**Release notes for NASA-produced MERIS and OLCI cyanobacteria index (CI\_cyano) data product to support the Cyanobacteria Assessment Network (CyAN) Project**

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# Version History

This is version 3; August 2020

Four U.S. federal agencies – EPA, NASA, NOAA, and USGS – collaborated to form the Cyanobacteria Assessment Network (CyAN) Project. This work is supported by the NASA Ocean Biology and Biogeochemistry Program/Applied Sciences Program (proposal 14-SMDUNSOL14-0001 and SMDSS20-0006) and by in-kind contributions from the U.S. EPA, NOAA, and the U.S. Geological Survey Toxic Substances Hydrology Program [*Schaeffer et al.*, 2015]. NASA’s principal role in CyAN is the production, validation, and distribution of satellite-derived cyanobacteria index (CI-cyano) data products from the ESA Medium Resolution Imaging Spectrometer onboard Envisat (MERIS; 2002-2012) and Ocean Colour Land Imager onboard Sentinel-3A (OLCI; 2017-present) and Sentinel-3B (2018-present) for the continental United States (CONUS) and Alaska (Table 1). This document accompanies NASA’s production of CI-cyano data products for MERIS and OLCI and is currently intended for CyAN Collaborators, who will be provided access for review and feedback.

*Table 1. Agency roles and responsibilities.*

|  |  |
| --- | --- |
| Agency | Role |
| EPA | Satellite application methods for management of freshwater HABs and water quality |
| NASA | Satellite data processing, evaluation/validation, quality control |
| NOAA | Satellite algorithms to detect and forecast HABs for marine systems and Great Lakes |
| USGS | Field freshwater HAB monitoring, ecological expertise, Landsat satellite management |

# Overview of data files and processing

As detailed metadata for each file can be found in Appendix A, this section provides only top-level details on file format and content. Briefly, the NASA Ocean Biology Processing Group (OBPG; https://oceancolor.gsfc.nasa.gov) at Goddard Space Flight Center (GSFC) generated the MERIS and OLCI CI\_cyano data files. The CI-cyano algorithm is fully described in *Wynne et al.* [2008], *Wynne et al.* [2010], and *Lunetta et al.* [2015]. The data files are temporal CI\_cyano composites at 300-m resolution. These composites were transformed to Albers Equal Area projection with an area-weighted interpolation to match the projections of the National Hydrography Dataset. Shuttle Radar Topography Mission (SRTM) 60-meter data provided the land mask (https://dds.cr.usgs.gov/srtm/version2\_1/SWBD/). The CI\_cyano value in each pixel represents the maximum CI\_cyano value for both the daily and 7-day composite periods. CONUS and Alaska composites are divided into and delivered as a regional numbered tile (Figure 1 and Figure 2), representing a spatial area made into a separate file. The data file name will use the column and row number to identify the tile location.

A close up

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*Figure 1. Envisat and Sentinel-3 CONUS satellite tiles (9X6 tiles)*

A screen shot of a building

Description automatically generated

*Figure 2. Envisat and Sentinel-3 Alaska satellite tiles (4x3 tiles)*

Each data file is stored in 8-bit GeoTIFF, where values of:

* 0 indicate below threshold CI\_cyano detection limits
* 1-253 are data
* 254 is land
* 255 are no data (e.g., a cloudy pixel)

Digital numbers (DN) can be converted to an estimated cyanobacteria abundance in cells/ml. This estimated is based on microcystis equivalents using a relationship established in western basin Lake Erie (Wynne et al., 2010).

* CI\_cyano = 10^(0.012 \* DN - 4.2)
* A screenshot of a cell phone

  Description automatically generatedcyanobacteria abundance (cells/ml) = CI\_cyano \* 1.0E+8

MERIS/OLCI data files follow this naming convention:

sensoryyyydddyyyyddd.datalevel\_temporalresolution\_product\_version\_resolution\_region

A file named *M20120642012070.L3m\_7D\_CYAN\_CI\_cyano\_CYAN\_CONUS\_300m\_5\_3*, for example, is decomposed as:

