



Product Specification Document (PSD)

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lakes
cci

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REFERENCE DOCUMENTS

PSD	Product Specification Document of the Lakes_CCI project Phase 1 (CCI-LAKES-016-PSD-V2.0)
URD	User Requirements Document of the Lakes_CCI project Phase 2 (CC-LAKES2-005-URD-V1.0)
ATBD	Algorithm Theoretical Basis Document
E3UB	End to End Uncertainty Budget

All documents are available through the project website: <https://climate.esa.int/en/projects/lakes/>



1. Introduction

The purpose of this product specification document (PSD) for the Lakes Climate Change Initiative project (Lakes_cci) is to translate a set of product requirements, detailed in the User Requirement Document (URD), into a specification of the data sets being generated. This document has been updated with respect to the next intended release of the Climate Research Data Package (CRDP), version 3.0.0, planned for the year 2025.

The URD contains a set of product requirements obtained through a review of existing reference documents and scientific literature, and collected from meetings of the Climate Modelling User group (CMUG, including related documents), Climate Research Group (CRG) and the wider lake research community, the latter via surveys. Table 1 contains those target requirements. Nevertheless, this does not mean that they are achieved.

Table 1. Synthesised observation of the target requirements for the Lake ECV thematic variables. Based on G: GCOS, Q: Questionnaire, P: Project team experience and L: Literature review.

Product	Lake Water Level	Lake Extent (or Lake Area)	Lake Surface Water Temperature	Lake Ice Cover (LIC)	Lake Ice Thickness (LIT)	Lake Water Leaving Reflectance (or Lake Colour)
Measurement uncertainty	1.5 cm for large lakes (G) 5 cm for the remainder (G)	5% (relative) (G) 2.5% (for 70 largest lakes) (G)	0.15 °K (P)	10% (G,P)	5 cm (P)	10-30% for peak waveband vs low signal bands (P/L), 0.1 mg m ⁻³ chlorophyll-a (L) and 1 g m ⁻³ suspended matter.
Stability	0.5 cm/decade (G)	2.5% /decade (G)	0.07 °K per decade (P)	1% /decade (G)	1 cm/decade (P)	1% /decade (G,P,L)
Spatial resolution	N/A : per lake (Q)	N/A : per lake (Q)	100 m (P)	100 m (P)	100 m (G)	100 m (P)
Temporal resolution	daily ground-based or satellite observations (G)	daily changes (G)	Daily (P)	daily observations (G,P)	Weekly observations (P)	Daily observations (Q)
Length of record	>10 years (L)	>10 years (L)	>10 years (L)	>10 years (L)	>10 years (L, P)	>10 years (L/P)



Product	Lake Water Level	Lake Extent (or Lake Area)	Lake Surface Water Temperature	Lake Ice Cover (LIC)	Lake Ice Thickness (LIT)	Lake Water Leaving Reflectance (or Lake Colour)
Maximum delay before availability of data (for climate users)	1 year (P)	1 year (P)	1 year (P)	1 year (P)	1 year (P)	1 year (P)

Table 2 synthesises requirements on products that apply to all variables. A primary requirement (satisfying most users) and a secondary requirement (an alternative that satisfies other users) are provided where relevant.

Table 2. Synthesised product requirements for the Lakes ECV

Aspect of products	Primary requirement	Secondary requirement
Slicing of data (Q)	Timeseries per lake	
Spatial aggregation (Q)	Per-lake values (LWE, LWL) Spatially resolved (LSWT, LIC, LWLR) Along-track values (LIT)	Per-lake values (LSWT, LIC, LIT, LWLR)
Data format (Q)	NetCDF	GEOTIFF
Access (Q)	FTP	Web mapping service
Availability of uncertainty (Q)	Required	
Projection (Q)	Regular latitude-longitude ("Level 3")	

The Lakes_cci dataset is generated on a global grid with daily time step. To meet the user requirement for per-lake data, scripts are available (https://github.com/ccilakes/lakes_cci_tools) to download only data slices describing a given lake or a defined zone and time period. Only NetCDF is used as data format, per the CCI data formatting standards. Access is provided through CEDA which supports HTTP, FTP as well as OpenDAP protocols.

The Lakes_cci has produced five releases of the Lakes climate data record during Phase 1 and Phase 2 of the project:

- [Lakes_cci V1.0](#): The lakes products were generated using existing algorithms. This dataset corresponds to the state of the art at the beginning of the project. This release provided the first harmonized set of the five products that comprise the lakes ECV (Level, Extent, Ice Cover, Temperature and Reflectance). It was released in May 2020 (Climate Research Data Package CRDP delivery V1)
- [Lakes_cci V1.1](#): Improvements in this intermediate version included new algorithms to estimate Lake Ice Cover and increased coverage for Lake Water Level and Lake Water Extent.



- [Lakes_cci V2.0.1](#): The lake products were generated using algorithm and wider product improvements achieved in the first phase of the project. This version, with improved algorithms and geographical coverage, has been released in March 2022.
- [Lakes_cci V2.0.2](#): As previous, but with correction applied to a small number of corrupted files.
- [Lakes_cci V2.1.0](#): with various consistency improvements, extended spatiotemporal coverage (including 2022) for the established set of 2000+ lakes, and first results on Lake Ice Thickness over Great Slave Lake, in separate files.

The current version of this PSD accompanies V3.0.0 of the Lakes_cci dataset. This version will include a new product: Lake Storage Changes as well as various anticipated algorithm updates, further improved spatial coverage across some ECV products, and increased the temporal coverage including the year 2023.

2. Description

The Lakes ECV dataset is composed of the following seven products:

- Lake Water Level (LWL)
- Lake Water Extent (LWE)
- Lake Surface Water Temperature (LSWT)
- Lake Ice Cover (LIC)
- Lake Ice Thickness (LIT)
- Lake Water-Leaving Reflectance (LWLR)
- Lake Storage Change (LSC)

These ECV Products are offered in a consistent merged format to provide users access to any combination of variables available within each daily aggregation interval.

2.1 Sources of satellite data

Data generated in the Lakes_cci project are derived from a wide range of satellite missions and instruments, as shown in Table 3.

Note that lake water extent product is derived from the lake water level product. Therefore, sensors listed in Table3 are the one used to define an a-priori relationship between water level and surface, i.e. the hypsometric curve.

Table 3. Satellites and instruments used to generate the Lakes ECV

Product	Satellite	Instrument	Temporal Coverage
LWL	TOPEX/Poseidon (T/P)	Poseidon-1	1992-2006
	Jason-1	Poseidon-2	2001-2013
	Jason-2	Poseidon-3	2008-2019
	Jason-3	Poseidon-3B	2016-2022
	Sentinel6A	Poseidon-4	2022-2023
	ERS-1	Radar Altimeter (RA)	1992-1995
	ERS-2	Radar Altimeter (RA)	1995-2011
	ENVISAT	Radar Altimeter (RA-2)	2002-2012
	SARAL	AltiKa	2013-2022



Product	Satellite	Instrument	Temporal Coverage
	Sentinel-3A	SAR Altimeter	2016-2023
	Sentinel-3B	SAR Altimeter	2018-2023
LWE	Landsat-4	MSS (Multispectral Scanner) TM (Thematic Mapper)	1982-1993
	Landsat-5	MSS (Multispectral Scanner) TM (Thematic Mapper)	1984-2013
	Landsat-7	ETM+	1999-2022
	Landsat-8	OLI	2013-2023
	Landsat 9	OLI 2	2021-2023
	Sentinel-2 A&B	MSI (Multi-Spectral Instrument)	2015-2023
LIC	Terra/Aqua	MODIS	1999/2002-2023
LIT	Jason-1	Poseidon-2	2001-2013
	Jason-2	Poseidon-3	2008-2019
	Jason-3	Poseidon-3B	2016-2022
	Sentinel6A	Poseidon-4	2022-2023
LSWT	ERS-2	ATSR-2	1995-2003
	Envisat	AATSR	2002-2012
	Metop-A/B	AVHRR	A:2007-2019 B:2012-2019
	Sentinel3A/B	SLSTR	A:2016-2023 B:2018-2023
	Terra	MODIS	2000-2022
LWLR	Envisat	MERIS	2002-2012
	Sentinel-3 A/B	OLCI A/B	2016/2018-2023
	Aqua	MODIS	2002-2023
LSC	See LWL and LWE	See LWL and LWE	1992-2023

Where sensor coverage overlaps in time, the ECV products may result in a combined observation record or select the most appropriate sensor. Details on these procedures are given in the Algorithm Theoretical Basis Document (ATBD).

A consequence of the diversity of products and sensors is that temporal and spatial resolutions as well as data availability are not identical between the thematic variables (Table 4). For example, a thermal observation resulting in a lake surface water temperature datum may have a different time of observation compared to ice or lake colour observations of the same day. Inconsistencies in the records (e.g. ice and open water observations reported for the same datum) are addressed in a dedicated activity in the Lakes_cci and applied to intermediary L2 outputs prior to producing the final product for users.

