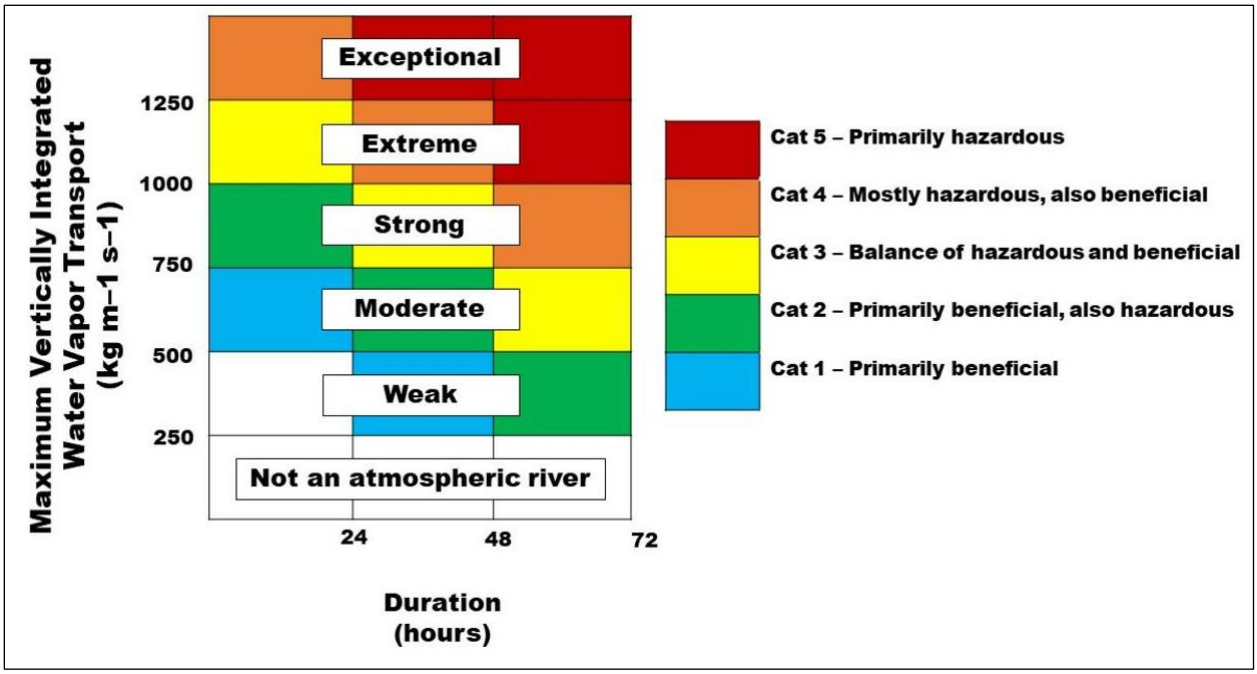
Figure 2. An Example of Atmospheric River Formation



Source: NOAA, "What Is an Atmospheric River?"

According to some estimates, multiple ARs are in motion around the Earth at any given time, with 90% of the planet's atmospheric water vapor concentrated in four to five ARs at a time. Scientists have begun categorizing ARs based on their maximum water vapor transported over a certain space and time (**Figure 3**; e.g., the U.S. West Coast December 2022-January 2023 ARs ranged from Cat 1 to Cat 4).

