EOCIS

EARTH OBSERVATION CLIMATE INFORMATION SERVICE

Quick Start Guide

Lake Catchment Change – Lake Colour Products

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1. Quick Start: Lake Catchment Change

The following will provide you with sufficient information to quickly get to grips with the Lake Catchment Change product(s) and to gain some familiarity with the information available.

1.1 What products are available?

Product name and acronym	Filename example	Version
Lake Water-Leaving Reflectance and derived indicators	EOCIS-Lakes-L3U-LWLR-Lake_Catchment-20200702-fv1.5.0.nc	1.5.0

Table 1 Dataset Products covered in this document

1.2 Summary information

Table 2 Summary Information for Lake Water-Leaving Reflectance

Product Name	**Lake Water-Leaving Reflectance and derived indicators**
Main observed variable(s)	The following variables are masked in the presence of cloud, cloud shadow, and land: Lake Water-Leaving Reflectance (RwXYZ) with XYZ denoting waveband: 443, 490, 560, 665, 705, 740, 783, 842, 865, 945, 1375, 1610, 2190 Chlorophyll *a* concentration Turbidity The following variables are provided for the full area: Normalized Difference Vegetation Index Normalized Difference Built-Up Index Augmented Normalized Difference Water Index Modified Normalized Difference Water Index
Geographical range of dataset	A specific lake catchment, e.g. Lough Neagh
Temporal range of dataset	2016-2023, each available Sentinel-2 overpass, no temporal agregation applied
Spatial resolution / gridding	UK CHUK Grid at 100m
Temporal sampling characteristics	No temporal resampling
Level of processing	L3 gridded data
Main auxiliary content	None
Dataset citation	Plymouth Marine Laboratory for EOCIS
Dataset journal reference	Chlorophyll-a and Turbidity algorithms were validated in Warren et al. 2021

1.2.1 Variables summary information

Table 3 Summary information for each variable for Lake Water-Leaving Reflectance

Variable name	Description	Units
Rw443 to Rw2190	Atmospherically corrected aquatic reflectance	Dimensionless
chla_top_2_weighted	Chlorophyll *a* concentration	mg m^{-3}
Turbidity	Turbidity	Normalised Turbidity Units
NDVI	Normalized Difference Vegetation Index	Dimensionless
NDBI	Normalized Difference Built-Up Index	Dimensionless
ANDWI	Augmented Normalized Difference Water Index	Dimensionless
MNDWI	Modified Normalized Difference Water Index	Dimensionless

1.3 What can these products be used for?

The Product(s) can be used to map variations in the reflectance of water bodies contained in the target lake catchment. The derived quantities turbidity and chlorophyll-a can be used to determine variability in the optical and biochemical conditions of the lake and other included water bodies.

High-resolution observations of LWLR are made with satellite sensors which are not specifically optimised to capture aquatic reflectance. Thus, the accuracy of atmospheric correction will depend on observation conditions. Remote sensing of very small water bodies is only possible when atmospheric conditions are favourable, due to mixing of reflected light from water and adjacent land in the atmosphere. These data are provided without strict quality filtering (which would remove the majority of observations over small water bodies) and should be interpreted with expert care.

The LWLR wavebands have been masked in the presence of detected cloud, cloud shadow and land pixels using the Idepix operator of the SNAP toolbox.

A set of vegetation, built-up area, and water indices (NDVI, NDBI, ANDWI, MDNWI) are included to aid users in selection data ranges and locations of interest.

1.4 Where to find these products for download

To access the dataset products(s) navigate to the locations indicated below:

Centre for Environmental Data Analysis:

- https://catalogue.ceda.ac.uk/uuid/6e329e32570d4d4f818b8f8aa18e7a85/

1.5 Using downloaded data

Noting the limitations mentioned in Section 1.3, the data can be readily used with software capable of reading and displaying the NetCDF format.

1.5.1 Import Data

Below follows an example using xarray to open, inspect, plot and filter variables contained in a typical lake catchment LWLR record, in this case for Lough Neagh in Northern Ireland.

