



Atmospheric Rivers: Background and Forecasting

Updated December 4, 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 snowpack-dominated watersheds. ARs significantly influence U.S. West Coast water conditions, producing on average 30%-50% of the region's [annual precipitation](#), and sometimes more. For example, from late December 2022 through mid-January 2023, ARs delivered about [half of California's average annual precipitation](#), and more ARs followed in the spring.

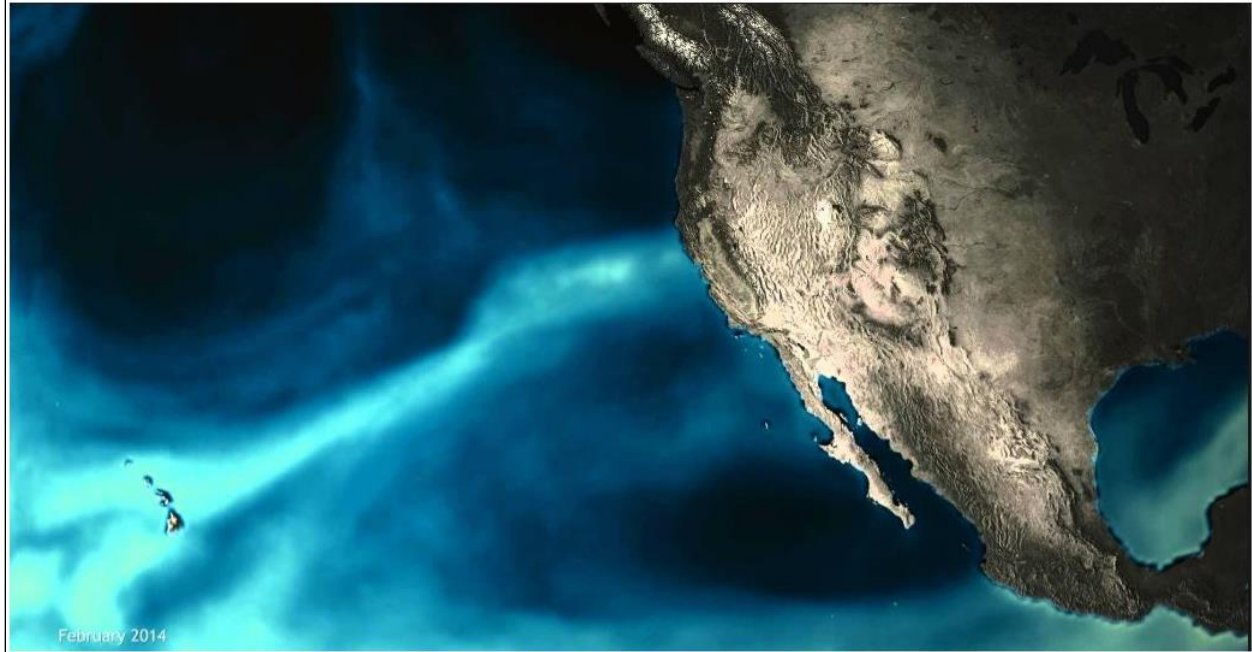
ARs may have implications for other U.S. regions, as well. For instance, ARs from the Gulf of Mexico contributed to central U.S. flooding in [1983 and 2008](#) and southern U.S. flooding in [2016](#). Congress may direct AR research and the use of AR information through authorizations and appropriations for agencies, such as the National Oceanic and Atmospheric Administration (NOAA) and U.S. Geological Survey (USGS), which conduct and support AR science, and the U.S. Army Corps of Engineers (USACE), which manages water resources and flood risks.

