How mountains affect El Niño-induced winter precipitation

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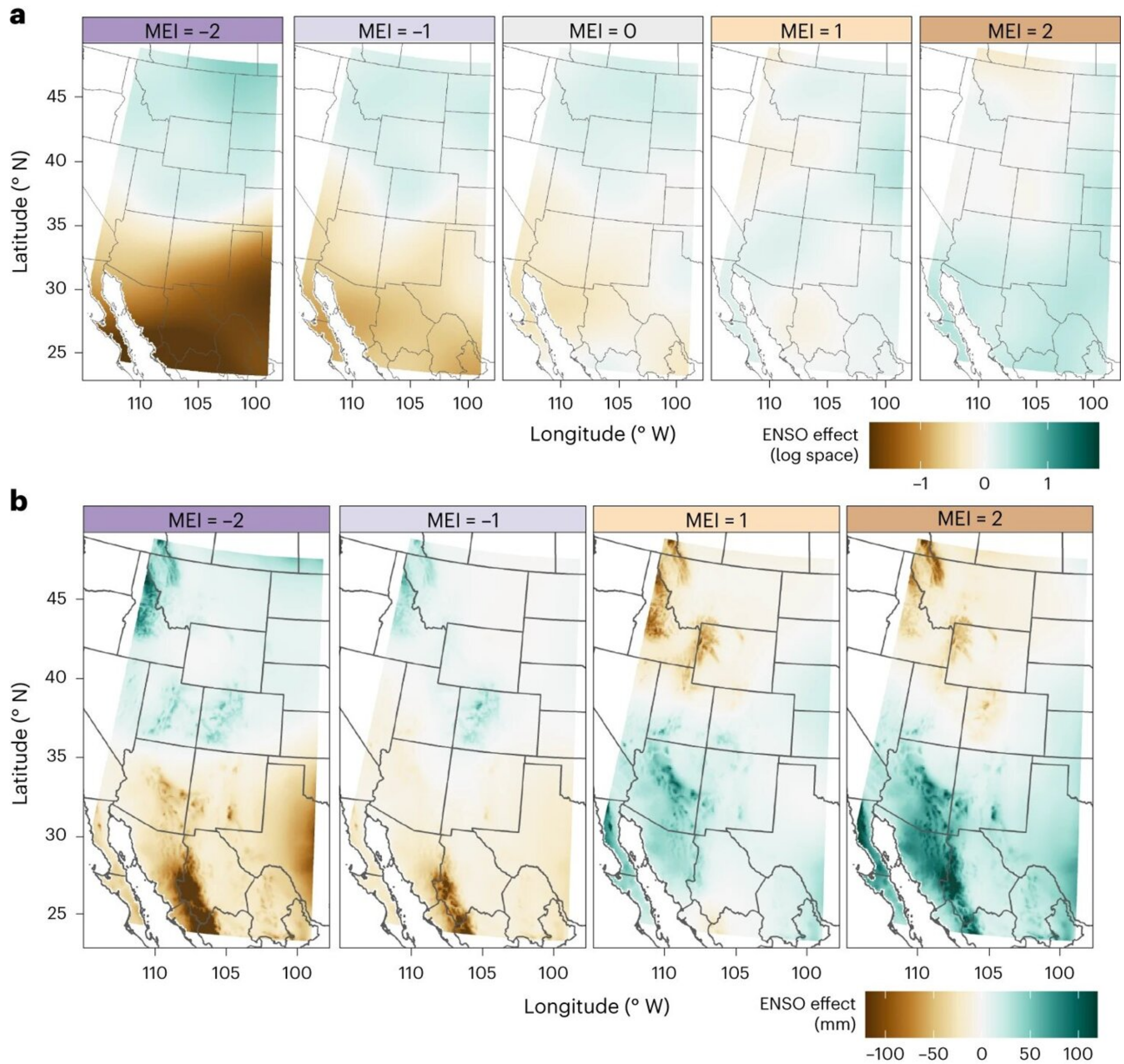

ENSO effects on winter precipitation. **a**, The top row shows the ENSO variable isolated from the first three climatology variables in equation (1). The ENSO effect is presented as anomalies in logarithm space, as in the model (equation (1)). **b**, The bottom row shows the ENSO effect as precipitation anomalies (mm) from neutral ENSO conditions (MEI = 0). Brown colors represent drier than typical, while green represents wetter than typical. Each panel corresponds to an MEI value, ranging from left to right, showing strong La Niña to strong El Niño, with the label color scheme corresponding to Fig. 3. Credit: *Nature Water* (2023). DOI:10.1038/s44221-023-00163-9

A consideration of how mountains influence El Niño and La Niña-induced precipitation change in western North America may be the ticket to more informed water conservation planning along the Colorado River, new research suggests.