* sensor: *M* = MERIS, L =OLCI
* yyyydddyyyddd : *20120642012070* = year 2012 day 064 to year 2012 calendar day 070
* datalevel: *L3m* = satellite processing level-3, mapped image
* temporalresolution: *7D* = 7 day temporal composite, DAY = daily maximum
* product:Project identifier (*CI\_cyano (CI cyanobacteria product), tc (true color))*: CYAN\_ CI\_cyano, CyANTC\_tc, CYANAK\_ CI\_cyano, CYANAKTC\_tc.
* version: *CYAN\_CONUS,* CYAN\_AK (Alaska)
* resolution : *300m* = pixel resolution
* region : *5*\_*3* = tile column (5) and row (3)

 \* The Alaska naming conventions follows a similar pattern with the single difference of “AK” replacing “CONUS” in the file name.

Data for OLCI are provided as 7-day composites and dailies for CI\_cyano and daily true color images. The OLCI products are merged Sentinel-3A and 3B from 2018-present. Data for MERIS are provided as 14-day composites from 2002-2007, when the instrument irregularly viewed the US and as 7-day composites and dailies from 2008-2012, when the instrument regularly collected data over the US. Daily

True color images are also provided for CONUS and Alaska for MERIS and OLCI with 2018 true colors being a composite of OLCI Sentinel-3A and 3B.

These data are validated Stage 2 of 4 on NASA’s data maturity level ranking. This is defined as “data product accuracy is estimated using a significant set (although not full US/global) of independent measurements obtained from selected locations and time periods and ground-truth/field program efforts. There have been some peer-reviewed publications on the accuracy, but for limited spatial areas.” Additional details on NASA’s data maturity levels can be found at

https://science.nasa.gov/earth-science/earth-science-data/data-maturity-levels .

For details on data product validation efforts and applications, see *Binding et al.* [2011], *Matthews et al.* [2012], *Moradi* [2014], *Lunetta et al.* [2015], *Matthews and Odermatt* [2015], *Palmer et al.* [2015a], *Palmer et al.* [2015b], *Tomlinson et al.* [2016], *Urquhart et al.* [2017, 2019], *Clark et al.* [2017], *Schaeffer et al.* [2018], *Mishra et al.* [2019], *Coffer et al.* [2020], *Stroming et al.* [2020].

# Processing version and reprocessing schedule

All data are processing version 3 (July 2020). Data are preliminary and to be used for evaluation purposes only. Known outstanding issues are listed below.

The CyAN Project and OBPG will periodically reprocess and redistribute the MERIS and OLCI CI\_cyano time-series. Reprocessing will occur every 10 to 16 months. The next reprocessing (version 4) will occur in Spring or Summer 2021.

# Version 3 improvements/changes

The following improvements have been implemented in version 3.

1. This version includes a merged OLCI CI\_cyano product combining the data from Sentinel-3A and Sentinel-3B from 2018-present. The merged product is the maximum value for each pixel. The utilization of two satellites greatly increases spatial and temporal coverage relative to the previous sentinel-3A coverage only.
2. True color daily imagery from 2018-present use a combined imagery from S3A and S3B OLCI. If there is sensor swath overlap the true color image shows the mean value.
3. The land mask has been updated with an improvement in Ohio and South Dakota lakes.
4. The GEOtiffs now include product version information in metadata
5. There was a switch made to area weighted binning. Area weighting uses the intersection of the pixel geometry and the bin geometry (in lat/lon space) as a weighting factor when adding the pixel value into the bin. Each pixel is added to all bins that it intersects. The old binning scheme added the pixel to the closest bin using the center lat/lon location of each. Each pixel is only added to one bin. The area weighting makes a much nicer picture. For example, if the pixel area is bigger than the bin area, then you will end up with lots of empty bin using the old method.
6. Code fixes have been made to improve masking, especially nearshore potentially stray light contaminated pixels.
7. The 39 degree zenith angle filter was removed for OLCI, which increased the number of pixel recovered. The filter was put in place for MERIS, but is not necessary for OLCI.
8. In the imagery non-detect values (e.g. below detection threshold) have been color-separated from no data values (e.g., a cloudy pixel). Non-detects are grey and no data are black.
9. Lake Pontchartrain coastal masking error removed resulting in full lake CI coverage.
10. More nearshore CONUS coast will be processed.

