RECLAMATION Managing Water in the West

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The Knowledge Stream
Research Update

Do Atmospheric Rivers Cause Heavy Downpours in the Intermountain West?

Detecting and modeling moisture sources associated with winter storms in Arizona, Colorado, and Idaho

Bottom Line

Determining potential pathways and sources for extreme precipitation events can help inform decisions about dam safety, flood hydrology, and future monitoring.

Better, Faster, Cheaper

The trajectory and modeling analyses performed here indicate winter storm attributes that result in extreme precipitation in Western States, which have applications to hydrologic hazard studies for dam safety and potentially for short-term (1- to 2-day) predictions at dam sites.

Principal Investigators

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Collaborators

- **FHCG in Reclamation's Technical Service Center**
- **NOAA's Earth System Research Laboratory**
- **Cooperative Institute for Research in Environmental Sciences (CIRES)**

Problem

Extreme precipitation events (abnormally heavy rainfall over 1 to 3 days) can quickly cause severe flooding, leading to safety and infrastructure problems. Determining how these events occur in the Intermountain West (between the Sierra Nevada/Cascade Mountains and the Continental Divide) would help water managers, emergency planners, and others better prepare for these extreme precipitation events. Growing recognition that we are living in an era of changing climate and potentially changing extremes underscores our urgency in advancing this understanding.

The Intermountain West has a complex topography, and moisture from the Pacific Ocean travels a great distance to fuel these storms. It is not clear how these large volumes of water reach their destination. Since flow over mountain causes air to cool and thus hold less moisture, air parcels may take unique pathways and/or have multiple moisture sources to retain enough water to have intense precipitation events in States such as Arizona, Colorado, and Idaho.

Atmospheric rivers (ARs)—long narrow bands of enhanced water vapor transport—are the dominant mechanism for generating intense precipitation events along the west coast of the United States (U.S.) during winter. While studies over the past 10 years have extensively explored the impact of ARs on the precipitation and teextrememperature west of the Sierra Nevada/Cascade Mountains, their influence on the weather in the Intermountain West remains an open question.

The Flood Hydrology and Consequences Group (FHCG) in Reclamation's Technical Service Center estimates extreme precipitation event (and hydrologic response) probabilities for Reclamation dam sites across the Intermountain West for Reclamation's Dam Safety Office. One technique to provide these estimates requires selection of storms that occurred somewhere in the greater region, situating them over the study basin of interest (called transposing), and then maximizing them within physical reason. Transposing the storms is done with substantial uncertainty; a common question is whether the resituation of such storms to a new location imposes a disconnect from the moisture sources required to fuel them.

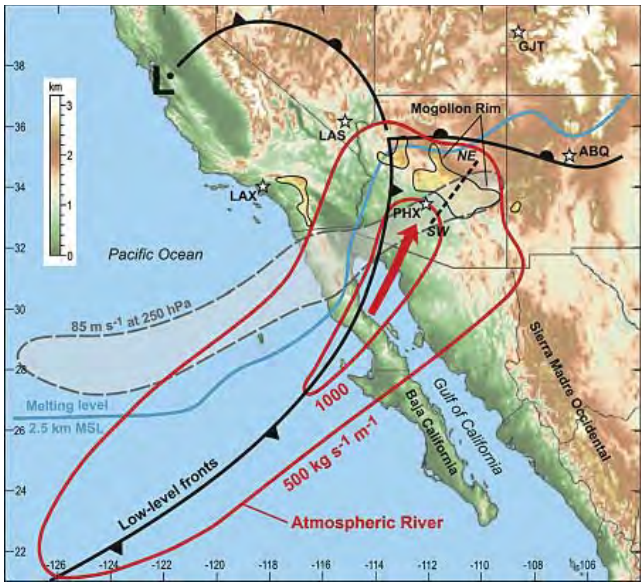

Figure 1. Schematic of conditions leading to heavy precipitation over central Arizona on January 21, 2010.