The LWL and LWE products, that are in point-data format, are duplicated into the grid for the area given under the nominal spatial delineation of that lake, derived from its maximum water extent.



Table 4. Spatial and temporal resolution range of the input and intermediary data.

Product	Spatial Resolution*	Temporal Resolution	Temporal Coverage
LWL	N/A	1 to 10 days	1992 – 2023
LWE	N/A	1 to 10 days	1992 – 2023
LIC	250 m	Daily	2000 - 2023
LIT	10 Km	1 to 10 days	2000-2023
LSWT	1 km	Up to daily	1995 - 2023
LWLR	300m – 1100 m	1-3 days	2002 - 2023
LSC	N/A	1 to 10 days	1992-2023

*Spatial resolution in meters refers to the nominal resolution at the equator, assuming the longitudinal and latitudinal pixel dimensions are similar), as is conventional in some domains and projections for land products. Resolution in degrees is the native sampling resolution.

2.2 Harmonisation

A central issue in the Lakes_cci project is the harmonisation of the ECV Products. Each product relies on specific sensing concepts and therefore sensors and missions, which are not necessarily synchronous nor do these provide consistent spatiotemporal coverage. First-order harmonization of the thematic variables ensures that each NetCDF file contains all information available for each product, identifying missing values as such. In the lakes_cci dataset V2.1.0, the LIT product containing a smaller number of lakes was, is provided separately. The harmonized product containing the remaining products in grid format has the following characteristics:

- Daily aggregation interval pinned to 12:00:00 UTC. Thematic variables that do not exist for a given date will be set to the netCDF fill value.
- Grid format with spatial resolution of 1/120 degrees (near 1 km at the equator)
- Variables not produced in grid format (LWL and LWE) are duplicated as described in the previous section.
- Datum: WGS84
- Extent: -180 to 180 degrees longitude, -90 to 90 degrees latitude, where positive signs point north and east. The pixel coordinate will be the centre of the pixel.
- The number of grid rows will be 21600, the number of grid columns will be 43200.

Further detail on product dimensions is provided in the sections below.

Uncertainty estimates and quality flags are provided for each product. The meaning of the quality flags is specified in the “flag_meaning” attribute in the product tables reported in Section 6. Quality flags and meanings vary between the products and are fully described in the Algorithm Theoretical Basis Document (ATBD) associated with the CRDP corresponding to this PSD. Procedures used to derive uncertainty estimates are provided in the End-to-End Uncertainty Budget document (E3UB).



3. File naming convention

3.1 Harmonised Product

As recommended in the CCI data standards document, the file names in the Lakes_cci are formed as:

ESACCI-<CCI Project>-<Processing Level>-<Data Type>-<Product String>-<Indicative Date>-fv<version>.nc

Where:

- <CCI Project>: LAKES
- <Processing Level>: L3S. The Lakes_cci product is Super-collated: observations combined from multiple instruments and observation times into a common spatiotemporal grid.
- <Data type>: LK_PRODUCTS
- <Product String>: MERGED. This means data derive from more than one platform and/or sensor
- <Indicative Date>: in YYYYMMDD format
- <Version>: V3.0.0

Thus, an example file name in the last data release is:

ESACCI-LAKES-L3S-LK_PRODUCTS-MERGED-20080808-fv3.0.0.nc

3.2 LIT

LIT product is generated by Lake and mission/pass number of the satellite observing the lake. The file names for LIT product are formed as:

ESACCI--<CCI Project>-<Processing Level>-<Product String>-<Lake name>-<Pass number>-<Start date>-<End date>-fv<version>.nc

Where:

- <CCI Project>: LAKES
- <Processing Level>: L3S. The Lakes_cci product is Super-collated: observations combined from multiple instruments and observation times into a common spatiotemporal grid.
- Product String: LIT for Lake Ice Thickness
- Pass number: number or the pass number off the satellite observing the lake
- Start date: first date with data in the file
- End date: last date with data in the file
- Version: 3.0.0



4. Global Attributes

To ensure consistency where the same global attributes apply to several ECVs, and to avoid ambiguity, relevant terms have been gathered in an ontology, defining the CCI entities and the relationship between those entities, including:

- project
- platform
- sensor
- institution

Table 5 contains the global attributes that are included in the output files following the CCI standards.

Table 5 Global data attributes provided with each file

Attribute	Value
title	ESA Lakes_cci product
institution	LWL: Laboratoire d'Etudes en Geodesie et Oceanographie Spatiales, Collecte Localisation Satellites
	LWE: Laboratoire d'Etudes en Geodesie et Oceanographie Spatiales, Collecte Localisation Satellites and ICUBE SERTIT Université de Strasbourg
	LSWT: University of Reading
	LIC: H2O Geomatics
	LIT: H2O Geomatics, Collecte Localisation Satellites
	LWLR: Plymouth Marine Laboratory
	LSC: Collecte Localisation Satellites
source	LWL: European Space Agency (ESA), National Aeronautics and Space Administration (NASA), European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), National Oceanic and Atmospheric Administration (NOAA).
	LWE: European Space Agency (ESA), National Aeronautics and Space Administration (NASA)
	LSWT: European Space Agency (ESA), European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), European Centre for Medium-Range Weather Forecasts (ECMWF), National Aeronautics and Space Administration (NASA)
	LIC: National Aeronautics and Space Administration (NASA)
	LIT: European Space Agency (ESA), National Aeronautics and Space Administration (NASA), European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), National Oceanic and Atmospheric Administration (NOAA)
	LWLR: European Space Agency (ESA), National Aeronautics and Space Administration (NASA)
	LSC: European Space Agency (ESA), National Aeronautics and Space Administration (NASA), European Organisation for the Exploitation of



Attribute	Value
	Meteorological Satellites (EUMETSAT), National Oceanic and Atmospheric Administration (NOAA).
history processing history of the dataset	LWL: Generated by Laboratoire d'Etudes en Geodesie et Oceanographie Spatiales, Collecte Localisation Satellites LWE: Generated by Laboratoire d'Etudes en Geodesie et Oceanographie Spatiales, Collecte Localisation Satellites and ICUBE SERTIT Université de Strasbourg LSWT: University of Reading LSWT processor version v2.6.1-146-gfe50b81_RES120 LIC: Lake ice cover processor by H2O Geomatics LIT Lake ice thickness processor by CLS LWLR: Calimnos processor by Plymouth Marine Laboratory, including calls to Idepix (SNAP) and POLYMER (Hygeos) algorithms LSC: Lake storage change processor by CLS
references	https://climate.esa.int/en/projects/lakes/
tracking_id	Universal Unique Identifier (UUID)
conventions	CF-1.11
product_version	v3.0.0
Summary	This dataset contains L3S daily ECV Lakes products: Water Level (LWL), Water Extent (LWE), Ice cover (LIC), Ice Thickness (LIT), Surface Water Temperature (LSWT), Water-Leaving Reflectance (LWLR) and Lake Storage Change (LSC). L3S data are observations combined from multiple instruments into a common spatiotemporal grid
keywords	Satellite, Lake, Climate Change, Lake Water Level, Lake Water Extent, Lake Surface Water Temperature, Lake Ice Cover, Lake Water Leaving Reflectance, Lake Storage Change; INSPIRE: Orthoimagery; GCMD: WATER-LEAVING RADIANCE, EARTH_SCIENCE-TERRESTRIAL_HYDROSPHERE,WATER_QUALITY_WATER_CHEMISTRY-CHLOROPHYLL, SUSPENDED_SOLIDS, TURBIDITY; GEMET: water, algal bloom, aquatic environment, freshwater, freshwater quality, ice, inland water, lagoon, lake, dam, phytoplankton, turbidity, water monitoring, water quality, water reservoir, climate, seasonal variation, environmental data, environmental monitoring, monitoring, remote sensing";
keywords_vocabulary	Infrastructure for Spatial Information (INSPIRE), NASA Global Change Master Directory (GCMD), General Multilingual Environmental Thesaurus (GEMET)
id	<i>Populated when the data package is generated (filename)</i>
naming_authority	lakes.esa-cci
cdm_data_type	Grid
comment	These data were produced for the ESA Lakes_cci project
date_created	YYYY-MM-DD <i>Populated when the data package is generated</i>
creator_name	ESA Lakes_cci



