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AquaSat Gives Water Quality Researchers New Eyes in the Sky

The distinctive green of chlorophyll a*, as seen on this algal bloom in Lake Erie, is one of the patterns used to create the innovative AquaSat data set. Credit: NASA Goddard Space Flight Center*

Nandita Basu studies how human activities can impact water quality, specifically how nutrient runoff can impact large areas. Think of the Mississippi River basin or the Chesapeake Bay watershed. Much of the work Basu, a professor of water sustainability and ecohydrology at the University of Waterloo in Canada, does looks at nitrogen and phosphorus concentrations in streams and rivers and then links them to sources in the landscape, such as agricultural land use.

It's work that necessarily depends on physical sampling of water in the field, but as Basu notes, researchers quickly find fundamental limits in this type of work.

"When you work with these water quality data, one thing that immediately becomes really evident is the *lack* of data. There are millions of streams, and there are only so many that we can go take samples from all the time," she said.

That's why Basu is so excited about AquaSat, a new data set from researchers at Colorado State University, the University of North Carolina, and others that correlates water quality samples from U.S. rivers, streams, and lakes with more than 30 years of remote sensing images taken by Landsat satellites operated by NASA and the U.S. Geological Survey.

"The AquaSat data set is absolutely amazing," she said. "I can imagine using it quite extensively."

Remote Eyes on Water Quality

Matthew Ross, an assistant professor of ecosystem science and sustainability at Colorado State University, is the lead author of a 2019 paper in *Water Resources Research* detailing the AquaSat project (bit.ly/AquaSat). As a postdoctoral researcher in Tamlin Pavelsky's lab at the University of North Carolina at Chapel Hill, however, Ross became interested in using satellites for larger-scale measurements. "I was sort of surprised that more people weren't using remote estimates of water quality," he said.

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The eight Landsat satellites have provided continuous and global imaging of terrain since 1972. Although those missions have focused on land, Ross and his colleagues realized that there should be "optically relevant" parameters in images of water too, meaning "things that change the color of water." For AquaSat, they were interested in chlorophyll *a,* a measure of algae in water that turns it green; sediment, which can yield a tan color; dissolved carbon, which can darken waters and is a measure of carbon leached from the landscape; and Secchi disk depth, a measure of total water clarity.

Ross and his colleagues then correlated images taken by Landsat 5, 7, and 8 between 1984 and 2019 with on-the-ground samples of the imaged bodies of water that measured the optically relevant parameters. Researchers pulled sample data from the U.S. Water Quality Portal and the Lake Multi-scaled Geospatial and Temporal Database (LAGOS) data set, both of which record water quality measurements in U.S. streams, rivers, and lakes. The resulting 600,000 matchups of remote sensing and sample data allow for more reliable predictions of water quality based on future Landsat imaging alone.

"It gives you a ground truth. It's basically a way to calibrate models that are using Landsat to estimate water quality parameters," Ross said. "We can use these more data-rich, empirically driven ways of prediction that previously weren't available because no data set like this existed before we made it."

Applications and Accessibility

"With this data set we can look at all of these lakes and rivers and look at the water quality trajectories over time," Basu said. For instance, researchers can track the water quality in a particular river over a 30-year period and correlate it with land use and farming practices in the surrounding landscape to estimate their impact. "Maybe," she noted, "the farming practices have not changed that much, but maybe it's climate that's changing the conditions."

Ross hopes to do more than just provide a new and useful data set for other water quality researchers. "Our goal is to make it a lot easier for anyone to use [the AquaSat data set] to build models that predict water quality," he said.

He has already seen some evidence that this is happening. The AquaSat data set is on Figshare (an open-access repository for figures, data sets, images, and videos), where it has attracted some amateur attention (bit.ly/Figshare-AquaSat).

"I've gotten a bunch of high school and early college computer science folks emailing me about how to train neural nets on our data," Ross said. "Those emails are always exciting because of the idea that there's a bigger community that can engage with the data in an easier way."