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IN12094

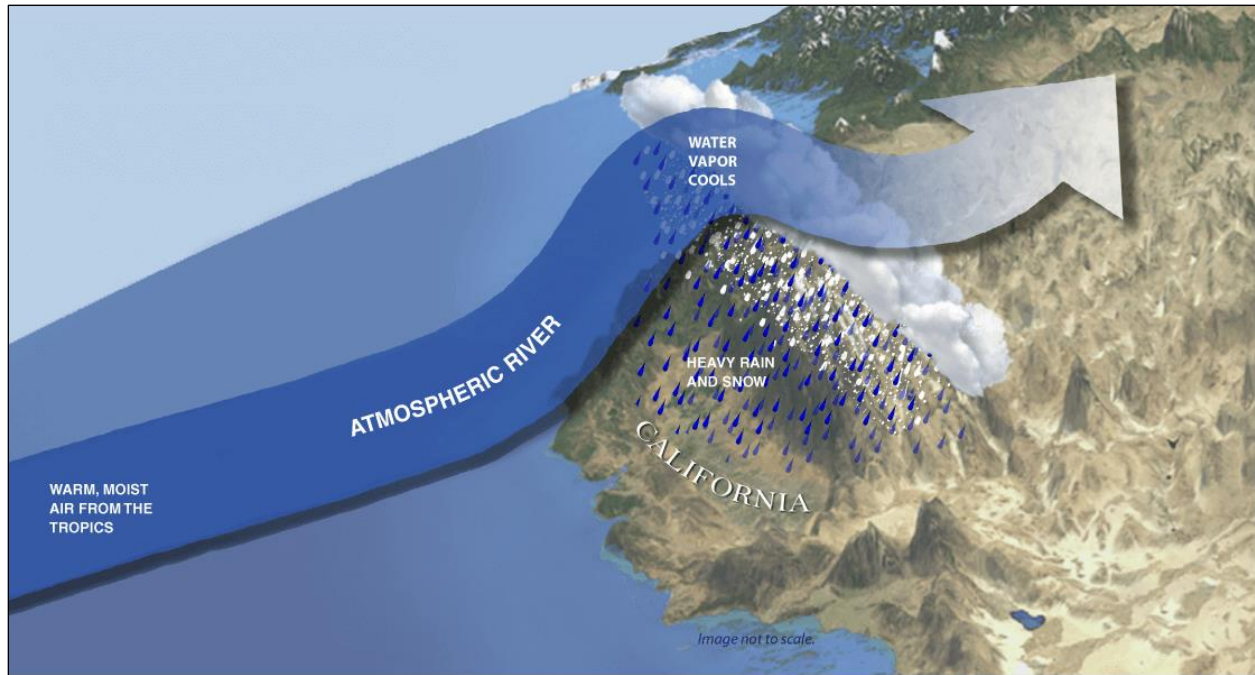
Figure 1. Atmospheric River Extending From Hawaii to the U.S. West Coast, 2014



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*.

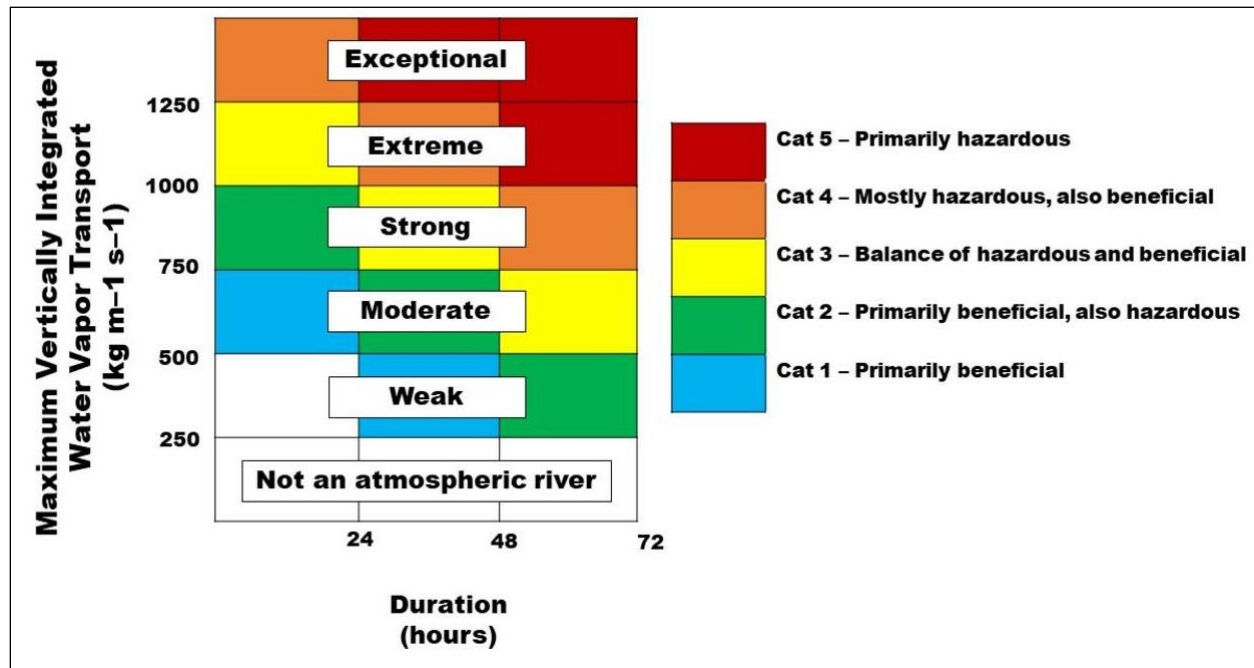
ARs typically form in tropical regions when winds over the ocean draw water vapor into narrow bands. AR interactions with land features, such as mountain ranges (**Figure 2**), or certain atmospheric conditions cause the water vapor to move upward in the atmosphere and then fall as heavy rain or snowfall. 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