Attribute	Value
creator_url	https://climate.esa.int/en/projects/lakes/
creator_email	lakes_cci@groupcls.fr
project	Climate Change Initiative - European Space Agency
geospatial_lat_min	-90.0
geospatial_lat_max	90.0
geospatial_lon_min	-180.0
geospatial_lon_max	180.0
geospatial_vertical_min	NA
geospatial_vertical_max	NA
time_coverage_start	UTC time coverage start in ISO-8601 format (YYYYMMDDTHHMMSSZ)
time_coverage_end	UTC time coverage end in ISO-8601 format (YYYYMMDDTHHMMSSZ)
time_coverage_duration	time coverage duration in ISO8601 format: P1D
time_coverage_resolution	time coverage resolution in ISO8601 format: P1D
standard_name_vocabulary	CF Standard Name Table v78
license	ESA CCI Data Policy: free and open access
platform	LWL: TOPEX/Poseidon, Jason-1, Jason-2, Jason-3, Sentinel-6A, Envisat, SARAL, GFO, Sentinel-3A, Sentinel-3B, ERS-1, ERS-2 LWE: Landsat-<4,5,7,8, 9>, , Sentinel-2, Sentinel-3A, Sentinel-3B + Lake Water Level from altimeters (see line above) LSWT: ERS-2, Envisat, Metop-A, Metop-B, Sentinel3A, Sentinel3B, Terra LIC: Aqua, Terra LIT: Jason-1, Jason-2, Jason-3, Sentinel-6A LWLR: Aqua, Envisat, Sentinel-3A, Sentinel-3B LSC : TOPEX/Poseidon, Jason-1, Jason-2, Jason-3, Sentinel-6A, Envisat, SARAL, GFO, Sentinel-3A, Sentinel-3B, ERS-1, ERS-2, Landsat-<4,5,7,8, 9>, , Sentinel-2, Sentinel-3A, Sentinel-3B
sensor	LWL: Poseidon-1, Poseidon-2, Poseidon-3, Poseidon-3B, RA, RA-2, AltiKa, SRAL; LWE:, MSI, SRAL, MSS, TM, ETM+, OLI, AMI LSWT: ATSR-2, AATSR, AVHRR-3, SLSTR, MODIS LIC: MODIS LWLR: MERIS, OLCI A/B, MODIS LSC: Poseidon-1, Poseidon-2, Poseidon-3, Poseidon-3B, RA, RA-2, AltiKa, SRAL, MSI, MSS, TM, ETM+, OLI, AMI
spatial_resolution	1 km at Equator
key_variables	lake_water_level, lake_water_extent, lake_ice_cover, lake_surface_water_temperature, chla, tsm, kd, cdom, phycocyanin, lake_storage_change, Rw[xxx] where * where xxx is one of 400, 412, 443, 469,



Attribute	Value
	490, 510, 531, 547, 560, 620, 645, 665, 674, 681, 709, 754, 779, 859, 885, 900, 1020nm
geospatial_lat_units	degrees_north
geospatial_lon_units	degrees_east
geospatial_lat_resolution	0.008333333
geospatial_lon_resolution	0.008333333
doi	<i>Dataset Digital Object Identifier</i> <i>Populated when the data package is generated</i>



5. Dimensions

Following the CCI data standards, the gridded products have the dimensions time, latitude and longitude (Table 6)

Table 6. Lakes_cci dimensions

Dimension Name	Attribute	Type	Value
time	units	c	seconds since 1970-01-01 00:00:00
time	standard_name	c	time
time	long_name	c	time
time	calendar	c	gregorian
lat	units	c	degrees_north
lat	standard_name	c	latitude
lat	long_name	c	latitude
lat	valid_min	f	-90
lat	valid_max	f	90
lat	axis	c	Y
lat	reference_datum	c	WGS84 datum
lat	bounds	c	lat_bounds
lon	units	c	degrees_east
lon	standard_name	c	longitude
lon	long_name	c	longitude
lon	valid_min	f	-180
lon	valid_max	f	180
lon	axis	c	X
lon	reference_datum	c	WGS84 datum
lon	bounds	c	lon_bounds



6. ECV Products

The attributes of the variables in the NetCDF files follow the CCI data standards guidelines and consequently, the CF recommendations.

6.1 Lake Water Level (LWL) variables

Table 7. Variables included in the thematic ECV Lake Water Level

Variable Name	Attribute	Type	Value
lake_water_level	long_name	c	Lake water level above geoid
lake_water_level	units	c	m
lake_water_level	valid_min	f	-100
lake_water_level	valid_max	f	6000
lake_water_level	_FillValue	f	9.96921e+36
lake_water_level	ancillary_variables	c	Water_surface_height_uncertainty
lake_water_level	grid_mapping	c	crs
lwl_uncertainty	long_name	c	water surface height uncertainty
lwl_uncertainty	units	c	cm
lwl_uncertainty	valid_min	s	0
lwl_uncertainty	valid_max	s	5000
lwl_uncertainty	scale_factor	f	0.01
lwl_uncertainty	_FillValue	s	-32767



Variable Name	Attribute	Type	Value
lwl_uncertainty	grid_mapping	c	crs
lwl_quality_flag	long_name	c	quality of the lake water level estimated
lwl_quality_flag	valid_min	b	0
lwl_quality_flag	valid_max	b	2
lwl_quality_flag	flag_meanings	c	best_quality medium_quality lower_quality
lwl_quality_flag	flag_values	b	0b, 1b, 2b
lwl_quality_flag	_FillValue	b	-127
lwl_quality_flag	comment	c	These are quality indicators, and they are important to properly use the data.
lwl_quality_flag	grid_mapping	c	crs



6.2 Lake Water Extent (LWE) variables

Table 8. Variables included in the thematic ECV Lake Water Extent

Variable Name	Attribute	Type	Value
lake_water_extent	long_name	c	Lake Water Extent
lake_water_extent	Units	c	km2
lake_water_extent	valid_min	f	0
lake_water_extent	valid_max	f	500000
lake_water_extent	_FillValue	f	9.96921e+36
lake_water_extent	anciliary_variables	c	lake_surface_water_extent_uncertainty
lake_water_extent	grid_mapping	c	crs
lwe_uncertainty	long_name	c	Water extent uncertainty
lwe_uncertainty	units	c	percent
lwe_uncertainty	valid_min	s	0
lwe_uncertainty	valid_max	s	5000
lwe_uncertainty	scale_factor	f	0.01
lwe_uncertainty	_FillValue	s	-32767
lwe_uncertainty	grid_mapping	c	crs
lwe_quality_flag	valid_min	b	0
lwe_quality_flag	valid_max	b	2
lwe_quality_flag	flag_meanings	c	best_quality medium_quality lower_quality
lwe_quality_flag	flag_values	b	0b, 1b, 2b



Variable Name	Attribute	Type	Value
lwe_quality_flag	_FillValue	b	-127
lwe_quality_flag	comment	c	These are quality indicators, and they are important to properly use the data
lwe_quality_flag	grid_mapping	c	crs

6.3 Lake Surface Water Temperature (LSWT) variables

Table 9. Variables included in the thematic ECV Lake Surface Water Temperature

Variable Name	Attribute	Type	Value
lake_surface_water_temperature	long_name	c	lake surface skin temperature
lake_surface_water_temperature	units	c	kelvin
lake_surface_water_temperature	valid_min	s	-200
lake_surface_water_temperature	valid_max	s	5000
lake_surface_water_temperature	scale_factor	f	0.01
lake_surface_water_temperature	add_offset	f	273.15
lake_surface_water_temperature	_FillValue	s	-32767
lake_surface_water_temperature	comment	c	The observations from different instruments have been combined.
lake_surface_water_temperature	ancillary_variables		lswt_uncertainty, lswt_quality_level
lake_surface_water_temperature	grid_mapping	cs	crs
lswt_uncertainty	long_name	c	total uncertainty in lake surface water temperature
lswt_uncertainty	units	c	kelvin
lswt_uncertainty	valid_min	s	0



Variable Name	Attribute	Type	Value
lswt_uncertainty	valid_max	s	10000
lswt_uncertainty	scale_factor	f	0.001
lswt_uncertainty	add_offset	f	0.0
lswt_uncertainty	_FillValue	s	-32767
lswt_uncertainty	comment	c	Total uncertainty was computed with LSWT uncertainties from the Optimal Estimation and bias correction uncertainty.
lswt_uncertainty	grid_mapping	c	crs
lswt_quality_level	long_name	c	Lake surface water temperature quality level
lswt_quality_level	valid_min	b	0
lswt_quality_level	valid_max	b	5
lswt_quality_level	flag_meanings	c	no_data bad_data worst_quality low_quality acceptable_quality best_quality
lswt_quality_level	flag_values	b	0b, 1b, 2b, 3b, 4b, 5b
lswt_quality_level	_FillValue	b	128b
lswt_quality_level	comment	c	These are quality indicators, and they are important to properly use the data.
lswt_quality_level	grid_mapping	cs	crs



