A Space Satellite Perspective to Monitor Water Quality **Using your Mobile Phone**

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Good water quality is important for human health, economic development, and the health of our environment. Across the country, we face the challenge of degraded water quality in many of our rivers, lakes, coastal regions, and oceans. The EPA National Rivers and Stream Assessment report found that more than half – 55 percent – of our rivers and streams are in poor condition for aquatic life. Likewise, the EPA Lakes Assessment found that 22 percent of our lakes are in poor condition for aquatic life. The reasons for unhealthy water quality are vast. Poor water quality has numerous impacts on ecosystems. The duration and frequency of harmful algal blooms, which trend during warm weather months, is one indicator of poor water quality. Having the ability to monitor and provide timely response to harmful algal blooms would be one step toward protecting the benefits people receive from good water quality (U.S. EPA 2010 and 2013).

The U.S. Environmental Protection Agency (EPA) is collaborating with other federal agencies including the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and U.S. Geological Survey (USGS), to assist in monitoring water quality of our lakes, reservoirs, estuaries, and other water bodies. Together, these federal agencies are working to provide the capability to detect and quantify cyanobacteria and nuisance algal blooms using satellite data. NASA, NOAA, and USGS provide the satellite imagery, and EPA maximizes access to the satellite data through user-friendly mobile technology.

One of the significant issues for management is access to timely and consistent data. Historically, few management decisions have been based on remotely sensed information because satellite data disseminated to management have been limited to either "pictures" or specialized formats. Managers will substantially benefit from alternative data structures that facilitate better public health protection of water bodies and evaluation of inter-annual and seasonal patterns. In all cases, timely distribution of satellite data is necessary to provide warnings within days and seasonal assessments in the same calendar year. If satellites are going to help managers respond to the immediate impacts of cyanobacteria and nuisance algal blooms, then timely, useful, and cost-effective delivery of information from the satellite data is needed (Schaeffer et al. 2013). In addition, satellite-derived data products will assist with more targeted deployment of existing federal, state, tribal, and municipal monitoring and research efforts to problem areas.

The Cyanobacteria Assessment Network (CyAN) Mobile App

Cyanobacteria blooms occur worldwide and are associated with human respiratory and skin irritation, poor taste and odor of drinking water, and human illness. Pets and other domestic animals, and wildlife are also affected by exposure to cyanotoxins. Rapid detection of potentially harmful blooms is essential to making environmental management decisions during periods of limited resources and funding. Traditionally, water quality monitoring is labor intensive and with low temporal and spatial coverage. Sample collection can be limited due to cost, time, and logistical constraints. To help water quality managers and decision makers monitor water bodies more effectively and comprehensively, EPA is developing the CyAN mobile application for use on Android devices. The CyAN app uses satellite-derived information from the European Space Agency (ESA) Medium Resolution Imaging Spectrometer (MERIS) and, in the future, from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS), ESA's Ocean Land Color Instrument (OCLI), and USGS's Landsat satellite to help make initial water quality assessments and quickly alert managers to potential problems and emerging threats. With the CyAN mobile app, water quality managers will have a user-friendly application that will reduce the complexities associated with harnessing satellite data to make fast, efficient initial assessments.

The development of this mobile application puts the satellite technology directly into the hands of water quality managers and the people who need to be informed. With the CyAN app, water quality managers will be able to view water quality on the scale of the United States, and zoom in to get near-real-time data for a local lake. They can also compare locations. As a result, environmental managers will be able to make better informed decisions based on near-real-time changes at a specific location. Additionally, using archived satellite imagery, water quality managers have the ability to look back, 10 or 15 years, for example, to compare how much things have changed to the present day. This historical archive will also allow water quality managers to estimate the rate of change, a huge advantage in prediction and mitigation.

The app is currently focused on producing cyanobacteria cell count concentrations (Lunetta et al. 2015 and Wynn et al. 2013), later versions will include measures of chlorophyll-*a*, turbidity, and water temperature. During 2015, the app is being developed for the Android operating system and is transitioning from alpha testing to beta testing. Initial testing will include the states of Florida and Ohio. After 2016, there are plans for the mobile application to expand the continental United States. Using satellite data technologies, and specifically, this application, to monitor and report blooms throughout a region or state would help manage events that may involve significant risk to the public.