Figure 3. Atmospheric River Strength Categories



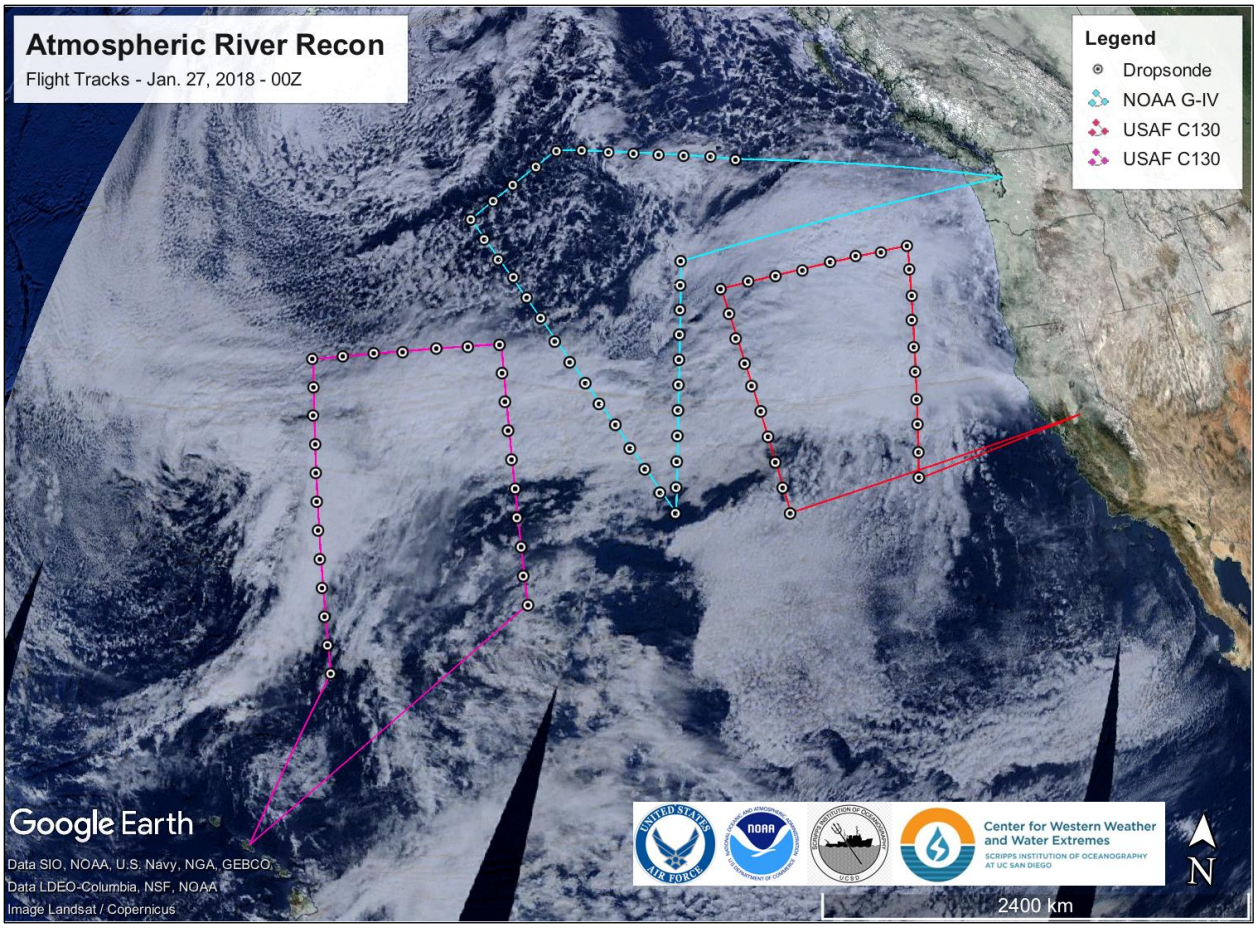
Source: USGS, "Rivers in the Sky: 6 Facts You Should Know About Atmospheric Rivers."

Notes: This rating scale, adapted from a 2019 article, uses 250 kg m-1 s-1 (i.e., 250 kilograms of water vapor per meter per second) intervals to categorize atmospheric rivers by their transport of water vapor, as well as duration as measured in hours.

Detection and Forecasting

NOAA, U.S. Geological Survey (USGS), and other scientists and partners employ a range of methods to observe and forecast ARs and their short- and longer-term impacts, including on snowpack, rivers and streams, and subsequent vegetation growth. Observations (e.g., wind, temperature, water vapor content) come from satellites, radar, and aircraft- or ocean-based missions (e.g., **Figure 4**). For example, scientists working on improving prediction of land-falling ARs in the western United States established an Atmospheric River Reconnaissance (AR Recon) partnership. AR Recon activities include coordinating and sharing western U.S. AR observations. Its participants are looking to expand AR Recon to the Gulf of Mexico and the North Atlantic. A limited number of land-based AR monitoring stations also have been deployed to collect data not well captured by other observing systems.

Figure 4. Tracks of Atmospheric River Reconnaissance Flights Deploying Dropsondes on January 27, 2018



