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FEATURE

Tracking Flood Volume Changes in the Developing World

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CALCULATING VOLUME REQUIRES MEASURES ALONG three dimensions—width, length, and height—not just the two (width and length) required to calculate area. Anyone who has faced flooding, such as the recent devastating floods in Bangladesh and northeastern India, likely understands this concept very well. Flood-affected people know that it is the volume of floodwater that does the worst of the damage.

In Bangladesh and northeastern India, heavy rains and flooding are not uncommon during second half of the year. What is uncommon is the severity of recent floods. Changing weather patterns due to climate change, uncoordinated land development, unregulated urbanization, the building of embankments, and deforestation in mountainous regions—all of these are often identified as factors that are worsening flood conditions.

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In the past, one critical piece of this flooding puzzle has eluded scientists and decision-makers: the volume of floodwater that typically passes through during such an episode. Knowing the volume of water can improve our understanding of inundation depth variability, flow patterns, recession time, and downstream impacts in relation to the conditions in the estuary impacted by tides and ocean circulation.

New tools now make it possible for us to estimate the total change in volume of floodwater experienced in a region like Bangladesh or northeastern India any time of the year. These tools are game changers that promise to provide vital information to decision-makers in a world of increasing climate extremes.

A New Approach to Measuring Floodwater Volume

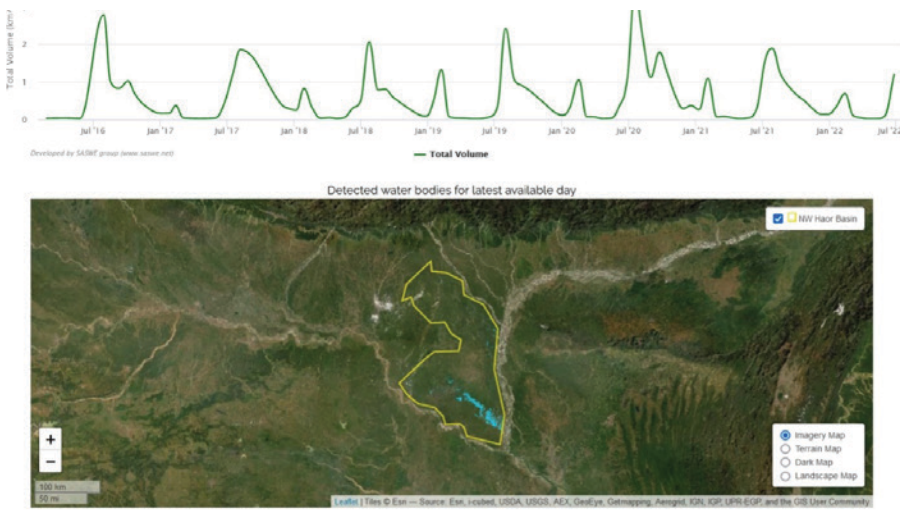
This volume estimation has been made possible with stakeholder engagement from the Bangladesh Water Development Board (BWDB), which mobilized a citizen-scientist program to measure lake height in collaboration with a NASA-supported program called Lake Observations by Citizen Scientists and Satellites (LOCSS). The LOCSS program uses satellite remote sensing to estimate areal extent of inundation (width times length), which is then combined with water height changes obtained from BWDB's citizen science lake-gauging program to calculate the volume changes from preceding estimates. Because gauges cannot be placed everywhere in the more than 600 lakes of the northeastern region, the technique also uses lake height measurements from additional satellites, such as radar altimeters where available, to derive a statistical relationship between inundated surface area and volume measured from the lowest observable elevation. This statistical relationship then helps parameterize the routine calculation of total change in water volume of the 600-plus lakes by routinely tracking only areal extent of water from satellites.

It is important to note that these estimates are not for total volume stored overland, but rather primarily for changes in volume. In Bangladesh, however, the two metrics are similar given that the region is completely dry during December–May and completely inundated during June–November.