6.4 Lake Ice Cover (LIC) variables

Table 10. Variables included in the thematic ECV Lake Ice Cover

Variable Name	Attribute	Type	Value
lake cover class	long_name	c	lake cover class
lake cover class	valid_min	b	1b
lake cover class	valid_max	b	3b
lake cover class	_FillValue	b	255b
lake cover class	flag_meanings	c	water ice cloud
lake cover class	flag_values	b	1b, 2b, 3b
lake cover class	ancillary_variables	c	lic_process_flag lic_rf_total_uncertainty lic_class_agreement fractional_ice_cover
lake cover class	grid_mapping	c	crs
lic_process_flag	long_name	c	Process flag
lic_process_flag	valid_min	b	1b
lic_process_flag	valid_max	b	3b
lic_process_flag	_FillValue	b	255b
lic_process_flag	flag_meanings	c	no_flag missing_data lic_high_temp
lic_process_flag	flag_values	b	1b, 2b, 3b
lic_process_flag	comment	c	These flags are used to inform the user of changes made to the date or provide additional information to the user no_flag: This indicates that there has been nothing to change the pixel values – it was retrieved as either ice or water. missing_data: This mask indicates grid cells where either no classification was made due to high solar zenith angles (>85 degrees) or no classification due to missing data



Variable Name	Attribute	Type	Value
			lic_high_temp: This indicates a grid cell where the temperature was greater than 278 K and the LIC class was ice. The grid cell is reclassified to water
lic_process_flag	grid_mapping	c	crs
lic_class_agreement	long_name	c	MODIS lake ice cover class agreement
Lic_class_agreement	comment	c	This provides information on how many overlapping MODIS swaths selected the final classification for that grid cell.
lic_class_agreement	units	c	1
lic_class_agreement	valid_min	b	0
lic_class_agreement	valid_max	b	100
lic_class_agreement	_FillValue	b	255
lic_class_agreement	grid_mapping	c	crs
lic_modis_overlap	Long_name	c	number of overlapping MODIS swaths
lic_modis_overlap	units	c	1
lic_modis_overlap	Valid_min	b	0
lic_modis_overlap	Valid_max	b	100
lic_modis_overlap	_FillValue	b	255
lic_modis_overlap	grid_mapping	c	crs
lic_rf_total_uncertainty	long_name	c	Random Forest total uncertainty per pixel
lic_rf_total_uncertainty	units	c	1
lic_rf_total_uncertainty	valid_min	f	0
lic_rf_total_uncertainty	valid_max	f	2



Variable Name	Attribute	Type	Value
lic_rf_total_uncertainty	_FillValue	s	-32767
lic_rf_total_uncertainty	grid_mapping	c	crs
lic_rf_quality_level	Long_name	c	"Random Forest quality flag"
lic_rf_quality_level	Valid_min	b	0b
lic_rf_quality_level	Valid_max	b	4b
lic_rf_quality_level	_FillValue	b	255b
lic_rf_quality_level	Flag_meanings	c	"lowest_quality" "poor_quality" "medium_quality" "good_quality" "best_quality"
lic_rf_quality_level	Flag_values	b	0b 1b 2b 3b 4b
lic_rf_quality_level	comment	c	<p>These flags are to indicate the quality of the lake ice cover class based on the total uncertainty calculated. The flag is based on a weighted agreement score. The agreement score is determined by dividing the number of pixels that agree and the total number of overlapping pixels. Normalized uncertainty is used to weight the agreement score, uncertainty is normalized between the known minimum of 0 and known maximum of 1.58.</p> <p>Lowest_quality: weighted agreement is 0 to 0.2</p> <p>Poor_quality: weighted agreement is within 0.21 to 0.4</p> <p>Medium_quality: weighted agreement is within 0.41 to 0.6</p> <p>Good_quality: weighted agreement is within 0.61 to 0.8</p> <p>Best_quality: weighted agreement is 0.8 or higher</p>
lic_rf_quality_level	Grid_mapping	c	crs
fractional_ice_cover	long_name	c	Fractional ice cover excluding clouds



Variable Name	Attribute	Type	Value
fractional_ice_cover	comment	c	This is the fraction of each lake covered by ice excluding cloud pixels. First the number of cloud pixels is subtracted from the number of lake pixels. Then the number of ice pixels is divided by this total.
fractional_ice_cover	units	c	percent
fractional_ice_cover	Valid_min	s	0
fractional_ice_cover	Valid_max	s	100
fractional_ice_cover	_FillValue	s	-32767
fractional_ice_cover	grid_mapping	c	crs
lic_total_cloud_cover	long_name	c	Total Cloud Cover over Lake
lic_total_cloud_cover	units	c	percent
lic_total_cloud_cover	Valid_min	s	0
lic_total_cloud_cover	Valid_max	s	100
lic_total_cloud_cover	_FillValue	c	-32767
lic_total_cloud_cover	grid_mapping		crs
ice_cover_area	long_name	c	Area of lake covered by ice
ice_cover_area	comment	c	This is a key GCOS requirement for lakes. Area of each lake covered by ice is calculated by multiplying the area of the lake by fractional ice cover.
ice_cover_area	units	c	Km ²
ice_cover_area	Valid_min	s	0
ice_cover_area	Valid_max	s	83000
ice_cover_area	_FillValue	s	-32767
ice_cover_area	grid_mapping	c	crs



6.5 Lake Ice Thickness (LIT) variables

Table 11. Variables included in the thematic ECV Lake Ice Thickness

Variable Name	Attribute/type	Type	Value
lake_ice_thickness	long_name	c	Lake ice thickness
lake_ice_thickness	units	c	m
lake_ice_thickness	valid_min	s	0
lake_ice_thickness	valid_max	s	10
Lake_ice_thickness	scale factor	f	0.001
lake_ice_thickness	_FillValue	s	-32767
lake_ice_thickness	grid_mapping	c	crs
lit_uncertainty	long_name	c	Lake ice thickness uncertainty
lit_uncertainty	units	c	m
lit_uncertainty	valid_min	s	0
lit_uncertainty	valid_max	s	1
lit_uncertainty	scale factor	f	0.0001
lit_uncertainty	_FillValue	s	-32767
lit_uncertainty	grid_mapping	c	crs
lit_quality_flag	long_name	c	Lake ice thickness quality flag
lit_quality_flag	valid_min	b	0
lit_quality_flag	valid_max	b	2
lit_quality_flag	flag_meanings	c	Best_quality no_data degraded_quality



Variable Name	Attribute/type	Type	Value
lit_quality_flag	flag_values	b	0b, 1b, 2b
lit_quality_flag	_FillValue	b	-127
lit_quality_flag	comment	c	Degraded measurement (quality flag 2) can be used but the fit quality is degraded (median of the reduced chi2 values in the RoI: $2.5 < \text{red_chi2} < 3$)
lit_quality_flag	grid_mapping	cs	crs



6.6 Lake Water Leaving Reflectance (LWLR) variables

Table 12. Variables included in the thematic ECV Lake Water Leaving Reflectance

Variable Name	Attribute	Type	Value
Rw[xxx]*	_FillValue	f	9.96921e+36
Rw[xxx]*	coordinates	c	lat lon
Rw[xxx]*	radiation_wavelength	c	[xxx]
Rw[xxx]*	radiation_wavelength_units	c	nm
Rw[xxx]*	long_name	c	Fully normalized water-leaving reflectance at [xxx] nm*
Rw[xxx]*	units	c	1 [dimensionless]
Rw[xxx]*	ancillary_variables	c	Rw[xxx]_uncertainty_bias, Rw[xxx]_uncertainty_rmsd
Rw[xxx]*	valid_min	f	0
Rw[xxx]*	valid_max	f	1
Rw[xxx]*	grid_mapping	c	crs
Rw[xxx]_uncertainty_bias*	_FillValue	f	9.96921e+36
Rw[xxx]_uncertainty_bias*	coordinates	c	lat lon
Rw[xxx]_uncertainty_bias*	radiation_wavelength	c	[xxx]
Rw[xxx]_uncertainty_bias*	radiation_wavelength_units	c	nm
Rw[xxx]_uncertainty_bias*	long_name	c	Bias uncertainty in fully normalized water-leaving reflectance at [xxx] nm
Rw[xxx]_uncertainty_bias*	units	c	1 [dimensionless]
Rw[xxx]_uncertainty_bias*	valid_min	f	-1
Rw[xxx]_uncertainty_bias*	valid_max	f	1
Rw[xxx]_uncertainty_bias*	grid_mapping	c	crs
Rw[xxx]_uncertainty_rmsd*	_FillValue	f	9.96921e+36
Rw[xxx]_uncertainty_rmsd*	coordinates	c	lat lon
Rw[xxx]_uncertainty_rmsd*	radiation_wavelength	c	[xxx]



