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Fact Sheet
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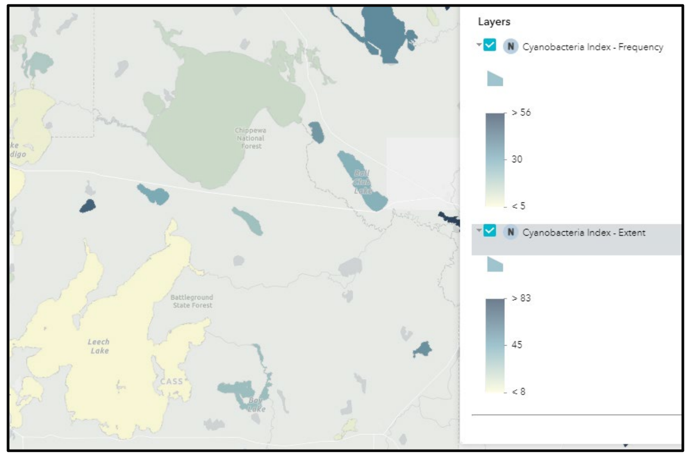
CyAN Extent and Bloom Frequency

Two EnviroAtlas national maps display 1) the annual spatial extent and 2) the frequency of cyanobacteria blooms observed in over 2,000 large lakes and reservoirs across the conterminous U.S. for the years 2008–2011 and 2017–2021 (annual updates are expected). These data were derived from satellite imagery acquired from the multiagency Cyanobacteria Assessment Network (CyAN).



Why are CyAN extent and bloom frequency important?

Though cyanobacteria (or blue-green algae) contribute to the aquatic food web, cyanobacterial algal blooms may cause a variety of economic, social, and environmental impacts. Harmful algal blooms and associated cyanobacteria disrupt fisheries, prevent recreational activity, and obstruct water supply processes at high economic costs. Algal bloom growth and subsequent algal biomass decay can cause hypoxia, leading to fish kills from oxygen deprivation. Blooms may also lead to taste and odor problems in treated drinking water. In terms of human health, cyanobacteria synthesize hepatoxins, neurotoxins, and dermatoxins, directly affecting humans and other organisms.

Despite the importance of cyanobacteria in water management, field monitoring is often time consuming and prohibitively expensive, resulting in limited availability of information for policymakers, managers, and other decision makers. Satellite-derived data provided with the CyAN product offer a spatial summary of cyanobacteria frequency and extent for over 2,000 large lakes and reservoirs across the continental U.S., allowing for better coordination of field monitoring efforts at high-risk locations.

The EnviroAtlas map for CyAN spatial extent estimates the annual spatial area of a lake or reservoir with detectable cyanobacterial blooms, expressed as a percent from 0 to 100[1,2]. Yearly data show a seasonal pattern, with maximum extent mainly occurring late summer and early autumn Data across years show a moderate increase in spatial extent in the South and Southeast in recent years. The EnviroAtlas CyAn frequency map displays the percentage of weeks in a year that cyanobacteria are detectable in an average lake or reservoir.

How can I use this information?

These two EnviroAtlas maps, CyAN Extent and CyAN Frequency, estimate the annual spatial extent and the annual temporal frequency (both expressed as percentages from 0 to 100) of cyanobacterial biomass for over 2,000 freshwater lakes in the conterminous U.S. Candidate lakes were of sufficient size and shape to accommodate at least three 300×300 meter satellite pixels. Scientific researchers can use this information to compare cyanobacteria extent and frequency with other landscape-scale environmental variables to better understand the contributing factors to bloom occurrence. In addition, these data allow for the study of local cyanobacteria processes by highlighting lakes where cyanobacteria bloom frequency and extent deviates from the local norm. These data could be used to select lakes for restoration projects or used in conjunction with other data in EnviroAtlas for monitoring and analyzing the impacts of cyanobacterial blooms.[3,4] For example, these data used with EnviroAtlas demographic data can highlight which human populations are susceptible to cyanobacteria exposure. These data could also be combined with land cover information to determine the land use types associated with frequent blooms.

How were the data for this map created?

These data were derived from two European Space Agency sensors: (1) the MEdium Resolution Imaging Spectrometer (MERIS) onboard the Envisat satellite (collected over the continental U.S. from 2008–2011) and (2) the Ocean and Land Colour Instrument (OLCI) onboard the Sentinel-3 satellite series, which began collecting data in 2016. Estimates of spectral surface albedo, Rhos, were generated by removing Rayleigh radiances from the satellite's top-of-atmosphere signal. Clouds were masked to eliminate their misidentification as a bloom using a spectral albedo threshold

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algorithm that accounts for turbid water. Likewise, snow and ice were masked using data from the National Snow and Ice Data Center.[5] Estimates of rhos were used to calculate the Cyanobacteria Index (CI-cyano) from two spectral shape algorithms described in the literature.[2,3] Field validation of the CI-cyano algorithm has been demonstrated in 6 studies listed below.[6,7,8,9] The CI-cyano data was then temporally aggregated to provide estimates of weekly maximum cyanobacteria concentration for 300×300 meter satellite pixels. The frequency of cyanobacteria blooms was defined for each satellite pixel as the proportion of satellite images for that pixel throughout the time-period exhibiting detectable cyanobacteria.[10] This resulted in values between 0 and 100%, where 100% indicated a cyanobacterial biomass was detected by the satellite sensor for every satellite image considered. To compute bloom frequency per lake, state, or other geographic boundary, the frequencies for each pixel within the boundary were averaged. The map for cyanobacterial spatial extent shows the median annual surface area of detectable cyanobacteria expressed in values between 0 and 100%.