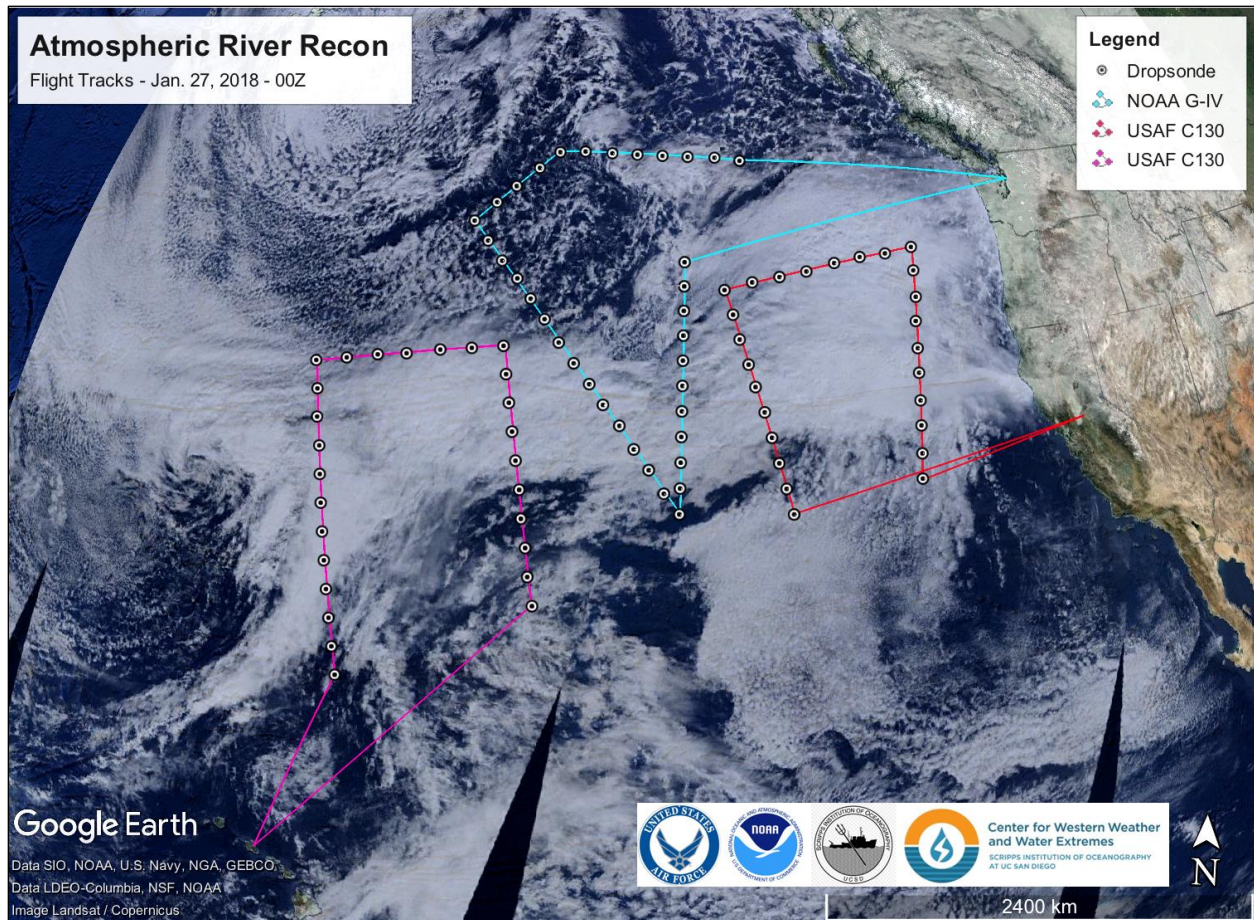
Source: USGS, “Rivers in the Sky: 6 Facts You Should Know About Atmospheric Rivers.”