Variable Name	Attribute	Type	Value
Rw[xxx]_uncertainty_rmsd*	radiation_wavelength_units	c	nm
Rw[xxx]_uncertainty_rmsd*	long_name	c	Root mean squared difference uncertainty in fully normalized water-leaving reflectance at [xxx] nm
Rw[xxx]_uncertainty_rmsd*	units	c	1 [dimensionless]
Rw[xxx]_uncertainty_rmsd*	valid_min	f	0
Rw[xxx]_uncertainty_rmsd*	valid_max	f	1
Rw[xxx]_uncertainty_rmsd*	grid_mapping	c	crs
chla	_FillValue	f	9.96921e+36
chla	coordinates	c	lat lon
chla	units	c	mg m ⁻³
chla	valid_min	f	0
chla	valid_max	f	1000
chla	long_name	c	Concentration of chlorophyll-a
chla	ancillary_variables	c	chla_uncertainty
chla	grid_mapping	c	crs
chla_uncertainty	_FillValue	f	9.96921e+36
chla_uncertainty	coordinates	c	lat lon
chla_uncertainty	units	c	percent
chla_uncertainty	valid_min	f	0
chla_uncertainty	valid_max	f	200
chla_uncertainty	long_name	c	Relative uncertainty in concentration of chlorophyll-a
chla_uncertainty	grid_mapping	c	crs
tsm	_FillValue	f	9.96921e+36
tsm	units	c	g m ⁻³
tsm	valid_min	s	0



Variable Name	Attribute	Type	Value
tsm	valid_max	s	10000
tsm	long_name	c	Total Suspended Matter dry weight
tsm	ancillary_variables	c	tsm_uncertainty
tsm	grid_mapping	c	crs
tsm_uncertainty	coordinates	c	lat lon
tsm_uncertainty	units	c	percent
tsm_uncertainty	valid_min	f	0
tsm_uncertainty	valid_max	f	200
tsm_uncertainty	long_name	c	Relative uncertainty in tsm
tsm_uncertainty	grid_mapping	c	crs
acdom440	_FillValue	f	9.96921e+36
acdom440	radiation_wavelength	c	440
acdom440	radiation_wavelength_units	c	nm
acdom440	coordinates	c	lat lon
acdom440	units	c	1
acdom440	valid_min	s	0
acdom440	valid_max	s	10
acdom440	long_name	c	Light absorption by Coloured Dissolved Organic Matter at 443 nm
acdom440	ancillary_variables	c	a_cdom_443_uncertainty
acdom440	grid_mapping	c	crs



Variable Name	Attribute	Type	Value
acdom440_uncertainty	coordinates	c	lat lon
acdom440_uncertainty	radiation_wavelength	c	440
acdom440_uncertainty	radiation_wavelength_units	c	nm
acdom440_uncertainty	units	c	percent
acdom440_uncertainty	valid_min	f	0
acdom440_uncertainty	valid_max	f	200
acdom440_uncertainty	long_name	c	Relative uncertainty in Light absorption by Coloured Dissolved Organic Matter at 443 nm
acdom440_uncertainty	grid_mapping	c	crs
Kd[xxx]**	_FillValue	f	9.96921e+36
Kd[xxx]**	coordinates	c	lat lon
Kd[xxx]**	radiation_wavelength	c	xxx** [unless xxx=PAR]
Kd[xxx]**	radiation_wavelength_units	c	nm [unless xxx=PAR]
Kd[xxx]**	units	c	1
Kd[xxx]**	valid_min	s	0
Kd[xxx]**	valid_max	s	50
Kd[xxx]**	long_name	c	Vertical diffuse attenuation coefficient at [xxx]** nm or integrated over the Photosynthetically Active Radiation (xxx=PAR) range
Kd[xxx]**	ancillary_variables	c	Rw[xxx]_uncertainty_bias, Rw[xxx]_uncertainty_rmsd
Kd[xxx]**	grid_mapping	c	crs
phycocyanin	_FillValue	f	9.96921e+36



Variable Name	Attribute	Type	Value
phycocyanin	coordinates	c	lat lon
phycocyanin	units	c	1
phycocyanin	valid_min	s	0
phycocyanin	valid_max	s	1000
phycocyanin	long_name	c	Concentration of phycocyanin
phycocyanin	ancillary_variables	c	n/a
phycocyanin	grid_mapping	c	crs
lwlr_quality_flags	_FillValue	u1	255
lwlr_quality_flags	coordinates	c	lat lon
lwlr_quality_flags	valid_min	u1	0
lwlr_quality_flags	valid_max	u1	128
lwlr_quality_flags	long_name	c	Quality flag of LWLR pixels
lwlr_quality_flags	flag_meanings	c	lwlr_cloud lwlr_land lwlr_snow_ice lwlr_bright_pixel lwlr_land_contaminated lwlr_atmospheric_correction_failure lwlr_poor_consistency lwlr_low_consistency
lwlr_quality_flags	Flag_values	u1	1, 2, 4, 8, 16, 32, 64, 128, 256,512,1024
lwlr_quality_flags	comment	c	These quality indicators inform the user on the reasons behind missing observations and on proper use of the data: lwlr_cloud: not processed due to suspected cloud lwlr_land: not processed due to suspected land lwlr_snow_ice: not processed due to suspected snow or ice lwlr_bright_pixels: masked due to extreme reflectance values lwlr_land_contaminated: risk of land influence on water signal



Variable Name	Attribute	Type	Value
			lwlr_atmospheric_correction_failure: no atmospheric correction result lwlr_high_solar_zenith_angle: low observation quality due to high solar zenith angle (>76 degrees) lwlr_poor_consistency: illegal combination of LWLR, LWST, and/or LIC lwlr_low_consistency: pixel includes at least some suspect combinations of LWLR, LWST, and/or LIC lwlr_floating_cyanobacteria: likely presence of cyanobacteria floating at the water surface (not derived for MODIS) lwlr_floating_macrophytes_or_mixed_pixel: likely presence of macrophytes floating at the water surface, or combined water-land-vegetation within pixel (not derived for MODIS)
lwlr_quality_flags	ancillary_variables	c	Rw[XXX], chl _a , tsm
lwlr_quality_flags	grid_mapping	crs	Crs

* where xxx is one of 400, 412, 443, 469, 490, 510, 531, 547, 560, 620, 645, 665, 674, 681, 709, 754, 779, 859, 885, 900, 1020nm. Specific source of sensor, potential application and time span for each LWLR variable can be found in



Table 13 and



Table 14. Uncertainty products are available only for a subset of the products.

** where xxx is one of 412, 560, 674 or PAR



Table 13 Waveband selection and unified reporting in LWLR variables (starting with 'Rw') across the MERIS, MODIS-Aqua and OLCI sensors. Sensor records are not currently merged in the Lakes_cci: MERIS is used over the 2002-2012 period, MODIS-Aqua in the 2012-2016 period, and OLCI in the period 2016-present (see



Table 14). Overlap between MODIS and the other sensors is only used to investigate inter-sensor bias. The OLCI band set is taken as the reference variable name, with MERIS/MODIS bands within 6 nm reported under the same variable. The variable attribute 'radiation_wavelength' specifies the sensor-specific centre wavelength of each band. All visible and near-infrared wavebands that are not exclusively used for cloud identification or atmospheric correction, are included.

	<i>Band centre (width) in nm</i>			<i>CCI band</i>	<i>Potential applications</i>
	<i>OLCI (Ref.)</i>	<i>MODIS-A</i>	<i>MERIS</i>		
1	400 (15)			1: 400	Aerosol correction, improved water constituent retrieval (yellow substance, pigment)
2	413 (10)	412 (44.9)	413 (10)	2: 412	Yellow substance and detrital pigments
3	443 (10)	443 (41.9)	443 (10)	3: 443	Chlorophyll-a absorption maximum, vegetation
4		469 (35.3)		4: 469	Chlorophylls and other accessory pigments
5	490 (10)	488 (32.1)	490 (10)	5: 490	Chlorophyll-a and accessory pigments
6	510 (10)		510 (10)	6: 510	Chlorophyll-a, sediment, turbidity, accessory pigment
7		531 (27.9)		7: 531	Accessory pigments, vegetation
8		547 (21)		8: 547	Chlorophyll-a reference
9	560 (10)	555 (29)	560 (10)	9: 560	Chlorophyll-a reference
10	620 (10)		620 (10)	10: 620	Suspended sediment, cyanobacterial pigment
11		645 (21.8)		11: 645	Suspended sediment, cyanobacterial pigment reference
12	665 (10)	667 (9.5)	665 (10)	12: 665	Chlorophyll-a (red chlorophyll-a absorption maximum), sediment, yellow substance/vegetation, turbidity
13	674 (7.5)	678 (8.7)	-	13: 674	Chlorophyll-a absorption/fluorescence, smile correction with OLCI 665 and 681 nm bands
14	681 (7.5)		681 (7.5)	14: 681	Chlorophyll-a fluorescence peak, red edge
15	709 (10)		709 (10)	15: 709	Chlorophyll-a fluorescence baseline, red edge transition
16	754 (7.5)	748 (10.2)	754 (7.5)	16: 754	O ₂ absorption/clouds, vegetation
17	761 (2.5)		761 (3.75)	-	O ₂ absorption band/aerosol correction.
18	764 (3.75)		-	-	Atmospheric correction