What are the limitations of these data?

These data were derived from remotely sensed satellite data which has several limitations to consider. Data gaps exist from cloud cover, sun glint contamination, and the presence of snow and ice. Satellite imagery used for this analysis has a spatial resolution of 300 m, meaning it does not detect smaller lakes and reservoirs. These methods have been peer-reviewed and partially validated, but there are additional known limitations and issues documented in NASA's Cyanobacteria Assessment Network Release Notes. Finally, satellite observations only consider the upper layer of the water column and cannot characterize blooms at depth.

How can I access these data?

EnviroAtlas data can be viewed in the Interactive Map, accessed through web services, or downloaded. EnviroAtlas provides these data for individual lakes. These data are also provided by EPA's Report on the Environment for regions and the conterminous U.S.

Where can I get more information?

There are numerous resources on the cyanobacteria remote sensing methods; a selection of these resources is listed below. Further information about the CyAN project can be found in NASA's Cyanobacteria Assessment Network website. For additional information on how the data were created, access the metadata for the data layer. To ask specific questions about these data, please contact the EnviroAtlas Team.

Acknowledgments

These data were generated as part of a multi-agency collaboration among NASA, NOAA, USGS, and EPA. The fact sheet was created by Amber Ignatius, Erin Urquhart, and Megan Coffer (EPA ORISE Postdoctoral Fellows), and Blake Schaeffer (EPA).

Selected Publications

1. Schaeffer, B.A., E. Urquhart, M. Coffer, W. Salls, R. Stumpf, K. Loftin, and P.J. Werdell. 2022. Satellites quantify the spatial extent of cyanobacterial blooms across the United States at multiple scales. *Ecological Indicators* 140: 108990.

2. Urquhart, E.A., B.A. Schaeffer, R.P. Stumpf, K.A. Loftin, and P.J. Werdell. 2017. A method for examining temporal changes in cyanobacterial harmful algal bloom spatial extent using satellite remote sensing. *Harmful Algae* 67: 144–152.

3. Zhang, J., D.J. Phaneuf, and B.A. Schaeffer. 2022. Property values and cyanobacterial algal blooms: Evidence from satellite monitoring of inland lakes. *Ecological Economics* 199: 107481.

4. Ignatius, A.R., S.T. Purucker, B.A Schaeffer, K. Wolfe, E. Urquhart, and D. Smith. 2022. Satellite-derived cyanobacteria frequency and magnitude in headwaters & near-dam reservoir surface waters of the Southern U.S. *Science of the Total Environment* 822: 153568.

5. Urquhart, E.A., and B.A. Schaeffer. 2020. Envisat MERIS and Sentinel-3 OLCI satellite lake biophysical water quality flag dataset for the contiguous United States. *Data in Brief* 28. 104826. Doi: 10.1016/j.dib.2019.

6. Seegers, B.N., P.J. Werdell, R.A. Wandermeulen, W.B. Salls, R.P. Stumpf, B.A. Schaeffer, T.J. Owens, S.W. Bailey, J.P. Scott, and K.A. Loftin. 2021. Satellites for long-term monitoring of inland U.S. lakes: The MERIS time series and application for chlorophyll-a. *Remote Sensing of the Environment* 266. Doi: 10.1016/j.rse.2021.112685.

7. Coffer, M.M., B.A. Schaeffer, K. Foreman, A. Porteous, K.A. Loftin, R.P. Stumpf, P.J. Werdell, E.A. Urquhart, R.J. Albert, and J.A. Darling. 2021a. Assessing cyanobacterial frequency and abundance at surface waters near drinking water intakes across the United States. *Water Research* 201. Doi: 10.1016/j.watres.2021.117377.

8. Mishra, S., R.P. Stumpf, B.A. Schaeffer, P.J. Werdell, K.A. Loftin, and A. Meredith. 2021. Evaluation of a satellite-based cyanobacteria bloom detection algorithm using field-measured microcystin data. *Science of the Total Environment* 774.

9. Whitman, P., B.A. Schaeffer, W.B. Salls, M. Coffer, S. Mishra, B. Seegers, K. Loftin, R. Stumpf, and P.J. Werdell. 2022. A validation of satellite derived cyanobacteria detections with state reported events and recreation advisories across US lakes. *Harmful Algae* 115: 102191.

10. Coffer, M.M., B.A. Schaeffer, W.B. Salls, E.A. Urquhart, K.A. Loftin, R.P. Stumpf, P.J. Werdell, and J.A. Darling. 2021b. Satellite remote sensing to assess cyanobacterial bloom frequency across the United States at multiple spatial scales. *Ecological Indicators* 128.