Declining snowpack over western US mapped at a finer scale

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Willem van Leeuwen, a University of Arizona professor of natural resources and the environment, measures snowpack in a "snow pit" along Arizona's Mogollon Rim during a snow survey in 2017. He is taking snow samples at different locations in the snowpack to make precise measurements of snow water equivalent (the amount of water that would result if the snowpack is melted). The measurements also review the history of the snowpack -- what kinds of storms led to the snowpack and what happened to it between storms. Credit: Patrick Broxton, copyright 2017

Researchers have now mapped exactly where in the Western U.S. snow mass has declined since 1982.

The research team mapped the changes in snow mass from 1982 to 2016 onto a grid of squares 2.5-miles on a side over the entire contiguous U.S.

A person could practically find the trend for their neighborhood, said first author Xubin Zeng, a University of Arizona professor of hydrology and atmospheric sciences. Grid size for previous studies was about 40 miles on a side, he said.

"This is the first time anyone has assessed the trend over the U.S. at the 2.5-mile by 2.5-mile pixel level over the 35-year period from 1982 to 2016," Zeng said. "The annual maximum snow mass over the Western U.S. is decreasing."

In the Eastern U.S., the researchers found very little decrease in snow mass.

Even in snowy regions of the West, most of the squares did not have a significant decrease in snow. However, some parts of the Western U.S. have had a 41 percent reduction in the yearly maximum mass of snow since 1982.

UA co-author Patrick Broxton said, "The big decreases are more often in the mountainous areas that are important for water supplies in the West."

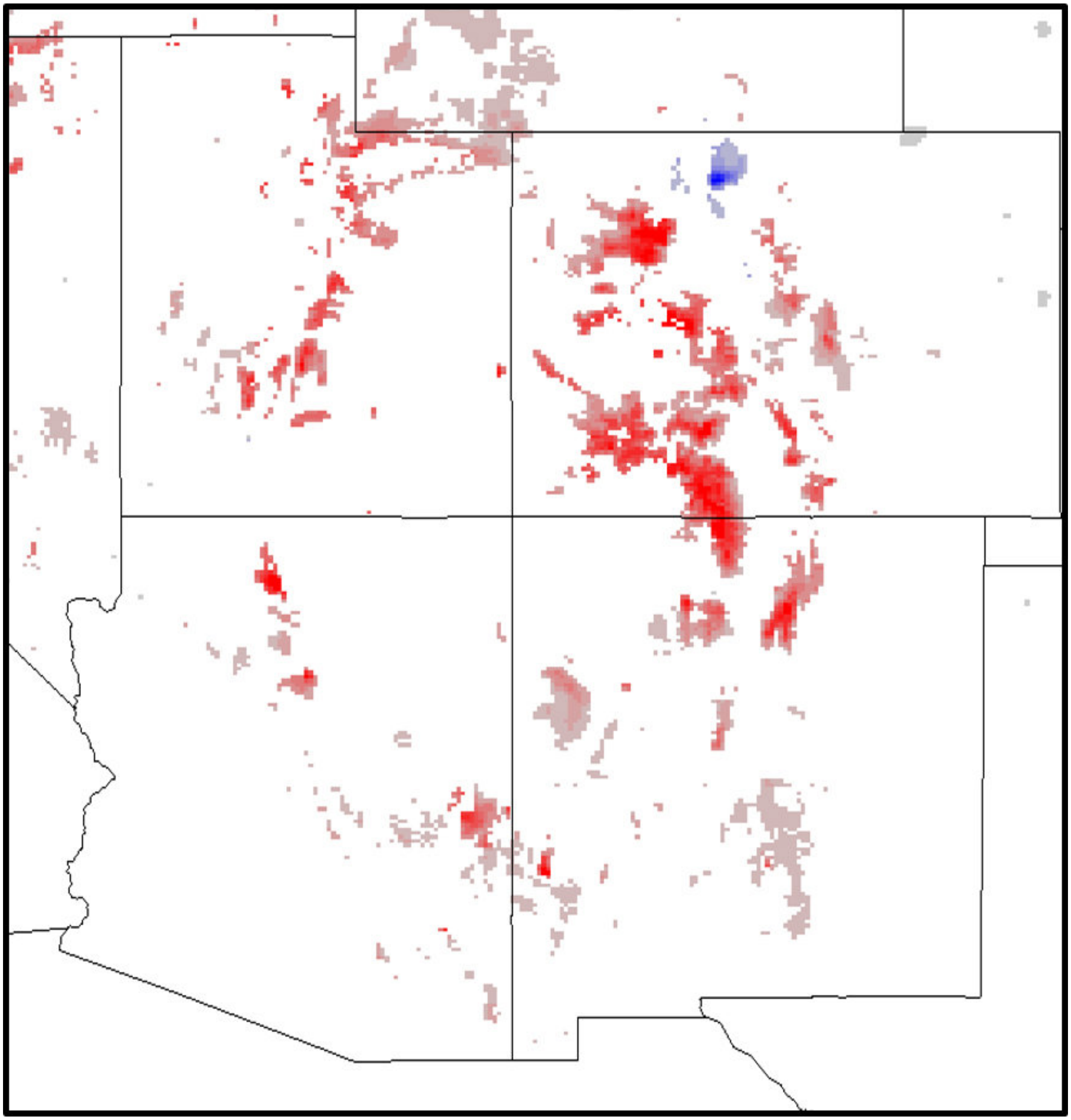
Snow mass is how much water it contains, which is important in regions where winter snows and subsequent snow melt contribute substantially to water resources. Snow melt contributes to groundwater and to surface water sources such as the Colorado River.