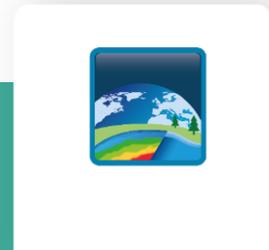


	<i>Band centre (width) in nm</i>			<i>CCI band</i>	<i>Potential applications</i>
	<i>OLCI (Ref.)</i>	<i>MODIS-A</i>	<i>MERIS</i>		
19	767 (2.5)		-	-	Fluorescence (land), O ₂ -A band for cloud top pressure
20	779 (15)		779 (15)	17: 779	Suspended sediment, atmospheric correction
21		859 (24.7)		18: 859	Vegetation, suspended sediment, water vapour reference
22	865 (20)	869 (6.2)	865 (20)	-	Atmospheric correction
23	885 (10)		885 (10)	19: 885	Suspended sediment, vegetation, atmospheric correction
24	900 (10)		900 (10)	20: 900	Water vapour absorption/vegetation monitoring
25	940 (20)		-	-	Water vapour absorption, atmospheric correction
26	1020 (40)		-	21: 1020	Water detection, atmospheric correction
27		1240 (5.4)		-	Cloud and aerosol
28		1640 (7.3)		-	Cloud and aerosol
29		2130 (1)		-	Cloud and aerosol



Table 14 Time span and sensor source for LWLR and derived variables.
MODIS-Aqua coverage is for a reduced number of lakes following validation of inter-sensor consistency. Eight LWLR bands are provided over the full time-series from 2002 to 2023. These are Chlorophyll-a, Turbidity, Rw412, Rw443, Rw490, Rw560, Rw665, and Rw754.

Variable	MERIS	MODIS-A	OLCI	2002-2011	2012	2013-2015	2016	2017-2023
Chlorophyll-a	x	x	x					
Turbidity	x	x	x					
Rw400			x					
Rw412	x	x	x					
Rw443	x	x	x					
Rw469		x						
Rw490	x	x*	x					
Rw510	x		x					
Rw531		x						
Rw547		x						
Rw560	x	x*	x					
Rw620	x		x					
Rw645		x						
Rw665	x	x*	x					
Rw674			x					
Rw681	x		x					
Rw709	x		x					
Rw754	x	x*	x					
Rw779	x		x					
Rw859		x						
Rw885	x		x					
Rw900	x		x					
Rw1020			x					



For conciseness, MODIS R_w bands with band centres < 6nm from MERIS/OLCI bands with an equivalent purpose are reported under the same name as the equivalent MERIS/OLCI band. This applies to MODIS bands (labelled as x) at 488, 555, 667, and 748 nm.

6.7 Lake Water Storage (LSC) variables

lake_storage_change	units	c	Million Cubic Meters (MCM)
lake_storage_change	valid_min	f	-100 000 000
lake_storage_change	valid_max	f	100 000 000
lake_storage_change	long_name	c	Lake storage change in relation to the oldest measurement date
lake_storage_change	ancillary_variables	c	Quality of the lake storage change estimated
lake_storage_change	grid_mapping	c	crs
lsc_quality_flag	long_name	c	Quality of the lake storage change estimated
lsc_quality_flag	valid_min	b	0
lsc_quality_flag	valid_max	b	2
lsc_quality_flag	flag_meanings	c	best_quality, medium_quality, lower_quality
lsc_quality_flag	flag_values	b	0b, 1b, 2b
lsc_quality_flag	_FillValue	b	-127
lsc_quality_flag	comment	c	These are quality indicators, and they are important to properly use the data.
lsc_quality_flag	grid_mapping	c	crs



7. Additional variables

The Coordinate Reference System (CRS) variable is included to explicitly indicate the system used for horizontal spatial coordinate values. This information is required for some GIS programmes and may be useful for some users

Table 15. Attributes of the additional variable with the Coordinate Reference System

Variable Name	Attribute	Type	Value
crs	grid_mapping_name	f	9.96921e+36
crs	longitude_of_prime_meridian	f	0
crs	semi_major_axis	f	6378137
crs	inverse_flattening	f	298.257223563
crs	crs_wkt	c	<pre> GEOCRS["WGS 84", DATUM["World Geodetic System 1984", ELLIPSOID["WGS 84",6378137,298.257223563, LENGTHUNIT["metre",1.0]]], PRIMEM["Greenwich",0], CS[ellipsoidal,3], AXIS["lat",north,ANGLEUNIT["degree",0.0174532925199433]], AXIS["lon",east,ANGLEUNIT["degree",0.0174532925199433]], AXIS["ellipsoidal height (h)",up,LENGTHUNIT["metre",1.0]]] </pre>

In addition, to comply with CCI data standards, the grid boundaries (latitude and longitude bounds) are included



8.Mask file

A file containing the lakes mask used to generate the dataset, as well as the distance to the nearest land of each pixel, is provided separately. It follows the same latitude and longitude dimensions as the ECV product files. The variables and their attributes are shown in Table 16.

Table 16. Attributes of the variables in the lake mask file

Variable Name	Attribute/type	Type	Value
lakes_cci_id	_FillValue	i	-2147483648
lakes_cci_id	long_name	c	Lake ID
lakes_cci_id	units	c	1
lakes_cci_id	valid_min	s	1
lakes_cci_id	valid_max	s	999999999
lakes_cci_id	comment	c	First digit for source database: 0=GLWD, 1=GLBL, 2=CGL2, 3=HYLA. Remaining digits: lake id at source
distance_to_land	_FillValue	s	-32678
distance_to_land	units	c	km
distance_to_land	long_name	c	distance_to_land
distance_to_land	valid_min	s	0
distance_to_land	valid_max	s	27183
distance_to_land	scale factor	f	0.01
distance_to_land	add_offset	f	0
distance_to_land	resolution	c	0.1 kilometers



Variable Name	Attribute/type	Type	Value
distance_to_land	comment	c	Distance to nearest land defined in in Carrea L., Embury O., Merchant C.J. (2015): GloboLakes: high-resolution global limnology dataset v1. Centre for Environmental Data Analysis, 21 July 2015. doi:10.5285/6be871bc-9572-4345-bb9a-2c42d9d85ceb.



9. Gap-filled product

The Lakes gap-filled dataset consists of spatial and temporal reconstructions of the following two products:

- Lake Surface Water Temperature (LSWT)
- Lake Ice Cover (LIC)

The gap-filled products are consistent and harmonised and they are offered as netCDF files:

- daily global files containing the LSWT+LIC variables for the 2024 lakes in a given day
- per-lake files containing LSWT+LIC variables for a specific lake for each day between 2000 and 2023.

An auxiliary file containing the list of the 2024 lakes with some information to locate files and lakes will be provided.

9.1 Data sources

The data sources for the LSWT and LIC reconstructions are the LSWT and LIC observations of the CRDP version 3.0.0 as described in this document.

9.2 Consistency

The LSWT and LIC gap-filled products are consistent: each cell can be classified as water, ice or land. Only for water cells a value of LSWT is reported. The water/land/ice classification and the LSWT value are present for each day for each cell belonging to one of the 2024 CCI lakes as defined in the ESA CCI lake mask (<https://doi.org/10.5281/zenodo.6699376>).

The product is delivered as a global daily file and as a per-lake file and has the following characteristics.

For the global daily file:

- Daily aggregation interval pinned to 12:00:00 UTC.
- Grid format with spatial resolution of 1/120 degrees (near 1 km at the equator)
- Datum: WGS84
- Extent: -180 to 180 degrees longitude, -90 to 90 degrees latitude, where positive signs point north and east.
- The pixel coordinate will be the centre of the pixel.
- The number of grid rows will be 21600, the number of grid columns will be 43200 (global daily product).

For the per-lake file:

- Daily aggregation interval pinned to 12:00:00 UTC.
- Grid format with spatial resolution of 1/120 degrees (near 1 km at the equator)
- Extent: defined for each lake as a box around the lake. The coordinates of the box are reported in a csv file of the lake list
- The pixel coordinate will be the centre of the pixel.

- The number of row and columns are defined as the sizes of the box around each of the lakes and reported in the csv file of lake list.

9.3 File naming convention

As recommended in the CCI data standards document, the file names in the Lakes_cci are formed as:

ESACCI-<CCI Project>-<Processing Level>-<Data Type>-<Product String>-<Indicative Date>-fv<version>.nc

Where:

- <CCI Project>: LAKES
- <Processing Level>: L4 is a product with no gaps which have been filled with interpolation/statistical techniques.
- <Data type>: LK_PRODUCTS
- <Product String>: MERGED. This means data derive from more than one platform and/or sensor
- <Indicative Date>: in YYYYMMDD format
- <Version>: V1.0.0

Thus, an example file name for the global product is:

ESACCI-LAKES-L4-LK_PRODUCTS-MERGED-20080808-fv1.0.0.nc

An example file name for the per-lake product is:

ESACCI-LAKES-L4-LK_PRODUCTS-PERLAKE_ID000000002-2000_2023-fv1.0.0.nc

9.4 Global attributes

To ensure consistency where the same global attributes apply to several ECVs, and to avoid ambiguity, relevant terms have been gathered in an ontology, defining the CCI entities and the relationship between those entities, including:

- project
- institution

Table 17 contains the global attributes that are included in the output files following the CCI standards.