The study, coinciding with a recent shift from a strong La Niña to a strong El Niño, brings a degree of precision to efforts to make more accurate winter precipitation predictions in the intermountain West by comparing 150 years of rain and snow data with historic El Niño-Southern Oscillation patterns.

Overall, the analysis shows increasing winter precipitation trends in the north and decreasing trends in the south, particularly during the latter part of the 20th century. It also sheds light on how mountains both amplify and obstruct precipitation, leading to heavier rainfall to their west and lower levels of precipitation to their east.

The more accurate estimate of where and how much winter precipitation has been driven by El Niños of the past may help guide future management of resources in western North America, one of the most water-stressed parts of the world, researchers say.

"Because of the seasonality of precipitation in the West, most of it falls during the winter. If you can predict how much precipitation you'll have in the winter, you'll have a good sense of what your summer dry period will look like in terms of your water allocation," said James Stagge, lead author of the study and an assistant professor of civil, environmental and geodetic engineering at The Ohio State University.

"Anything we can do to improve our ability to predict how much water we'll get during this critical period allows cities, farmers, water managers and member states of the Colorado River Compact to prepare for upcoming drought and potentially start to go into conservation ahead of time so they're not caught flat-footed."

The study is published in *Nature Water*.

El Niño and La Niña together constitute the El Niño Southern Oscillation (ENSO), representing warmer or cooler than normal ocean temperatures, respectively, in a section of the Pacific Ocean between South America and Australia. This anomaly has a widespread impact on temperatures and precipitation—including extreme drops or increases of each—around the world.

In this study, Stagge and colleagues singled out the intermountain West, historically understudied in relation to ENSO patterns, for analysis of El Niño and La Niña wintertime precipitation effects using water gauge readings dating to 1871—in this way, linking actual precipitation levels to not only a specific geographic location but its elevation as well.

The readings were matched with ENSO trends documented by the Multivariate ENSO Index maintained by the National Oceanic and Atmospheric Administration (NOAA), which provides real-time and historic ENSO data.

"Rather than using climate models, we're using only observations, which allow us to be a little bit closer to reality," Stagge said. "We didn't use averages—we showed more precise information about where precipitation fell between the designations of El Niño and La Niña. We put each gauge in its specific location, assigned it an elevation, and looked at how it changed depending on whether it was an El Niño or La Niña year: Was it wetter or drier than normal?"

This approach unearthed finer details of historical patterns—especially in the northern portion of the intermountain region, where variations in elevation have made it more complicated to track ENSO effects on winter precipitation.

The study suggests that along this corridor, the presence of mountains can be expected to amplify the El Niño-related increase in precipitation by between 2 and 6 times—but that increase is most evident on the western side of mountains because of what is known as the orographic effect. Moist air from the Pacific moves west to east and then is pushed up over mountains into the cooler atmosphere and releases precipitation—leaving the air dry once it gets to the other side.

"All the rain falls on the west side, and then by the time it gets to the east side of the mountains, there's no more moisture to fall," Stagge said. "Add in the effect of ENSO, and it's just like a multiplier, so the wet side gets a lot wetter during El Niño in the south and much drier during La Niña."

The effect of ENSO on precipitation in the region is considered a dipole, with opposite effects in the north and south, and this study supported that conclusion: Winter precipitation has tended to increase in northern Utah and Wyoming during La Niña, and winters were wetter than normal in New Mexico and Arizona during El Niño.

That said, the analysis found that the two regions don't respond in the same way to the ENSO effect. In the south, one increment of El Niño temperature difference is linked to a corresponding increment of precipitation change. In the north, precipitation change doesn't occur on a continuous scale based on the strength of the ENSO, but instead operates more like a light switch—it either happens or it doesn't.

"That may have to do with the complexity of the topography," Stagge said. "In the south, the Sierra Nevadas are not blocking the air flow, like they are for Utah and Wyoming."

That finding has implications for water managers hoping to know what to expect in the winter, he said, Forecasts focusing on the strength of El Niño or La Niña are more informative in the north, while quantitative temperature change estimates would be more useful in the south.

Stagge hopes to connect with NOAA about combining data and modeling tools to work on forecasts for the very near future.

"Water is a determining factor in western North America. It drives the economy, it drives extremely large cities, and all of these stakeholders are concerned about it," he said. "If we're able to better understand or in some cases predict precipitation in this part of the world, then we have a better chance of preparing for water shortages."

More information: Stagge, J.H. et al. Orographic amplification of El Niño teleconnections on winter precipitation across the Intermountain West of North America. *Nature Water* (2023). DOI: 10.1038/s44221-023-00163-9
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