Snow is also important for winter sports and the associated tourism, which is a multi-billion-dollar industry in the U.S.

If all the squares in the Western U.S. that had a 41 percent reduction in snow mass were added up, the combined area would be equal in size to South Carolina, said Zeng, who holds the Agnese N. Haury Chair in Environment. He and his team looked at the interannual and multidecadal changes in snow mass for the contiguous U.S.

Zeng's team also found over the period 1982-2016, the snow season shrank by 34 days on average for squares that, if combined, would equal the size of Virginia.

"The shortening of the snow season can be a late start or early ending or both," Zeng said. "Over the Western U.S. an early ending is the primary reason. In contrast, in the Eastern U.S. the primary driver is a late beginning."



The pink-to-red areas in this map of the US Four Corners region (Utah, Colorado, Arizona and New Mexico) shows areas with statistically significant decreases in annual snow mass since 1982. Those areas correspond to many of the region's highest mountain ranges. Darker colors represent larger trends. Photo credit: Patrick Broxton, copyright 2018. Credit: Patrick Broxton, copyright 2018.

Temperature and precipitation during the snow season also have different effects in the West compared with the East, the researchers found.

In the West, the multidecadal changes in snow mass are driven by the average temperature and accumulated precipitation for the season. The changes in the Eastern U.S. are driven primarily by temperature.

The paper, "Snowpack Change from 1982 to 2016 Over Conterminous United States," by Zeng, Broxton and their co-author Nick Dawson of the Idaho Power Company in Boise, Idaho, is scheduled for publication in *Geophysical Research Letters* today.

Previous estimates of interannual-to-multidecadal changes in snow mass used on-the-ground, or point, measurements of snow height and snow mass at specific stations throughout the contiguous U.S.

One such network of data is the National Weather Service Cooperative Observer Program (COOP), in which more than 10,000 volunteers take daily weather observations at specific sites throughout the U.S.

The other is the U.S. Department of Agriculture's SNOwpack TELemetry, or SNOTEL, network, an automated system that collects snowpack and other climatic data in the mountains of the Western U.S. However, for many locations, such measurements are unavailable.

Zeng and his colleagues used an innovative method to combine data collected by COOP and SNOTEL with a third data set called PRISM that gives temperature and precipitation data over all of the lower 48 states and is also based on on-the-ground measurements.

The result is a new data set that provides daily information about snow mass and snow depth from 1982 to the present for the entire contiguous

U.S.

Developing the new dataset has allowed the UA-led research team to examine the changes in temperature, precipitation and snow mass from 1982 to 2016 for every 2.5-mile by 2.5-mile square in the contiguous U.S, as well as to study how snow can affect weather and climate.

"Snow is so reflective that it reflects a lot of the sunlight away from the ground. That affects air temperature and heat and moisture exchanges between the ground and the atmosphere," said Broxton, an associate research scientist in the UA School of Natural Resources and the Environment.

Zeng is now working with NASA to figure out a way to use satellite measurements to estimate snow mass and snow depth.

NASA and the UA's Agnese Nelms Haury Program in Environment and Social Justice funded the research.

More information: Xubin Zeng et al, Snowpack Change From 1982 to 2016 Over Conterminous United States, *Geophysical Research Letters* (2018). DOI: 10.1029/2018GL079621

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