Import using python and xarray

```
import xarray as xr
import os

filename='EOCIS-Lakes-L3U-LWLR-Lake_Catchment-20230614-Lough_Neagh-fv1.5.0.nc'
ds = xr.open_dataset(filename)
ds
```

Illustrative results:

```
<xarray.Dataset>
Dimensions:                (time: 1, x: 1209, y: 1061)
Coordinates:
  * time                   (time) datetime64[ns] 2023-06-14T11:43:49
    crsOSGB                int64 ...
  * x                      (x) int32 41650 41750 ... 162250 162350 162450
  * y                      (y) int32 577750 577650 ... 471950 471850 471750
    lat                    (y, x) float32 ...
    lon                    (y, x) float32 ...
Data variables: (12/20)
    Rw443                  (time, y, x) float32 ...
    Rw490                  (time, y, x) float32 ...
    Rw560                  (time, y, x) float32 ...
    Rw665                  (time, y, x) float32 ...
    Rw705                  (time, y, x) float32 ...
    Rw740                  (time, y, x) float32 ...
    ...                     ...
    chla_top_2_weighted    (time, y, x) float32 ...
    NDVI                   (time, y, x) float64 ...
    NDBI                   (time, y, x) float64 ...
    ANDWI                  (time, y, x) float64 ...
    MNDWI                  (time, y, x) float64 ...
    spatial_ref            int64 ...
Attributes: (12/34)
    geospatial_lat_min:          54.01691436767578
    geospatial_lat_max:          55.0373420715332
    geospatial_lon_min:          -7.601479530334473
    geospatial_lon_max:          -5.633663177490234
    date_created:                Tue Oct  1 15:47:27 2024
    time_coverage_start:         20230820T094549
```

```
...                              ...
geospatial_lat_resolution:  100m
key_variables:              Lake water-leaving reflectance in 13 waveband..
acknowledgement:            This work was supported by the Natural Enviro..
program:                    EOCIS
program_url:                https://eocis.org
program_email:              EOCIS@reading.ac.uk
```

1.5.2 Plotting data

Continuing from the import above, we can plot some of the data. Note that the spatial extent of the data is the whole catchment. To better understand where products related to observable water, we first determine a land versus water mask using the Mean Normalised Differential Water Index.

Plotting code:

```
# Plot the MDNWI
ax = ds.MNDWI[0].plot.imshow()
```

Illustrative results:

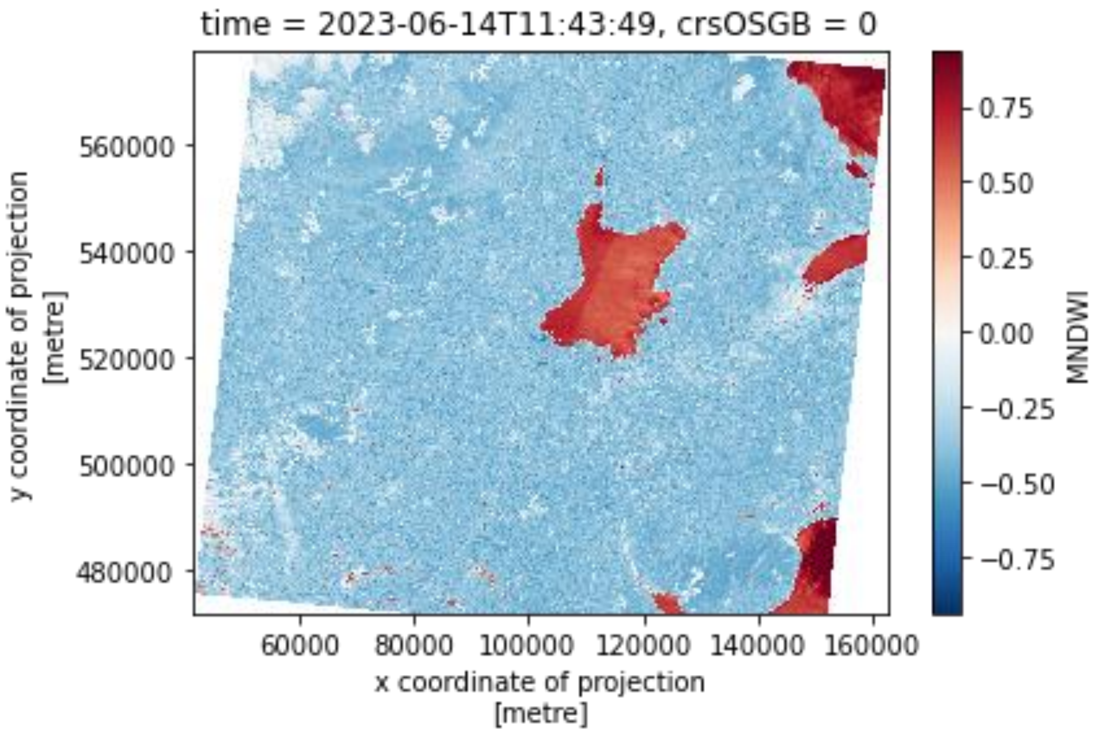

Figure 1 New layer formed from the input product

1.5.3 Filtering data

We can now apply the water mask to show data in variables that are specific to water.

Filtering code:

```
chla_valid_min = 0    # for visualisation only

chla_valid_max = 100  # for visualisation only

ax = ds.chla_top_2_weighted[0].where(ds.MNDWI[0]>0.0)\
                              .plot.imshow(vmin=chla_valid_min,
                                           vmax=chla_valid_max)
friendly_clabel = "Chl-a [mg/m3]"
ax.colorbar.set_label(friendly_clabel)
```

Illustrative results:

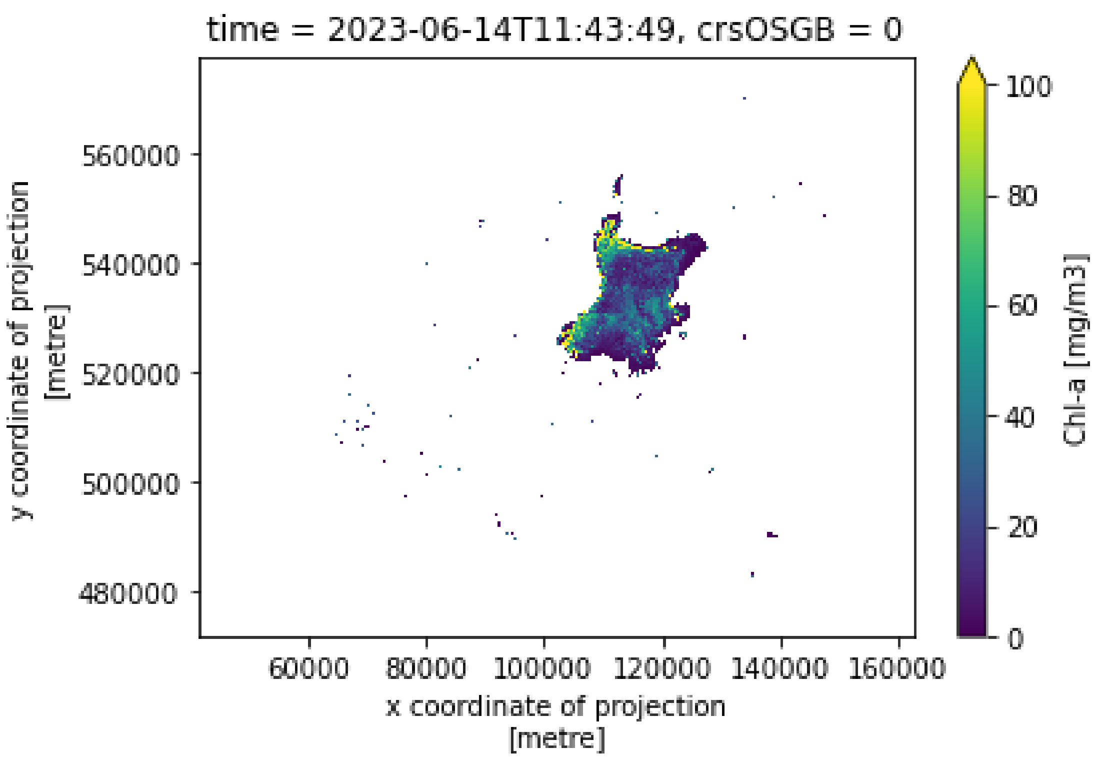

Figure 2 Filtered data layer

1.5.4 Subsetting data

We may choose to ignore the very small water bodies in the catchment, subsetting the area around Lough Neagh itself. Note that there are various ways to do this. For example, packages such as rioxarray and geopandas can be used to 'clip' the data around the lake based on a shapefile. Here, we simple slice the dataset along the x and y dimensions to suit our needs.