Monitoring Cyanobacteria Concentrations Using the CyAN App – An Example

A lake manager could use the CyAN app on a weekly basis to monitor water bodies throughout a region. Cyanobacteria thresholds would be set for locations to be monitored using location pins set within the app (Figures 1 and 2). When satellite-derived levels of cell counts reach these thresholds, the location pins would change colors. Location pins change colors like a stop-light. Green pins indicate the lowest threshold, yellow and orange pins indicate moderate levels, and red indicate high concentrations (Figure 2). At a quick glance of a cell phone, tablet, or laptop, environmental managers could identify a potential problem that would then allow them to better focus their energy and resources to achieve an outcome. An outcome might include manually collecting water samples from that water body for more information or even issuing a public advisory to close local beaches to recreation, if necessary.

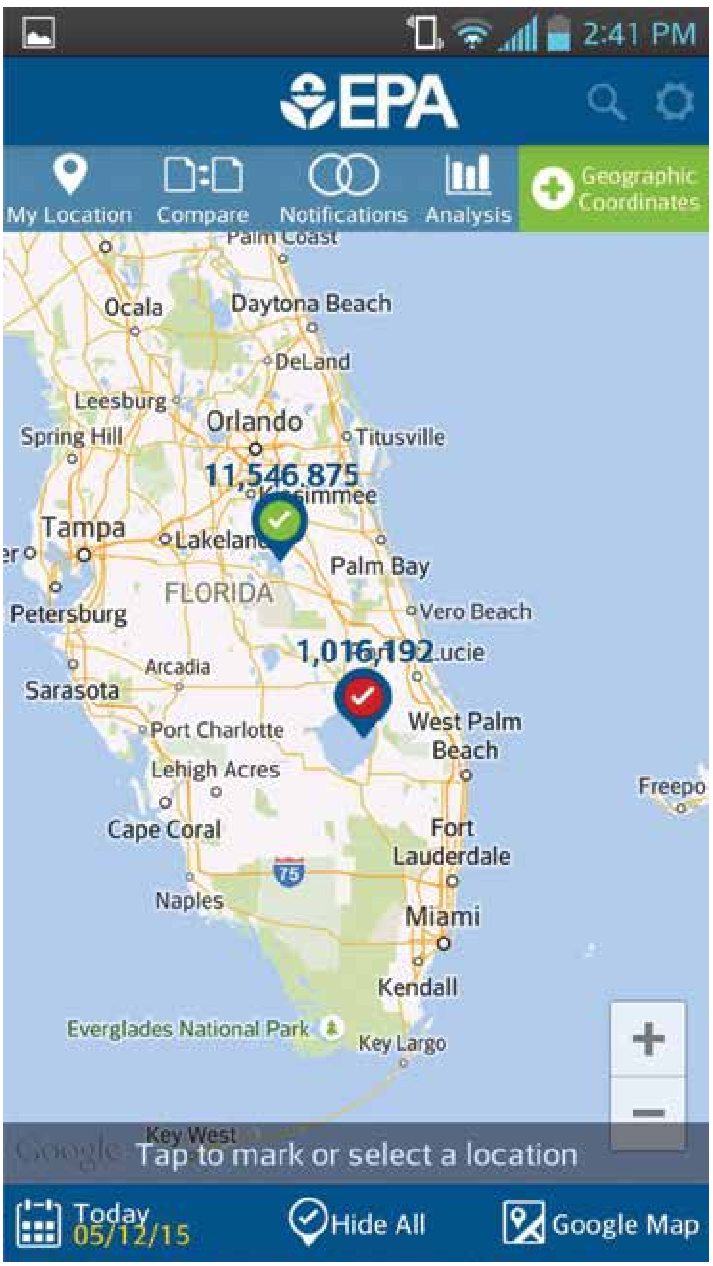

Figure 1. An example of how a water quality manager can drop location pins in their water bodies of interest and the pins change colors depending on user settings (see Figure 2).

Figure 2. Users can set their own thresholds for cyanobacteria cell counts since states and localities address these harmful algal blooms differently.

The development of this mobile application puts the satellite imagery and data directly into the hands of water quality managers and the people who need to be informed (Figure 3). The mobile app uses a default view of Google Earth or Google Maps. The user will be able to adjust the date on the map to view data collected on different days (Figure 4).

Frequently Asked Questions

Question: How does a satellite measure water quality?

Answer: Your eyes help you distinguish the color of water from blue, green, brown, and colors in between based on changes in the color spectrum. Satellites essentially perform the same function as your eyes by looking at the visible spectrum of light. Mathematical equations, typically referred to as atmospheric corrections and algorithms, allow scientists to quantify different water quality variables that can change the color of water.

Question: What satellites are used to monitor water quality?