Table 17. Lakes_cci gap-filled product global attributes for the global daily file and the per-lake file

Attribute	Value
title	ESA Lakes_cci product
institution	LSWT: University of Reading
	LIC: H2O Geomatics
source	LSWT: ESA CCI LAKES CRDP v3.0.0
	LIC: ESA CCI LAKES CRDP v3.0.0
history	LSWT: DINEOF
	LIC:

processing history of the dataset	
references	https://climate.esa.int/en/projects/lakes/
tracking_id	Universal Unique Identifier (UUID)
conventions	CF-1.11
product_version	v1.0.0
Summary	This dataset contains L4 daily harmonised Ice cover (LIC) and Surface Water Temperature (LSWT) for the period 2000 to 2023 using LIC and LSWT observations of the ESA CCI product v3.0.0. L4 data are spatially and temporally reconstructed data derived from observations combined from multiple instruments into a common spatiotemporal grid.
keywords	Satellite, Lake, Climate Change, Lake Surface Water Temperature, Lake Ice Cover; INSPIRE: Orthoimagery; GCMD: EARTH_SCIENCE-TERRESTRIAL_HYDROSPHERE; GEMET: water, aquatic environment, freshwater, ice, inland water, lagoon, lake, dam, water monitoring, water reservoir, climate, seasonal variation, environmental data, environmental monitoring, monitoring, remote sensing";
keywords_vocabulary	Infrastructure for Spatial Information (INSPIRE), NASA Global Change Master Directory (GCMD), General Multilingual Environmental Thesaurus (GEMET)
id	<i>Populated when the data package is generated (filename)</i>
naming_authority	lakes.esa-cci
cdm_data_type	Grid
comment	These data were produced for the ESA Lakes_cci project
date_created	YYYY-MM-DD <i>Populated when the data package is generated</i>
creator_name	ESA Lakes_cci
creator_url	https://climate.esa.int/en/projects/lakes/
creator_email	lakes_cci@groupcls.fr
project	Climate Change Initiative - European Space Agency
geospatial_lat_min	-90.0 <i>[For the per-lake file it is the lat min of the box around the lake]</i>
geospatial_lat_max	90.0 <i>[For the per-lake file it is the lat max of the box around the lake]</i>
geospatial_lon_min	-180.0 <i>[For the per-lake file it is the lon min of the box around the lake]</i>
geospatial_lon_max	180.0 <i>[For the per-lake file it is the lon max of the box around the lake]</i>
geospatial_vertical_min	NA
geospatial_vertical_max	NA
time_coverage_start	UTC time coverage start in ISO-8601 format (YYYYMMDDTHHMMSSZ)
time_coverage_end	UTC time coverage end in ISO-8601 format (YYYYMMDDTHHMMSSZ)

time_coverage_duration	time coverage duration in ISO8601 format: P1D
time_coverage_resolution	time coverage resolution in ISO8601 format: P1D
standard_name_vocabulary	CF Standard Name Table v78
license	ESA CCI Data Policy: free and open access
spatial_resolution	1 km at Equator
key_variables	lake_ice_cover, lake_surface_water_temperature
lake_identifier	<i>Lake id [this is an entry only in the per-lake file]</i>
lake_name	<i>Lake name [this is an entry only in the per-lake file]</i>
geospatial_lat_units	degrees_north
geospatial_lon_units	degrees_east
geospatial_lat_resolution	0.008333333
geospatial_lon_resolution	0.008333333
doi	<i>Dataset Digital Object Identifier</i> <i>Populated when the data package is generated</i>

9.5 Dimensions

Following the CCI data standards, the gridded products have the dimensions time, latitude and longitude (Table 18).

Table 18 Lakes_cci gap-filled product dimensions for the global daily file and the per-lake file

Dimension Name	Attribute	Type	Value
time	units	c	seconds since 1970-01-01 00:00:00
time	standard_name	c	time
time	long_name	c	time
time	calendar	c	gregorian
lat	units	c	degrees_north
lat	standard_name	c	latitude
lat	long_name	c	latitude
lat	valid_min	f	-90
lat	valid_max	f	90
lat	axis	c	Y
lat	reference_datum	c	WGS84 datum
lat	bounds	c	lat_bounds
lon	units	c	degrees_east
lon	standard_name	c	longitude
lon	long_name	c	longitude

lon	valid_min	f	-180
lon	valid_max	f	180
lon	axis	c	X
lon	reference_datum	c	WGS84 datum
lon	bounds	c	lon_bounds

9.6 Product description

The attributes of the variables in the NetCDF files for the global daily and for the per-lake products follow the CCI data standards guidelines and consequently, the CF recommendations.

9.6.1 Lake Surface Water Temperature

Variable name	Attribute/type	Type	Value
analysis_lswt	long_name	c	Gap-filled lake surface water temperature
analysis_lswt	units	c	kelvin
analysis_lswt	valid_min	s	-200
analysis_lswt	valid_max	s	5000
analysis_lswt	scale_factor	f	0.01
analysis_lswt	add_offset	f	273.15
analysis_lswt	_FillValue	s	-32767
analysis_lswt	comment	c	Spatial and temporal reconstructions of the lake surface water temperature from the observations of the ESA CCI LAKES product v3.0.0 (lake_surface_water_temperature).
analysis_lswt	grid_mapping	cs	crs
analysis_lswt_flag	long_name	c	Gap-filled lake surface water temperature flag for the source of the gap filling process
analysis_lswt_flag	valid_min	b	1
analysis_lswt_flag	valid_max	b	2



analysis_lswt_flag	flag_meanings	c	Observations, interpolations
analysis_lswt_flag	flag_values	b	1b, 2b
analysis_lswt_flag	_FillValue	b	128b
analysis_lswt_flag	comment	c	Flag to indicate source of LSWT reconstructions
analysis_lswt_flag	grid_mapping	cs	crs
analysis_lswt_uncertainty	long_name	c	estimation of uncertainty in gap-filled lake surface water temperature
analysis_lswt_uncertainty	units	c	kelvin
analysis_lswt_uncertainty	valid_min	s	0
analysis_lswt_uncertainty	valid_max	s	10000
analysis_lswt_uncertainty	scale_factor	f	0.001
analysis_lswt_uncertainty	add_offset	f	0.0
analysis_lswt_uncertainty	_FillValue	s	-32767
analysis_lswt_uncertainty	comments	c	Total uncertainty was computed with LSWT uncertainties from the Optimal Estimation and bias correction uncertainty.
analysis_lswt_uncertainty	grid_mapping	cs	crs
analysis_lswt_fraction_obs	long_name	c	Fraction of lake mask with lake surface water temperature observations used for the gap filling
analysis_lswt_fraction_obs	units	b	1
analysis_lswt_fraction_obs	valid_min	b	0
analysis_lswt_fraction_obs	valid_max	b	1



analysis_lswt_fraction_obs	_FillValue	b	128b
analysis_lswt_fraction_obs	comments	c	Fraction of the lake with lake surface water temperature observations in the ESA CCI LAKES LSWT product v3.0.0 (lake_surface_water_temperature)

9.6.2 Lake Ice Cover

Variable name	Attribute/type	Type	Value
analysis_lake_cover_class	long_name	c	Gap filled lake cover class
analysis_lake_cover_class	valid_min	b	1b
analysis_lake_cover_class	valid_max	b	2b
analysis_lake_cover_class	_FillValue	b	255b
analysis_lake_cover_class	flag_meanings	c	water ice
analysis_lake_cover_class	flag_values	b	1b, 2b
analysis_lake_cover_class	grid_mapping	cs	Crs
analysis_lic_probability	long_name	c	Probability of Gap Filled Data per pixel
analysis_lic_probability	units	c	1
analysis_lic_probability	valid_min	f	0
analysis_lic_probability	valid_max	f	1
analysis_lic_probability	_FillValue	s	-32767
analysis_lic_probability	grid_mapping	cs	crs
fractional_ice_cover	Long_name	c	Fractional ice cover



fractional_ice_cover	comment	c	This is the fraction of each lake covered by ice.
fractional_ice_cover	units	c	percent
fractional_ice_cover	Valid_min	b	0
fractional_ice_cover	Valid_max	b	100
fractional_ice_cover	_FillValue	b	-32767
ice_cover_area	Long_name	c	Area of lake covered by ice
ice_cover_area	comment	c	This is a key GCOS requirement for lakes. Area of each lake covered by ice is calculated by multiplying the area of the lake by fractional ice cover.
ice_cover_area	units	c	Km2
ice_cover_area	Valid_min	b	0
ice_cover_area	Valid_max	b	83000
ice_cover_area	_FillValue	b	-32767