Subsetting code:

```
subset = ds.sel(x=slice(100000,130000),y=slice(560000, 510000))


ax = subset.chla_top_2_weighted[0].where(subset.MNDWI[0]>0.0)\
                                    .plot.imshow(vmin=chla_valid_min,
                                                 vmax=chla_valid_max)
ax.colorbar.set_label(friendly_clabel)
```

Illustrative results:

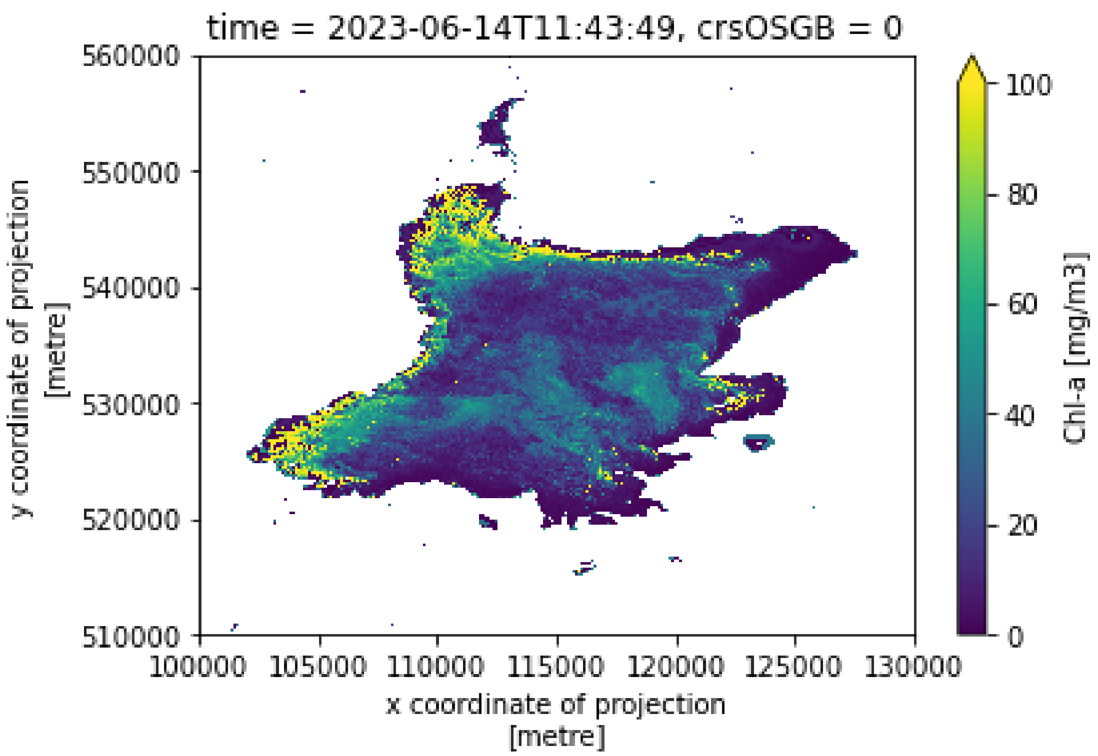

Figure 3 Subset of data layer

1.5.5 Re-Gridding/Formatting

Finally, it may be beneficial for comparison to other products to resample the data to a coarser resolution. Here we move from 100m to 1km by coarsening the dataset.