Answer: In the past scientist have used satellites like the European Space Agency's Envisat MEdium Resolution Imaging Spectrometer (MERIS) or NASA's SeaStar Sea-Viewing Wide Field-of-View Sensor (SeaWiFS). Today, the NASA Aqua satellite Moderate Resolution Imaging Spectroradiometer (MODIS) is probably the most commonly used. The USGS Landsat series has also been used to monitor water quality. In the near future the European Space Agency will launch Sentinel-3 with the Ocean and Land Colour Instrument (OLCI) and further into the future NASA is developing the Pre-aerosol, clouds, and ocean ecosystem (PACE) mission.

Question: What water quality parameters can satellites measure?

Water quality parameters that can be derived from satellite are those that cause a change to water color. Other parameters may be estimated by making use of additional information through appropriate biogeophysical assumptions, ancillary data, and mechanistic models. Typically, robust and reliable parameters include quantitative measures of water clarity (similar to Secchi depth), chlorophyll concentration, sediment, colored dissolved organic matter, trophic status, and temperature.

Question: What are the spatial and temporal resolutions of satellites?

Answer: The satellite sensor pixel spatial resolution ranges from 1 km to 30 meters. Temporal resolution, or the amount of time that passes between measuring the same location repeatedly, ranges between every day and every 16 days. The 30-meter sensors have the longest time between site revisits and the 1 km sensors pass over a location once every day. Cloud cover will also impact the temporal coverage, because these satellite sensors cannot measure through clouds.

Question: Is it true satellites will eliminate the need for traditional monitoring?

Answer: No. There are still many limitations when monitoring water quality from satellite. Satellite data should be viewed as a complement to other field and modeling data sets to help provide solutions to problems. The satellite data provide water quality managers a guide to deploy traditional monitoring resources in a targeted, more efficient manner in order to confirm the satellite data.

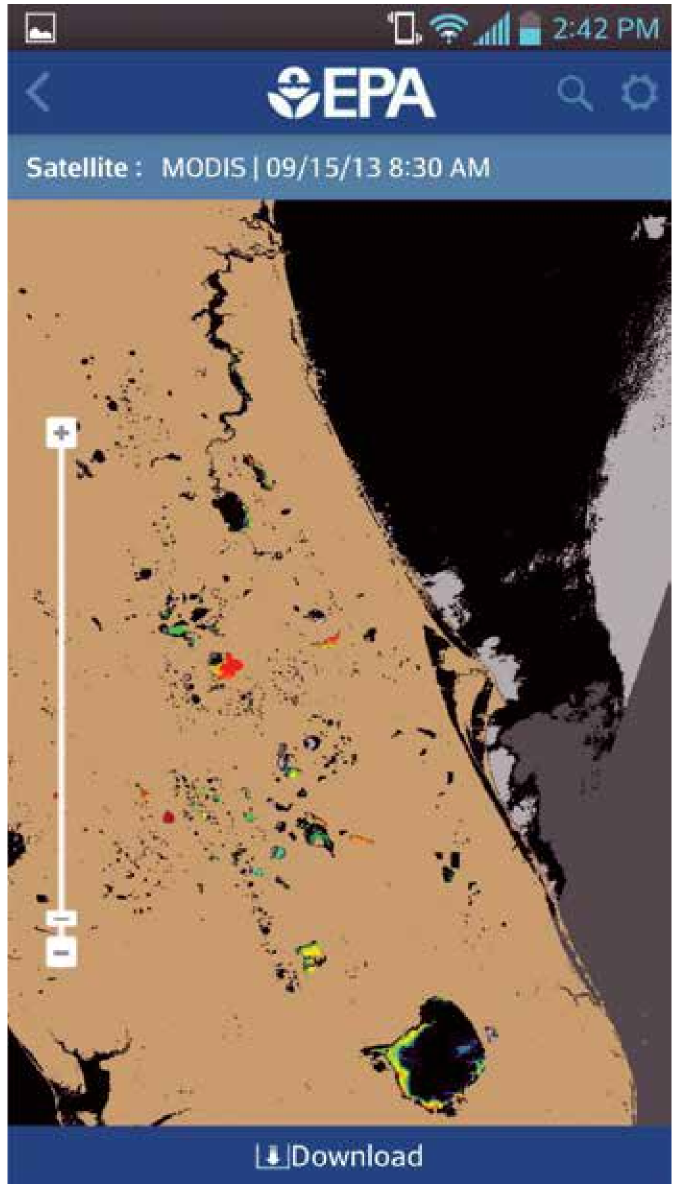

Figure 3. Example satellite imagery for Florida that can be displayed within the mobile application. These geotiff files can also be downloaded so additional analysis can be conducted on computers. Note the color scale on the satellite imagery is not the same as the location pins. Satellite imagery color scale represents quantitative values of cyanobacteria cell count where blue color is low concentrations and red is high concentrations, much the same way someone reads a temperature map in a newspaper.