Solution

Reclamation's Science and Technology Program and the FHCG teamed up with the Cooperative Institute for Research in Environmental Sciences (CIRES), a joint

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institute of the National Oceanic and Atmospheric Administration (NOAA) and University of Colorado at Boulder, to help understand the processes of these extreme precipitation events. The approach includes:

- Identifying historical extreme wintertime precipitation events in the Intermountain West.
- Diagnosing processes contributing to extreme precipitation events and ARs using trajectories that track the path of air parcels.
- Analyzing weather patterns using modern reconstructions of historical atmospheric conditions through a process called re-analysis, where observations are integrated into a historical atmospheric simulation.
- Performing high-resolution atmospheric simulations on several extreme events and exploring sensitivity to event ingredients.

Application and Results

As a first step, a sophisticated network of observations and high-resolution model experiments was used to deconstruct an individual winter storm that brought heavy rain and flooding to central Arizona on January 21, 2010. The storm contained a very strong AR ahead of the cold front (Figure 1) a portion of which crossed southern Baja California, where the mountains are lower and thus the air retained more moisture as the AR moved into Arizona. Once the AR reached central Arizona it encountered the steep cliffs of the Mogollon Rim at nearly the optimal angle to produce the most precipitation. This study demonstrated that ARs can penetrate inland from the Pacific Ocean to central Arizona resulting in heavy rains, snow at higher elevations, and flooding.

A second step sought to identify the moisture sources that contributed to heavy precipitation events near Boise, Idaho, over the watersheds for the Arrowrock and Anderson Ranch Dams. The top 150 precipitation events since 1978 were identified and then trajectories (similar to the path balloons would take as they are carried by the wind), were computed over the 5 previous days to determine where the moist air parcels originated. While the trajectory paths reaching southwest Idaho were very diverse, the greatest number crossed northern California, just to the north of the highest portion of the Sierra Nevada Mountains (Figure 2). The preferred pathway was confirmed using a statistical method to determine the dominant patterns of moisture transport. This method indicated that the most common pattern is associated with a strong AR coming onshore over northern California and/or Oregon, then moving eastward across Idaho, northern Nevada and Utah, and dissipating in Wyoming. Other important pathways include: southern California across Arizona and into southwest Colorado; over southern Baja California into Arizona and along the U.S.-Canadian border.

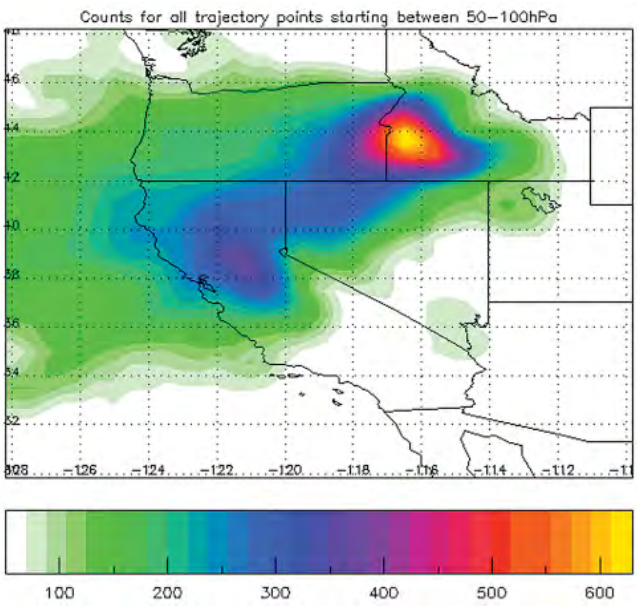

Figure 2. Number of trajectories passing through a given location that terminate in southwest Idaho during periods of heavy precipitation.

"Developing a better understanding of the long and complex pathways that winter storms use to deliver moisture to the Intermountain West is useful to water managers."

John England
Hydraulic Engineer,
Reclamation's Technical Service Center

Future Plans

- **Transfer the knowledge, methods, and data generated from this research to the FHCG.**
- **Enhance the statistical methods to classify and group extreme events.**
- **Develop the capability to make a large set of simulations of extreme events to explore the upper range of potential precipitation amounts in key watersheds.**
- **Document AR characteristics including their seasonality and duration, and examine how climate variability and change may influence ARs and their impact on precipitation in the Western U.S.**
- **Derive realistic temporal and spatial probable maximum storm distributions for regions in the Western U.S.**

More Information

www.usbr.gov/research/projects/detail.cfm?id=1740