# Known issues

The following issues will be addressed or resolved in future releases of these data.

(1) A snow/flag that identifies ice has been applied, but has not yet been verified**.** Ice can potentially register as high CI counts, so caution should be used where snow/ice might be visible. It is currently unknown if CyAN could detect cyanobacteria under thin ice in lakes and reservoirs.

(2) The SRTM land mask may cover dry lakes, and may exclude other lakes. There is a need for an eroded landmask.

(3) A flag has been added to identify mixed pixels that are potentially inclusive of land and water. The flag has not yet been verified, so caution should be used where mixed pixels may occur at the land/water interface.

(4) Undetected thin clouds can potentially register as high CI counts (elevating CI beyond the minimum detect threshold value).

(5) Retrievals are considered more robust for lakes ≥ 900 m window width as defined in *Clark et al.* [2017]. This 900 m window width provides a minimum of a 3 x 3-pixel array in a water body. Smaller water bodies and rivers are not masked and their data may be erroneous.

(7) Satellite data processing does not account for changes in water levels due to cycles such as drought and flood.

(8) Published US validation locations are Lake Erie, Florida, Ohio, Vermont, New Hampshire, Rhode Island, Connecticut, Massachusetts, Oregon, California, Indiana, New Jersey, New York, Utah, New Hampshire, Vermont, Maine, California, Oregon, and Idaho.

Difference CyAN and NOAA-produced products

We thought it may be worth including the following text regarding CyAN (NASA produced) and NOAA produced product differences with the release:

Known differences between NOAA/NCCOS and CyAN CI products

- Flagging

o NOAA/NCCOS land=252, invalid=251,253,254,255

o CyAN land=254, invalid=255

- Range of valid data values

o NOAA/NCCOS 0-250

o CyAN 0-253

Differences in pixel values will also be noted due to differences in binning/mapping methods and differences in land masks used.

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# Appendix A: CyAN MERIS metadata