Right now, building models and making water quality predictions require some coding skills, but Ross said the ultimate goal is to create a user-friendly interface that could be used by water quality and environmental professionals to make decisions about water resources, such as reservoirs. "Getting these data and ideas into the hands of municipalities is certainly one of my long-term goals," he said.

Beyond creating more user-friendly access to AquaSat going forward, Ross says he hopes to extend the data set with additional satellite imagery, such as the NASA Moderate Resolution Imaging Spectroradiometer (MODIS), satellites, and future missions.

"I'd say the biggest game changer for doing full-stack hydrologic sciences from space is the SWOT mission, which is launching in 2022," he said. The Surface Water and Ocean Topography satellite will provide the water height of large rivers and lakes. These data, according to Ross, could be combined with Landsat color information to allow researchers to do things like estimate the discharge and sediment volume in an ungauged river.

But the future projects Ross is most excited about involve getting enough on-the-ground data to validate satellite imagery in parts of the world that have little water quality data available to begin with. "In places that are changing rapidly, like in Honduras or Brazil, South Africa or other places, going back in time with Landsat satellites there is incredibly valuable," he said. "To me, that's one of the biggest value adds and why it's so important to make this data set global, so we can validate a more global model."

By **Jon Kelvey** (@jonkelvey), Science Writer

Space Weather Lessons from a 1928 Dirigible Tragedy

The airship Italia*, shown above in what is now Stolp, Poland, in 1928, crashed later that year after returning from a journey over the North Pole. Credit: German Federal Archive, CC BY-SA 3.0 DE (bit.ly/ccbysade3-0)*

On 15 April 1928, when the dirigible *Italia* lifted off from Milan, Italy, the crew hoped it would be the second airship ever to reach the North Pole. Over a month later, on 24 May, expedition leader Umberto Nobile sent a triumphant radio message to a ship anchored at the airship's base camp near Ny-Ålesund, in the Norwegian archipelago of Svalbard: The mission was a success. But it would be the last message the base camp would ever receive from the *Italia.*

Ten days later, a young Russian with a homemade radio picked up a desperate SOS signal originating 1,900 kilometers (1,180 miles) away. The *Italia* had crashed on sea ice north of Svalbard on its return journey, killing 17 and leaving nine surviving crew members attempting desperately to contact the base ship to send help. The shipwrecked crew could pick up a news station from Rome, 4,000 kilometers (2,485 miles) away, but no matter what frequency they tried, their cries for help could not reach their camp on the other side of the Svalbard Archipelago. The stranded crew were eventually rescued after weeks on the ice.

"This was completely mysterious to them, I'm sure," said Delores Knipp, former editor in chief of *Space Weather* and a research professor at the University of Colorado Boulder. "They could not understand how they could receive a signal from Rome—very distant—but not be able to contact what appeared to be a very close-by potential rescue ship."

Unbeknownst to the *Italia*'s crew, their plight was caused by an unlucky confluence of space weather disturbances, according to a new retrospective analysis by a team of Italian researchers published in *Space Weather* (bit.ly/Italia-shipwreck). The crew had crash-landed in what is known as a radio skip zone, where radio signals can't be received, during a period of turbulent solar and geomagnetic activity that prevented the signal from getting through.

"This is a history lesson that could replay during other explorations such as lunar or interplanetary travels, so possible communication issues due to disturbed space weather conditions must be taken in due consideration even more nowadays," said Ljiljana Cander, a visiting scientist at the Rutherford Appleton Laboratory in the United Kingdom and a coauthor of the study.

A Different Kind of Storm

High-frequency radio communication takes advantage of a layer of the atmosphere ionized by solar radiation, which extends from 50 to 1,000 kilometers above Earth's surface. Space weather is the term for the phenomena—often solar and electromagnetic disturbances—that affect this layer.

In 1928, radio was still a nascent technology and one that had been used largely at midlatitudes. Few explorers had attempted to reach the North Pole, and fewer still had succeeded. They knew that the poles were capable of brutal terrestrial weather events with howling winds and icy conditions. But they had no real concept of space weather or any idea that it behaved dramatically differently at northern latitudes as well.

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