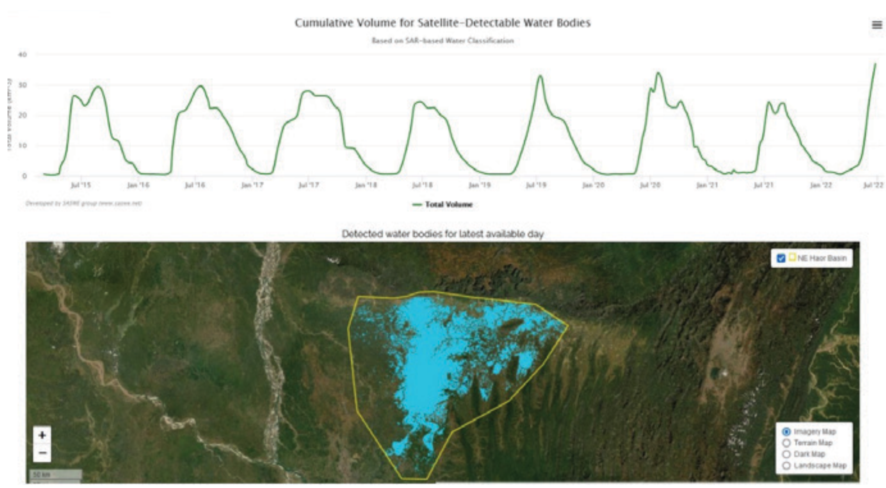
The LOCSS work has led to the co-development of one tool that is currently operational for the northeastern region for the BWDB, which invested in and maintained an in situ lake-gauging network solely for this purpose. Now, for the first time, it is possible to see the temporal pattern of floodwater volume that typically passes through the region during the wet phase of a year (Figure 1, bottom image). Our volume-tracking tool confirms that 2022 is indeed anomalous, with total volume at 41 cubic kilometers (as of June 30, 2022)—an amount that has not been experienced in recent times.

The ability to track changes in surface water volume using satellites and in situ gauges in a cost-effective manner has also prompted BWDB and the Bangladesh government to extend the lake-gauging network country-wide to build national-level monitoring capability. Such estimates of change in surface water volume have the potential to drive national policy planning on water security. For example, based on discussions stimulated by the tool for the northeastern region in 2020, BWDB has already approached Bangladesh's Ministry of Water Resources with an innovative idea to use a small fraction of this "excess" flooded freshwater (about 1 km³) in an ecologically safe manner to build a drinking-water bottling plant. The motivation is to address drinking-water scarcity in Dhaka, a megacity of more than 20 million people, and generate revenue for BWDB to carry out more water research and development.

Using this more expansive lake-gauging network, we have been able to develop another [operational tool for the northwestern region](#) (known locally as the Barind region). While the northeast is wet and flood prone, as evident from the June 2022 floods, the [northwest Barind region is arid and drought-prone](#). Yet the two regions, separated by just 100 miles, are both breadbaskets of the country. The stark contrast is visible in screenshots from the two operational tools taken during the last week of June (Figure 1). Such satellite-based tools for tracking surface water volume can trigger some ambitious brainstorming on what can be done within ecological safety barriers to balance water availability between neighboring water-surplus and water-deficit regions that are critical to the country's food security



Northwestern region of Bangladesh



Northeastern region of Bangladesh

Figure 1. The tools for tracking surface water volume change in the northwestern and northeastern regions of Bangladesh. The screenshots for total volume change pertain to June 30, 2022. Source: S. Ahmad et al., "Understanding Volumetric Water Storage in Monsoonal Wetlands of Northeastern Bangladesh," *Water Resources Research* 56 (2020): e2020WR027989, https://doi.org/10.1029/2020WR027989.

Coming Next: The SWOT Satellite

Bangladesh provides just one example of the impact satellite remote sensing can have by allowing for estimates of volume. With the planned [Surface Water and Ocean Topography (SWOT) satellite mission](#), it is not unreasonable to expect similar impacts around the world when it comes to more actionable decision-making or improved scientific analysis of global surface water dynamics in the context of a changing Earth.

The SWOT mission, jointly developed by NASA and the French space agency (Centre National d'Etudes Spatiales) with contributions from the Canadian and UK space agencies, is designed to provide spatially extensive, high-resolution, and high-frequency measurements of water elevation for the hydrology and oceanography

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communities. For the first time in history, the world will have a publicly available global data product based on satellite remote sensing that provides estimates of surface water volume change for water bodies larger than 250×250 meters. Until now, such estimates had to be created using in situ gauges (which are limited in spatial coverage), a digital elevation model that is subject to uncertainty, or quasi-simultaneous satellite measurement of area and elevation from different satellite platforms where both coverage and accuracy can be limited.

SWOT is a global mission. No other satellite will collect similar data on surface water volume change with a measurement frequency of at least once in 21 days with a short latency. We now have every reason to believe that the extra dimension we expect from the SWOT satellite will generate tangible impact in places around the world where volume change estimation has been impossible using traditional methods. ■

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