Humans control majority of freshwater ebb and flow on Earth, study finds

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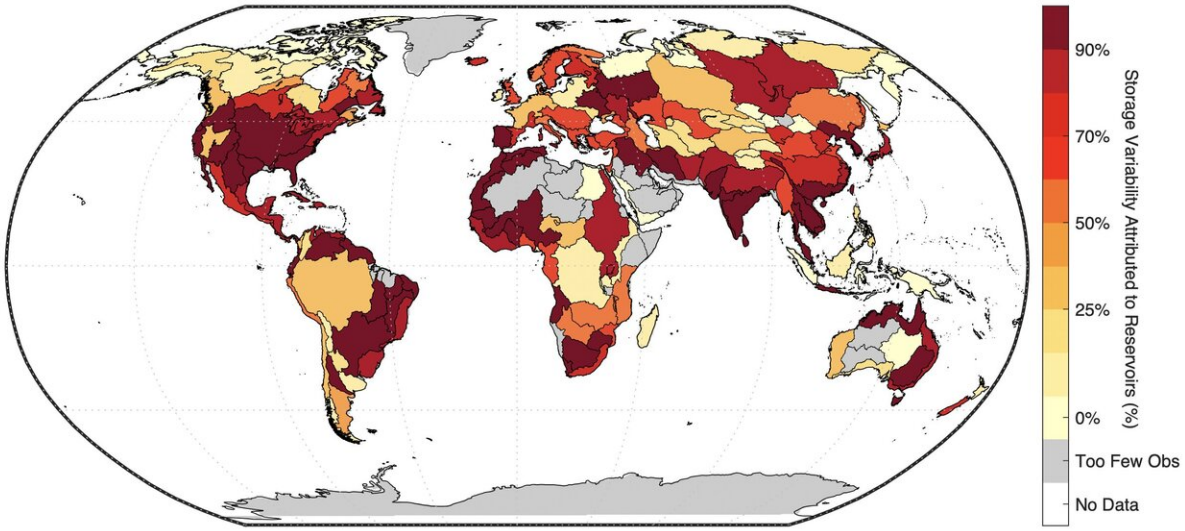

Proportion of seasonal surface water storage variability associated with reservoirs by hydrologic basin from Oct 2018 to July 2020. Darker colors represent higher influence of human-managed reservoirs on surface water storage and lighter colors represent less influence. Reservoirs in the continental U.S., Middle East, western and southern Africa, eastern South America and the Indian subcontinent show particularly high influence. Credit: Cooley et al. 2021, *Nature*

Humans have made a remarkable impact on the planet, from clearing forests for agriculture and urbanization to altering the chemistry of the

atmosphere with fossil fuels. Now, a new study in the journal *Nature* reveals for the first time the extent of human impact on the global water cycle.

The study used NASA's Ice, Cloud and Land Elevation Satellite (ICESat-2) to assemble the largest ever dataset of seasonal water levels in more than 227,000 lakes, ponds and reservoirs worldwide. The data reveal that even though human-managed reservoirs comprise only a small percentage of all water bodies, they account for 57% of the total seasonal water storage changes globally.

"We tend to think of the water cycle as a purely natural system: Rain and snowmelt run into rivers, which run to the ocean where evaporation starts the whole cycle again," said Sarah Cooley, a postdoctoral researcher at Stanford University who launched the research project while a graduate student at Brown University. "But humans are actually intervening substantially in that cycle. Our work demonstrates that humans are responsible for a majority of the seasonal surface water storage variability on Earth."

Cooley led the work with Laurence Smith, a professor of environmental sciences at Brown, and Johnny Ryan, a postdoctoral researcher at the Institute at Brown for Environment and Society.

The researchers say the study provides a critical baseline for tracking the global hydrological cycle as climate change and population growth put new stresses on freshwater resources.

An extraordinary dataset

Launched into orbit in 2018, ICESat-2's primary mission is to track changes in the thickness and elevation of ice sheets around the world. It does so with a laser altimeter, which uses pulses of light to measure

elevation to an accuracy of 25 millimeters. Cooley, who has experience using satellites to study water levels in Arctic lakes, was interested in bringing the satellite's precise measurement capacity to bear on lake levels worldwide.

Cooley says that ICESat-2's laser altimeter has far greater resolution than instruments used to measure water levels in the past. That made it possible to gather a large, precise dataset that included small ponds and reservoirs.

"With older satellites, you have to average results over a large area, which limits observations to only the world's largest lakes," Cooley said. "ICESat has a small footprint, so we can get levels for small lakes that we couldn't get close to before. That was important for understanding global water dynamics, since most lakes and reservoirs are pretty small."

From October 2018 to July 2020, the satellite measured water levels in 227,386 bodies of water, ranging in size from the American Great Lakes to ponds with areas less than one tenth of a square mile. Each water body was observed at different times of year to track changes in water levels. The researchers cross-referenced the water bodies they observed with a database of reservoirs worldwide to identify which water bodies were human-controlled and which were natural.

While countries like the U.S. and Canada gauge reservoir levels and make that information publicly available, many countries don't publish such data. And very few non-reservoir lakes and ponds are gauged at all. So there was no way to do this analysis without the precise satellite observations, the researchers said.

Commandeering the water cycle

The study found that while natural lakes and ponds varied seasonally by

an average of .22 meters, human-managed reservoirs varied by .86 meters. Added together, the much larger variation in reservoirs compared to natural lakes means that reservoirs account for 57% of the total variation. In some places, however, human influence was even stronger than that. For example, in arid regions like the Middle East, American West, India and Southern Africa, variability attributed to human control surges to 90% and above.

"Of all the volume changes in freshwater bodies around the planet—all the floods, droughts and snowmelt that push lake levels up and down—humans have commandeered almost 60% of that variability," Smith said. "That's a tremendous influence on the water cycle. In terms of human impact on the planet, this is right up there with impacts on land cover and atmospheric chemistry."

As the first global quantification of human impacts on the water cycle, the results will provide a crucial baseline for future research on how the impacts affect ecosystems around the world, the researchers say.

In a separate study published recently in *Geophysical Research Letters*, the research team was able to use ICESat-2 data to shed light on how reservoir water is being used. The study showed that in places like the Middle East, reservoir levels tend to be lower in summer and higher in the winter. That suggests that water is being released in the dry season for irrigation and drinking water. In contrast, the trend in places like Scandinavia was the opposite. There, water is released in the winter to make hydroelectric power for heating.

"This was an exploratory analysis to see if we can use remote sensing to understand how reservoirs are being used at a global scale," Ryan said.

Smith says he expects satellites to play an increasing role in study of the Earth's water cycle. For the past few years, he has been working with

NASA on the Surface Water and Ocean Topography mission, which will be dedicated entirely to this kind of research.

"I think within the next three years we are going to see an explosion of high-quality satellite hydrology data, and we're going to have a much better idea of what's going on with water all over the planet," Smith said. "That will have implications for security, trans-boundary water agreements, forecasting crop futures and more. We're right on the edge of a new understanding of our planet's hydrology."

More information: Human alteration of global surface water storage variability, *Nature* (2021). DOI: 10.1038/s41586-021-03262-3 , dx.doi.org/10.1038/s41586-021-03262-3

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