Coarsening code:

```
coarsen_x_by = 10  # reduction factor
coarsen_y_by = 10
coarsened = subset.coarsen(x=coarsen_x_by,
```

```
                                        y=coarsen_y_by,
                                        boundary='trim').mean()


ax = coarsened.chla_top_2_weighted[0].where(coarsened.MNDWI[0]>0.0)\
                                        .plot.imshow(vmin=chla_valid_min,
                                                     vmax=chla_valid_max)


ax.colorbar.set_label(friendly_clabel)
```

Illustrative results:

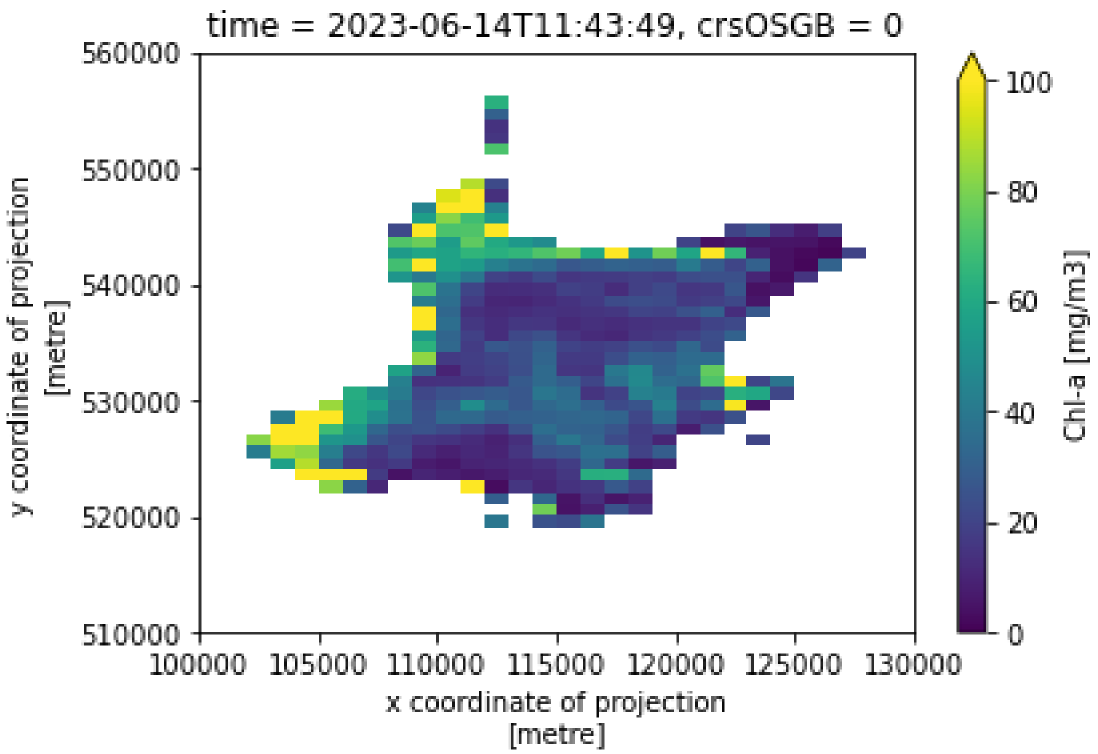

Figure 4 Coarsened data subset

1.5.6 Extracting a time series

The data are provided at daily time steps, one netCDF file covering each datums where a Sentinel-2 overpass was registered. Thus, to extract time-series information it is necessary to index multiple files. This is facilitated in xarray using the xarray.open_mfdataset method and matplotlib library as shown below.

Time series extraction code:

```
import xarray as xr
import matplotlib.pyplot as plt

# Access all chlorophyll-a observations
```

```
path_to_data = '/replace/with/appropriate/path/EOCIS*.nc'  #substitute correct path

ts = xr.open_mfdataset(path_to_data,
                       data_vars=['chla_top_2_weighted'],
                       chunks='auto')

# Select a coordinate in the image projection
station_y = 530000
station_x = 115000
pixvals = ts.chla_top_2_weighted[:].sel(x=station_x,
                                         y=station_y,
                                         method='nearest').values
# plot results
fig = plt.figure()
ax = fig.add_axes((0.2, 0.2, 0.7, 0.7))
ax.plot(ts.time.values, pixvals, marker='o', linewidth=0.1, markersize=2)
ax.set_ylabel('Chl-a [mg/m3]')
ax.set_xlabel('Time')
fig.show()
```

Illustrative results:

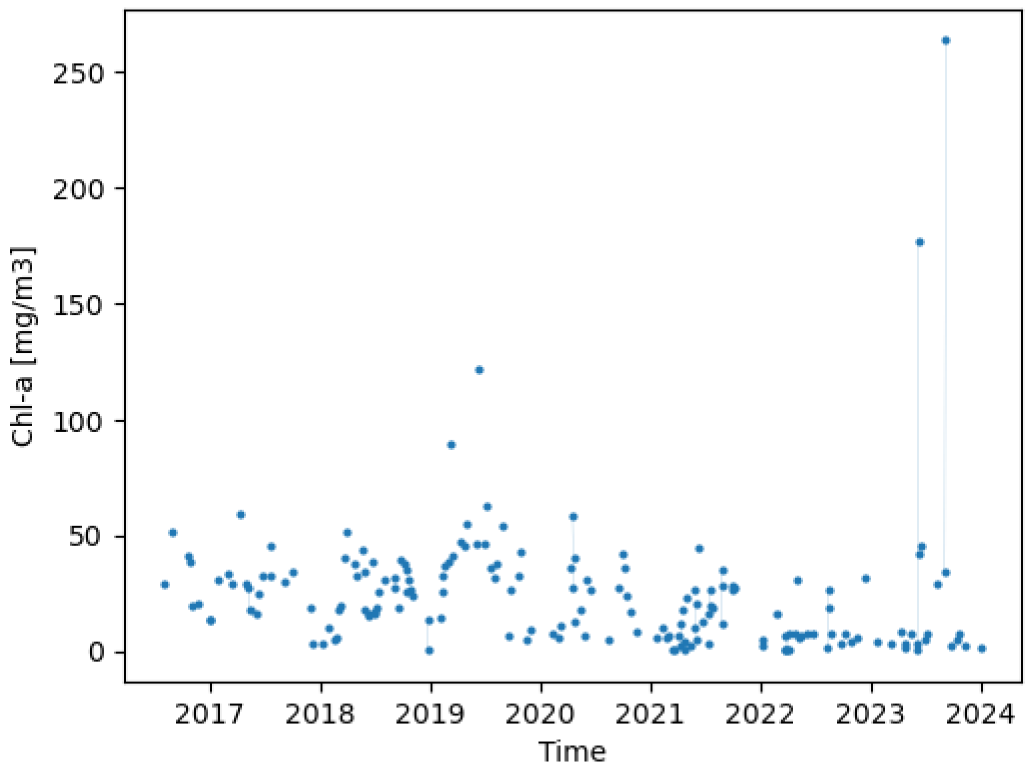

Figure 5 Time series of chlorophyll-a product at pixel location. Extreme values in the summer of 2023 correspond to reports of surface aggregation of cyanobacteria, which are erroneously interpreted as mixed column biomass.

1.6 Interactive visualisation / data access

Not applicable. Please follow the EOCIS website for updates.

1.7 Your obligations when using these products

By accessing this product you agree to cite the dataset digital object identifier (doi) and corresponding journal article describing the dataset every time you publish results obtained in whole or in part by use of UK EOCIS products. These citations are given under Summary Information.

The reference to the dataset should mention "created by the UK Earth Observation Climate Information Service". The product name and acronym in Table 1 and should be used to avoid confusion and enable traceability.

1.8 Further Information

This data set is provided on a demonstration basis, and is part of a wider set of results describing the dynamics of lake catchments in the UK for the period 2016-2023. Please contact the authors for any further information, such as on-demand production.

1.9 References

Warren, M. A., Simis, S. G. H., & Selmes, N. (2021). Complementary water quality observations from high and medium resolution Sentinel sensors by aligning chlorophyll-a and turbidity algorithms. Remote Sensing of Environment, 265, 112651. Doi: 10.1016/j.rse.2021.112651

History of modifications / Change Log

Version	Date	Changes	Person
1.1	30 Sep 2024	Initial Draft	SGHS
1.2	19 Dec 2024	Revised version: masking information, time-series plot example, added dataset location	SGHS

Related Documents / Reference Documents

Document	Author	Reference

Acronyms and/or Abbreviations

Acronym / Abbreviation	Definition
EOCIS	

General definitions

Term	Definition