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<gco:CharacterString>This dataset shows the concentration of cyanobacteria in fresh water bodies and estuaries of the continental United States and Alaska derived from 300x300 meter Envisat MEdium Resolution Imaging Spectrometer (MERIS), and Sentinel-3 Ocean and Land Colour Imager (OLCI) satellite imagery. This dataset was produced through partnership with the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the United States Geological Survey (USGS), and the United States Environmental Protection Agency (USEPA). Envisat MERIS data is available from 2002-2012 and Sentinel-3 OLCI data is available from 2016 to present.The data files are temporal CI\_cyano composites at 300-m resolution. These composites were transformed to Albers Equal Area projection with an area-weighted interpolation to match the projections of the National Hydrography Dataset. Shuttle Radar Topography Mission (SRTM) 60-meter data provided the land mask (https://dds.cr.usgs.gov/srtm/version2\_1/SWBD/). The CI\_cyano value in each pixel represents the maximum CI\_cyano value for both the daily and 7-day composite periods. CONUS and Alaska composites are divided into and delivered as a regional numbered tile, representing a spatial area made into a separate file. The data file name will use the column and row number to identify the tile location.Each data file is stored in 8-bit GeoTIFF, where values of: 0 indicate below threshold CI\_cyano detection limits1-253 are data254 is land 255 are no data (e.g., a cloudy pixel)Digital numbers (DN) can be converted to an estimated cyanobacteria abundance in cells/ml. This estimated is based on microcystis equivalents using a relationship established in western basin Lake Erie (ref).CI\_cyano = 10^(0.012 \* DN - 4.2)cyanobacteria abundance (cells/ml) = CI\_cyano \* 1.0E+8MERIS/OLCI data files follow this naming convention:sensoryyyydddyyyyddd.datalevel\_temporalresolution\_product\_version\_resolution\_regionA file named M20120642012070.L3m\_7D\_CYAN\_CI\_cyano\_CYAN\_CONUS\_300m\_5\_3, for example, is decomposed as: sensor= M= MERIS,L =OLCIyyyydddyyyddd= 20120642012070= year 2012 day 064 to year 2012 calendar day 070datalevel= L3m= satellite processing level-3, mapped imagetemporalresolution= 7D= 7 day temporal composite,DAY = daily maximumproduct: Project identifier = CYAN\_ CI\_cyano, CyANTC\_tc, CYANAK\_ CI\_cyano, CYANAKTC\_tc. CI\_cyano (CI cyanobacteria product), tc (true color)version= CYAN\_CONUS, CYAN\_AK (Alaska)resolution= 300m= pixel resolutionregion= 5\_3= tile column (5) and row (3)Data for OLCI are provided as 7-day composites and dailies. The OLCI products are merged Sentinel-3A and 3B from 2018-present. Data for MERIS are provided as 14-day composites from 2002-2007, when the instrument irregularly viewed the US and as 7-day composites and dailies from 2008-2012, when the instrument regularly collected data over the US. These data are validated Stage 2 of 4 on NASA’s data maturity level ranking. This is defined as “data product accuracy is estimated using a significant set (although not full US/global) of independent measurements obtained from selected locations and time periods and ground-truth/field program efforts. There have been some peer-reviewed publications on the accuracy, but for limited spatial areas.” Additional details on NASA’s data maturity levels can be found athttps://science.nasa.gov/earth-science/earth-science-data/data-maturity-levels . The CyAN implementation of CI proceeds as follows. Derivative spectral shapes (SS) where rs is spectral Rayleigh-corrected top-of-atmosphere reflectance and the superscript – and + indicate one sensor waveband less and more, respectively, than the target sensor waveband. The wavelength(-), wavlength(), and wavelength(+)for MERIS -SS(681) encompasses sensor wavebands 665, 681, and 709 nm, while SS(665) incorporates 620, 665, and 681 nm (Lunetta et al., 2014). This combined SS algorithm is referred to as CI\_multi in Lunetta et al. (2014). The original CI defined as -SS(681) provides a metric of biomass independent of the presence of cyanoHABs (Wynne et al. 2008). The negative SS(681) signal results from the combination of strong chlorophyll-a absorption at that wavelength with insignificant fluorescence from cyanobacteria at 681 nm (Seppälä et al., 2007; Wynne et al., 2008; Binding et al., 2011). This was thought distinct from non-cyanobacteria phytoplankton, which would have an increased fluorescence signal combined with chlorophyll absorption resulting in a comparably higher reflectance. However, as dense blooms of true algae can have relatively weak fluorescence, observations have been made since that the standalone -SS(681) CI algorithm occasionally also identifies these other algal blooms (Matthews et al. 2012, Wynne et al., 2013). Therefore, the original CI from Wynne et al. (2008) without the SS(665) exclusion criteria could be a combination of a signal from cyanobacteria and non-cyanobacteria blooms (aka CI = CI\_cyano + CI\_noncyano). Though the CI algorithm has been proven to deliver robust estimates of biomass for cyanobacteria blooms it is not necessarily appropriate for non-cyanobacteria biomass estimates (Wynne et al., 2010, 2013). Therefore, CI was modified adding the SS(665) as exclusionary criteria to better ensure estimates of cyanobacteria biomass (e.g., Matthews 2012; Wynne et al., 2013; Lunetta et al., 2014; Coffer et al. 2020). Coffer et al. (2020) details the evolution of the CyAN CI\_cyano (referencing CI\_cyano as CI\_multi from Lunetta et al and then proceeded to use just the abbreviation CI to represent CI\_cyano) including the use of SS(665) to differentiate cyanoHAB blooms from other algae defined by Matthews et al (2012). The focus of this paper will reference CI\_cyano to make clear it uses the spectral shape around 665 nm as exclusion criteria to avoid false positives that can result from classifying other algal blooms as cyanobacteria blooms. Wynne et al. (2018) provides some details of CyAN CI, CI\_cyano, and CI\_noncyano products and additional QA information such as a correction for clear water, masks and exclusion criteria.</gco:CharacterString>

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<gco:CharacterString>This work is supported by the NASA Ocean Biology and Biogeochemistry Program (14-SMDUNSOL14-0001), Applied Sciences Program (SMDSS20-0006) and by in-kind contributions from the U.S. EPA, NOAA, and the U.S. Geological Survey Toxic Substances Hydrology Program. </gco:CharacterString>

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