Question: What about the mobile application? How do I access it?

Answer: Since this mobile application is brand new software there will likely be a number of "bugs" in the system. We are working with a limited number of external partners to beta test the software. If you are interested in potentially testing the software please contact one of the co-authors. We will do our best to work with you and provide more details. Once our beta tests are complete the mobile application will be made available through the Google Play Store for free. At this time we are only focused on the Android operating system and at some point in the future we may develop the application for iOS.

Acknowledgements

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References

Lunetta, R.S., et al. 2015. Evaluation of cyanobacteria cell count detection derived from MERIS imagery across the eastern USA. *Remote Sensing of Environment,* 157:24-34.

Schaeffer, B.A., et al. 2013. Barriers to adopting satellite remote sensing for water quality management. *International Journal of Remote Sensing,* 34 (21): 7534-7544.

U.S. EPA. 2010. National Lakes Assessment. EPA 841-F-09-007.

U.S. EPA. 2013. National Rivers and Streams Assessment 2008-2009: A Collaborative Survey – DRAFT. EPA 841-D-13-001.

Wynne, T.T., et al. 2013. Evolution of a cyanobacterial bloom forecast system in western Lake Erie: Development and initial evaluation. *Journal of Great Lakes Research,* 39: 90-99.

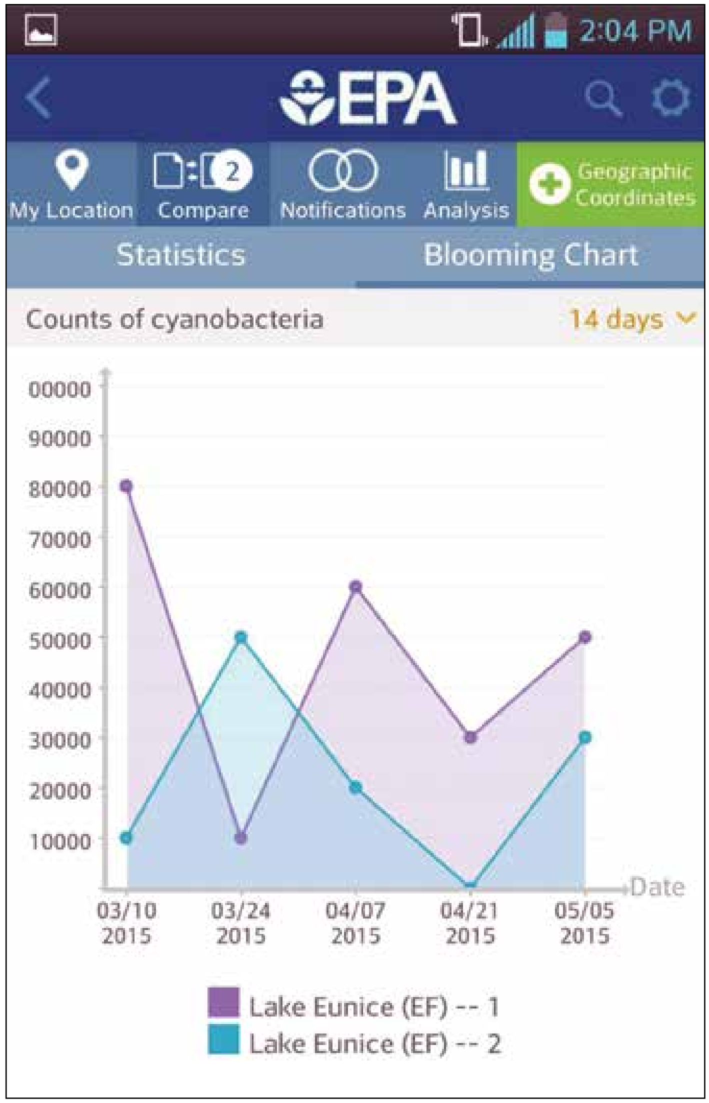

Figure 4. Example of how the mobile application displays changes in concentration for different location pins over time.

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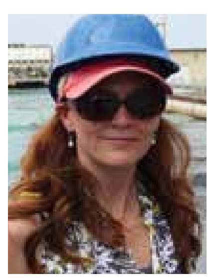

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