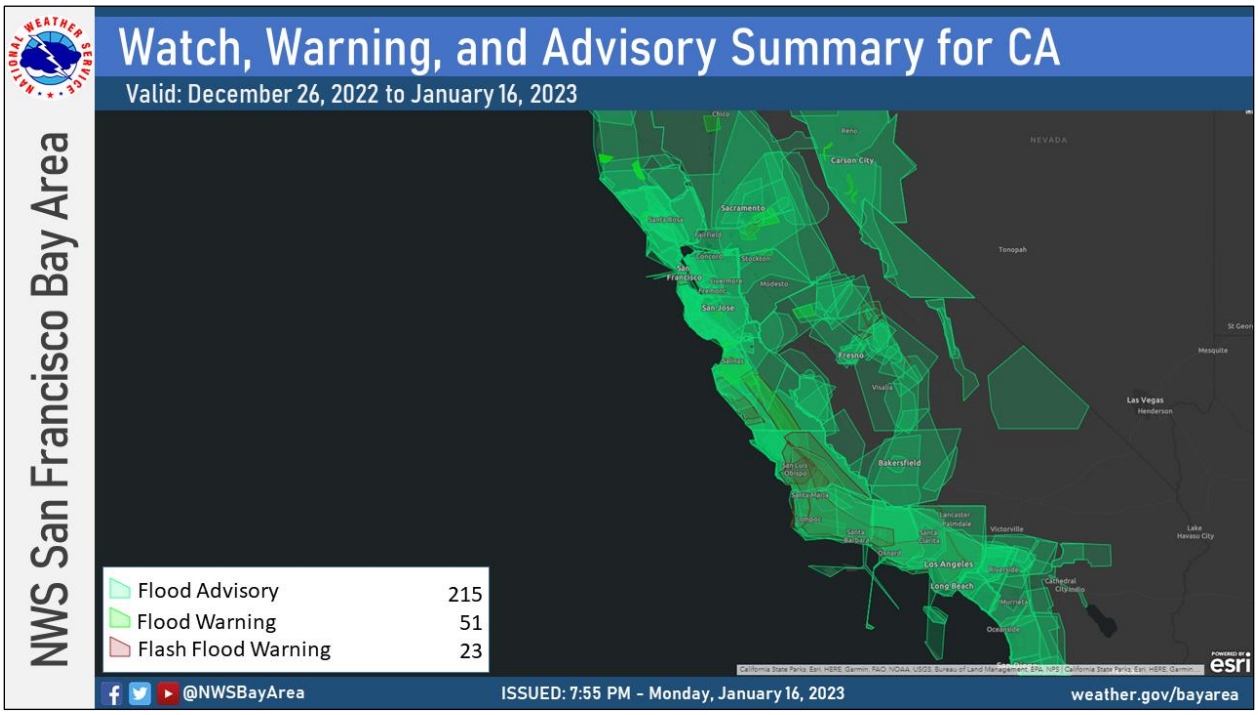
Source: Courtesy photo provided by U.S. Air Force, "Hurricane Hunters Complete Atmospheric River Reconnaissance."

Notes: *Dropsondes* are weather reconnaissance devices that measure conditions as the devices fall from an aircraft at altitude over water. For a summary of atmospheric river reconnaissance flights and dropsondes, see Center for Western Weather and Water Extremes, "Atmospheric River Reconnaissance."

NOAA and others use these observations in forecasting models. NOAA's National Weather Service uses the model outputs to issue outlooks and warnings for AR-related weather events, such as rain, snow, wind, high surf, flooding, thunderstorms, and tornadoes (e.g., **Figure 5**).

Figure 5. Flood Watch, Warning, and Advisory Summary for California

Due to Precipitation from December 26, 2022, to January 16, 2023, Atmospheric Rivers



Source: NOAA, National Weather Service, San Francisco Bay Area, CA, Weather Forecast Office, "A Parade of Storms Impact Bay Area."

Emergency managers and infrastructure operators also may use AR information. One example is using AR forecasts, along with other information, to inform when to release water from reservoirs—known as Forecast Informed Reservoir Operations (FIRO)—to reduce flood risk and enhance water supplies.

As understanding of ARs improves, scientists are exploring how ARs may change with a warming climate. Some research (as noted by the USGS and NOAA) suggests a warmer climate may alter West Coast ARs' frequency, intensity, and location. While globally ARs in a warming climate may be associated with more precipitation, the effects on precipitation may not be uniform along the U.S. West Coast. Potential changes to AR-related rain and snowfall may further encourage improved understanding and forecasting of ARs for watersheds that receive significant AR precipitation.

Additional Considerations

In recent years, Congress has supported AR-related activities through appropriations for the NOAA Office of Marine and Aviation Operations to observe and predict ARs (explanatory statement accompanying P.L. 117-103) and authorization for USACE to expand its FIRO efforts (P.L. 116-260, §157, Division AA), among other ways. Following the U.S. West Coast ARs in late December 2022 and early 2023, the 118th Congress may consider assessing federal efforts to advance the understanding and forecasting of ARs and their impacts, including on flood risk and water supplies.

Author Information

Eva Lipiec
Analyst in Natural Resources Policy

Nicole T. Carter
Specialist in Natural Resources Policy

Disclaimer