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

Federal and nonfederal agencies and institutions 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 have established an Atmospheric River Reconnaissance (AR Recon) partnership. AR Recon activities include coordinating and sharing AR observations on the U.S. West Coast, and more recently in the Gulf of Mexico and southeastern United States. 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 Drogsondes on January 27, 2018

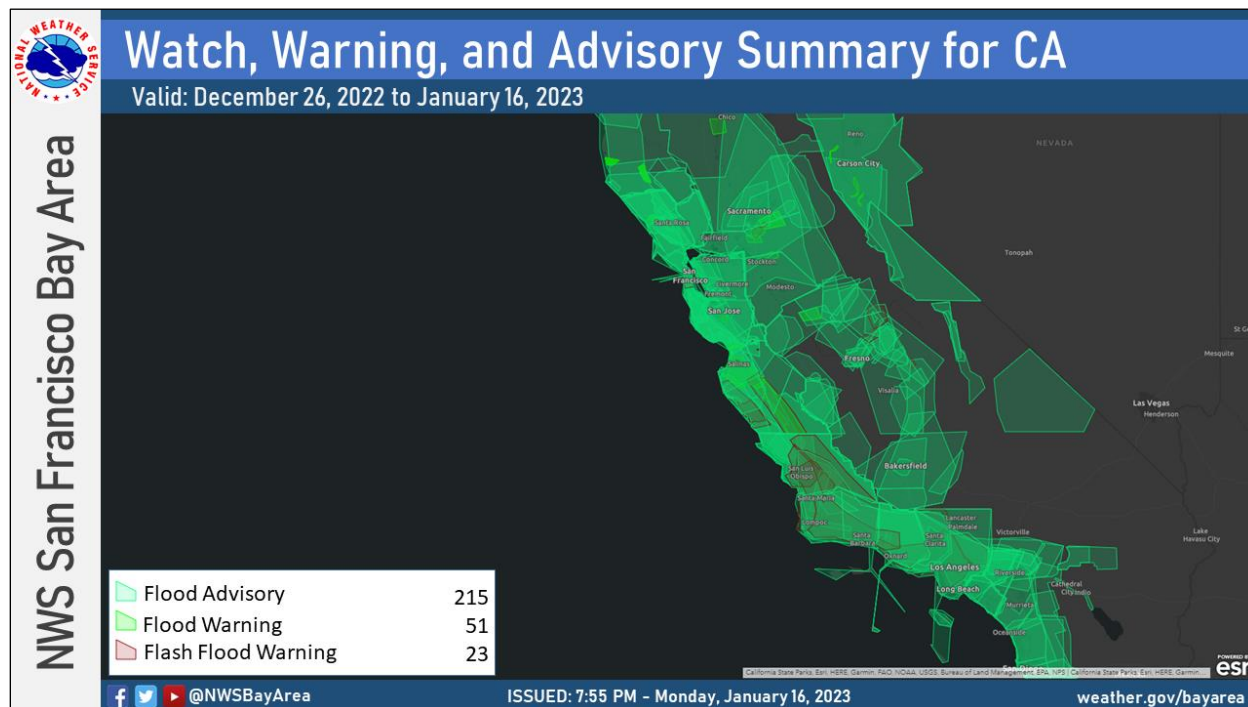


Source: Courtesy photo provided by U.S. Air Force, “[Hurricane Hunters Complete Atmospheric River Reconnaissance.](#)”

Notes: *Drogsondes* 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 drogsondes, 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. For example, managers may use 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 U.S. 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 NOAA to observe and predict ARs (explanatory statement accompanying P.L. 117-328) and authorization for USACE to expand its FIRO efforts to other river basins (P.L. 116-260, §157, Division AA; P.L. 117-263, Division H, Title LXXXI, §8303), among other ways. 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.

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