9.6.3 Auxiliary variables

Variable Name	Attribute/type	Type	Value
lakes_cci_id	_FillValue	i	-2147483648
lakes_cci_id	long_name	c	Lake ID
lakes_cci_id	units	c	1
lakes_cci_id	valid_min	s	1
lakes_cci_id	valid_max	s	9999999999



lakes_cci_id	comment	c	First digit for source database: 0=GLWD, 1=GLBL, 2=CGL2, 3=HYLA. Remaining digits: lake id at source
distance_to_land	_FillValue	s	-32678
distance_to_land	units	c	km
distance_to_land	long_name	c	distance_to_land
distance_to_land	valid_min	s	0
distance_to_land	valid_max	s	27183
distance_to_land	scale factor	f	0.01
distance_to_land	add_offset	f	0
distance_to_land	resolution	c	0.1 kilometers
distance_to_land	comment	c	Distance to nearest land defined in in Carrea L., Embury O., Merchant C.J. (2015): GloboLakes: high-resolution global limnology dataset v1. Centre for Environmental Data Analysis, 21 July 2015. doi:10.5285/6be871bc-9572-4345-bb9a-2c42d9d85ceb.

9.6.4 Auxiliary file

A csv file containing the list of the ESA CCI LAKES 2024 lakes is provided together with the product netCDF file. The information provided in the files are listed in Table 19. The list of lakes is provided to help users familiarize themselves with the available lakes and quickly locate the file for a specific lake.

Table 19 Content of the csv file provided with the gap-filled LSWT+LIC dataset

Columns of the csv files	Comments
Lake id	Lake identifier which is part of the per-lake filename
Lake name	Name of the lake
Country	Country (-ies) where the lake is situated



Lat centre	Latitude of the lake centre defined as the point of the lake which is the most distant to land (as defined in Carrea L., Embury O., Merchant C.J. (2015): GloboLakes: high-resolution global limnology dataset v1. Centre for Environmental Data Analysis, 21 July 2015. doi:10.5285/6be871bc-9572-4345-bb9a-2c42d9d85ceb.)
Lon centre	Longitude of the lake centre defined as the point of the lake which is the most distant to land (as defined in Carrea L., Embury O., Merchant C.J. (2015): GloboLakes: high-resolution global limnology dataset v1. Centre for Environmental Data Analysis, 21 July 2015. doi:10.5285/6be871bc-9572-4345-bb9a-2c42d9d85ceb.)
Max distance to the closest land	Distance of the lake centre (as defined in Carrea L., Embury O., Merchant C.J. (2015): GloboLakes: high-resolution global limnology dataset v1. Centre for Environmental Data Analysis, 21 July 2015. doi:10.5285/6be871bc-9572-4345-bb9a-2c42d9d85ceb.) to the closest land
Lake surrounding box lat min	Minimum latitude of the surrounding box used in the per-lake file
Lake surrounding box lat max	Maximum latitude of the surrounding box used in the per-lake file
Lake surrounding box lon min	Minimum longitude of the surrounding box used in the per-lake file
Lake surrounding box lon max	Maximum longitude of the surrounding box used in the per-lake file



Appendix A - Acronyms

This is a generic list containing acronyms commonly used in the project

AATSR	Advanced Along Track Scanning Radiometer
AATSR	Advanced Along Track Scanning Radiometer
AERONET-OC	AErosol RObotic NETwork - Ocean Color
AMI	Active Microwave Instrument
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
APP	Alternating Polarization mode Precision
ASAR	Advanced Synthetic Aperture Radar
ASLO	Association for the Sciences of Limnology and Oceanography
ATBD	Algorithm Theoretical Basis Document
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced very-high-resolution radiometer
BAMS	Bulletin of the American Meteorological Society
BC	Brockman Consult
C3S	Copernicus Climate Change Service
CCI	Climate Change Initiative
CDR	Climate Data Record
CDOM	Coloured Dissolved Organic Matter
CEDA	Centre for Environmental Data Archival
CEMS	Centre for Environmental Monitoring from Space
CEOS	Committee on Earth Observation Satellites
CF	Climate and Forecast
CGLOPS	Copernicus Global Land Operation Service
CIS	Canadian Ice Service
CLS	Collecte Localisation Satellite
CMEMS	Copernicus Marine Environment Monitoring Service
CMUG	Climate Modelling User Group
CNES	Centre national d'études spatiales
CNR	Compagnie Nationale du Rhône
CORALS	Climate Oriented Record of Altimetry and Sea-Level
CPD	Communication Plan Document
CR	Cardinal Requirement
CRG	Climate Research Group
CSWG	Climate Science Working Group
CTOH	Center for Topographic studies of the Ocean and Hydrosphere
DUE	Data User Element
ECMWF	European Centre for Medium-Range Weather Forecasts
ECV	Essential Climate Variable
ELLS-IAGRL	European Large Lakes Symposium-International Association for Great Lakes Research
ENVISAT	Environmental Satellite
EO	Earth Observation
EOMORES	Earth Observation-based Services for Monitoring and Reporting of Ecological Status
ERS	European Remote-Sensing Satellite
ESA	European Space Agency
ESRIN	European Space Research Institute
ETM+	Enhanced Thematic Mapper Plus



EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAQ	Frequently Asked Questions
FCDR	Fundamental Climate Data Record
FIDUCEO	Fidelity and Uncertainty in Climate data records from Earth Observations
FP7	Seventh Framework Programme
GAC	Global Area Coverage
GCOS	Global Climate Observing System
GEMS/Water	Global Environment Monitoring System for freshwater
GEO	Group on Earth Observations
GEWEX	Global Energy and Water Exchanges
GloboLakes	Global Observatory of Lake Responses to Environmental Change
GLOPS	Copernicus Global Land Service
GTN-H	Global Terrestrial Network – Hydrology
GTN-L	Global Terrestrial Network – Lakes
H2020	Horizon 2020
HYDROLARE	International Data Centre on Hydrology of Lakes and Reservoirs
ILEC	International Lake Environment Committee
INFORM	Index for Risk Management
IPCC	Intergovernmental Panel on Climate Change
ISC	International Science Council
ISO	International Organization for Standardization
ISRO	Indian Space Research Organisation
JRC	Joint Research Centre
KPI	Key Performance Indicators
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
LIC	Lake Ice Cover
LIT	Lake Ice Thickness
LSC	Lake Storage Change
LSWT	Lake Surface Water Temperature
LWE	Lake Water Extent
LWL	Lake Water Level
LWLR	Lake Water Leaving Reflectance
MERIS	MEDium Resolution Imaging Spectrometer
MGDR	Merged Geophysical Data Record
MODIS	Moderate Resolution Imaging Spectroradiometer
MSI	MultiSpectral Instrument
MSS	MultiSpectral Scanner
NASA	National Aeronautics and Space Administration
NERC	Natural Environment Research Council
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NSERC	Natural Sciences and Engineering Research Council
NSIDC	National Snow & Ice Data Center
NTU	Nephelometric Turbidity Unit
NWP	Numerical Weather Prediction
OLCI	Ocean and Land Colour Instrument
OLI	Operational Land Imager
OSTST	Ocean Surface Topography Science Team
PML	Plymouth Marine Laboratory
PP	Payment Plan
PRISMA	PRecursore IperSpettrale della Missione Applicativa
Proba	Project for On-Board Autonomy



QSR	Linear Correlation Coefficient
R	Linear Correlation Coefficient
RA	Radar Altimeter
RMSE	Root Mean Square Error
SAF	Satellite Application Facility
SAR	Synthetic Aperture Radar
SeaWIFS	Sea-viewing Wide Field-of-view Sensor
SIL	International Society of Limnology
SLSTR	Sea and Land Surface Temperature Radiometer
SoW	Statement of Work
SPONGE	SPaceborne Observations to Nourish the GEMS
SRD	System Requirements Document
SSD	System Specification Document
SST	Sea Surface Temperature
STSE	Support To Science Element
SWOT	Surface Water and Ocean Topography
TAPAS	Tools for Assessment and Planning of Aquaculture Sustainability
TB	Brightness Temperature
TM	Thematic Mapper
TOA	Top Of Atmosphere
TR	Technical Requirement
UNEP	United Nations Environment Programme
UoR	University of Reading
UoS	University of Stirling
US	United States
VIIRS	Visible Infrared Imaging Radiometer Suite
WCRP	World Climate Research Program
WHYCOS	World Hydrological Cycle Observing Systems
WMO	World Meteorological Organization
WP	Work Package

