Researchers create first global map of water in Moon's soil

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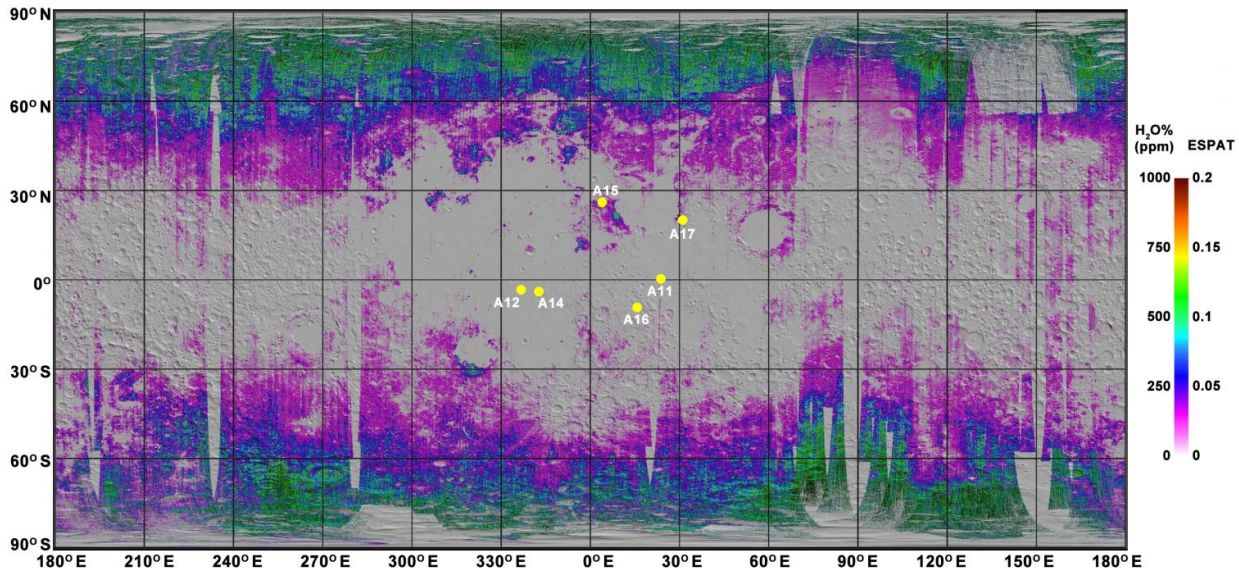

A new map reveals quantities of water trapped in the lunar soil. The amounts increase toward the poles, suggesting that much of the water was implanted by the solar wind (yellow dots mark Apollo landing sites). Credit: Milliken lab / Brown University

In research that may prove useful to future lunar explorers, scientists from Brown University have created the first quantitative map of water and its chemical building blocks trapped in the uppermost portion of the Moon's soil.

The study, published in *Science Advances*, builds on the initial discovery in 2009 of water and a related molecule—hydroxyl, which consists of one atom each of hydrogen and oxygen—in the lunar soil. The latest study uses a new calibration of data taken from NASA's Moon Mineralogy Mapper, which flew aboard India's Chandrayaan-1 spacecraft, to quantify how much water is present on a global scale.

"The signature of water is present nearly everywhere on the lunar surface , not limited to the polar regions as previously reported," said the study's lead author, Shuai Li, who performed the work while a Ph.D. student at Brown University and is now a postdoctoral researcher at the University of Hawaii. "The amount of water increases toward the poles and does not show significant difference among distinct compositional terrains."

The water concentration reaches a maximum average of around 500 to 750 parts per million in the higher latitudes. That's not a lot—less than is found in the sands of Earth's driest deserts—but it's also not nothing.

"This is a roadmap to where water exists on the surface of the Moon," said Ralph Milliken, an associate professor at Brown and Li's co-author. "Now that we have these quantitative maps showing where the water is and in what amounts, we can start thinking about whether or not it could be worthwhile to extract, either as drinking water for astronauts or to produce fuel."

The researchers say that the way the water is distributed across the Moon gives clues about its source. The distribution is largely uniform rather than splotchy, with concentrations gradually decreasing toward the equator. That pattern is consistent with implantation via solar wind—the constant bombardment of protons from the sun, which can form hydroxyl and molecular water once emplaced.

Although the bulk of the water mapped in this study could be attributed

to solar wind, there were exceptions. For example, the researchers found higher-than-average concentrations of water in lunar volcanic deposits near the Moon's equator, where background water in the soil is scarce. Rather than coming from solar wind, the water in those localized deposits likely comes from deep within the Moon's mantle and erupted to the surface in lunar magma. Li and Milliken reported those findings separately in July of this year.

The study also found that the concentration of water changes over the course of the lunar day at latitudes lower than 60 degrees, going from wetter in the early morning and evening to nearly bone dry around lunar noon. The fluctuation can be as much as 200 parts per million.

"We don't know exactly what the mechanism is for this fluctuation, but it tells us that the process of water formation in the lunar soil is active and happening today," Milliken said. "This raises the possibility that water may re-accumulate after extraction, but we need to better understand the physics of why and how this happens to understand the timescale over which water may be renewed."

Li says that laboratory research could be useful in better understanding these kinds of processes. "We hope this motivates the planetary community to continue lab experiments to understand the interaction of solar wind with the lunar soil and possible mechanisms for how water migrates across the lunar surface on these relatively short timescales," he said.

As useful as the new maps may be, they still leave plenty of unanswered questions about lunar water. The Moon Mineralogy Mapper, which supplied the data for the research, measures light reflected off of the lunar surface. That means that it can't look for water in places that are permanently shadowed from the sun's rays. Many scientists think these permanently shadowed regions, such as the floors on impact craters in

the Moon's polar regions, could hold large deposits or water ice.

"Those ice deposits may indeed be there," Milliken said, "but because they are in shadowed areas it's not something we can easily confirm using these data."

It's also not clear how deep into the soil the water mapped in the study goes.

"We're only sensing the upper millimeter or so of soil, and we can't say for sure what the water content is like underneath that," Milliken said. "The distribution of water with depth could make a big difference in terms of how much water is actually there."

Still, the researchers say, the study provides a good starting point for thinking about how lunar water resources might be utilized.

"It remains to be seen whether extraction could be feasible," Milliken said. "But these results show us what the range of water availability across the surface is so we can start thinking about where we might want to go to get it and whether it makes economic sense to do so."

More information: "Water on the surface of the Moon as seen by the Moon Mineralogy Mapper: Distribution, abundance, and origins" *Science Advances* (2017). advances.sciencemag.org/content/3/9/e1701471

Provided by Brown University

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