Consortium Members

D4.3: Product User Guide (PUG)

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1. Introduction

The Product User Guide (PUG) contains the description of version 1.1 of the Lakes_cci dataset, this project is part of the Climate Change Initiative led by the European Space Agency (ESA). The PUG provides the end user with practical information regarding the use of the different products included in the Lakes Essential Climate Variable (ECV).

This PUG accompanies version 1.1 of the CDRP of the Lakes_cci and details its file content, format, standards applied for variables calculation, software tools enabled to read the data.

The user shall rely on the CRDP meta data to know exactly which data has been used to generate the CRDP. Lakes_cci project

The overarching objective of the Lakes_cci project is to produce and validate a consistent data set of the variables grouped under the Lakes ECV. This includes aiming for the longest period of combined satellite observations by designing and operating processing chains, designed to be ultimately feature in a sustainable production system

The Lakes project covers multiple variables: Lake Water Level, Lake Water Extent, Lake Surface Water temperature, Lake Ice Cover, and Lake Water-Leaving Reflectance.

To achieve this global objective, the specific objectives for the Lakes project are:

- **To assess** the requirements of the climate research community and thereby ensure consistency in the (further) development of the Lakes ECV processing system. The criteria will be revisited to propose complementary groups of lakes for each of the lake ECV product.
- **To develop**, test and select the best algorithms and standards to produce high quality Lake products for climate applications across sensors. A range of algorithms and methods will be assessed to yield the longest possible period of observations for each variable, and the largest possible subset of lakes for which a complete set of variables can be provided.
- **To provide** a specification of the operational production system, aligned with related activities in the Copernicus programme (e.g. Global Land Service, C3S). The system will include new algorithms developed and validated within the project to meet user requirements.
- **To validate** the Lake ECV products through the involvement of independent climate research groups. Five Use Case studies are proposed for the demonstration of products and their value to climate science and applications.
- **To generate** new interest in the EO climate datasets produced for inland water bodies within the community of limnologists, operating at local to global spatial scales and likely to use varying subsets of the Lakes ECV products.

1.1. Lakes_cci products

Lakes are of significant interest to the scientific community, local to national governments, industries and the wider public. A range of scientific disciplines including hydrology, limnology, climatology, biogeochemistry and geodesy are interested in distribution and functioning of the millions of lakes (from small ponds to inland seas) from the local to the global scale. Remote sensing provides an opportunity to extend the spatio-temporal scale of lake observation. In this context, the Lakes_cci develops products for the following five thematic climate variables:

- Lake Water Level (LWL): fundamental to understand the balance between water inputs and water loss.
- Lake Water Extent (LWE): a proxy for change in glacial regions (lake expansion) and drought in many arid environments, water extent relates to local climate for the cooling effect that water bodies provide.
- Lake Surface Water temperature (LSWT): correlated with regional air temperatures and a proxy for mixing regimes, driving biogeochemical cycling and seasonality.
- Lake Ice Cover (LIC): freeze-up in autumn and advancing break-up in spring are proxies for gradually changing climate patterns and seasonality.

- Lake Water-Leaving Reflectance (LWLR): a direct indicator of biogeochemical processes and habitats in the visible part of the water column (e.g. seasonal phytoplankton biomass fluctuations), and an indicator of the frequency of extreme events (peak terrestrial run-off, changing mixing conditions).

In this context, Lakes_cci represents a unique framework to provide **consistent and homogenous** data to the multiple communities of lake scientists. The project actively engages with this community to assess the utility and future improvement of Lakes_cci products.

1.2. User requirements

During the first months of the project, a user requirement analysis was conducted to define the specification of the lakes_cci product to address the needs of the key user of this ECV. The approach involved a review of existing requirements that were specified both in the Statement of Work and in the Lakes_cci as those specified by the Global Climate Observing System (GCOS). Then, a new set of user requirements for Lakes_cci have been obtained through an online survey, which was open to both current and potential users of the ECV Lakes for both climate and more general applications.

Table 1 shows observation target requirements for the Lakes ECV products. The general method of synthesis for these targets is to adopt the most stringent well-justified statement of requirement. **The synthesis is therefore a statement of target requirements and does not represent a statement of what will or can be achieved.**

The traceability of the contents is given by superscripts on the targets as follows:

- G: source is GCOS (2016)
- Q: source is the Lakes_cci questionnaire
- P: source is the project team's experience
- L: source is the literature review

Table 1. Synthesised observation target requirements for the Lakes ECV

Product	Lake Water Level (LWL)	Lake Water Extent (LWE)	Lake Surface Water Temperature (LSWT)	Lake Ice Cover (LIC)	Lake Water Leaving Reflectance or Lake Colour (LWLR)
Measurement uncertainty	1.5 cm for large lakes (G) 5 cm for the reminder (G)	5% (relative) (G) 2.5% (for 70 largest lakes) (G)	0.15°K (P)	LIC: 10% (G,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)	LIC: 1% /decade (G)	1% /decade (G,P,L)
Spatial resolution	N/A : per lake (Q)	N/A : per lake (Q)	100 m (P)	LIC: 100 m (P)	100 m (P)
Temporal resolution	daily ground-based or satellite observations (G)	daily changes (G)	Daily (P)	LIC: daily observations (G,P)	Daily observations (Q)
Length of record	>10 years (L)	>10 years (L)	>10 years (L)	>10 years (L)	>10 years (L/P)
Maximum delay before availability of	1 year (P)	1 year (P)	1 year (P)	1 year (P)	1 year (P)

Product	Lake Water Level (LWL)	Lake Water Extent (LWE)	Lake Surface Water Temperature (LSWT)	Lake Ice Cover (LIC)	Lake Water Leaving Reflectance or Lake Colour (LWLR)
data (for climate users)					

2. Instruments overview

Multiple data from multiple satellite missions is required for the successful generation and validation of all component products for the lake essential climate variable within ESA CCI project.

The Table 2 summarises the satellite/sensor used in the estimation of the products that are part of the ECV Lakes. The user shall refer to the CRDP meta data to get the exactly list of satellite/sensors used.

Table 2. Missions and instruments used in the generation of the lakes_cci dataset

Satellite	Sensor	Product				
		LWL	LWE	LSWT	LIC	LWLR
Topex/Poseidon	Poseidon-1					
Jason-1	Poseidon-2					
Jason-2	Poseidon-3					
Jason-3	Poseidon-3B					
ENVISAT	Radar Altimeter (RA-2)					
	AATSR					
	MERIS					
SARAL	AltiKa					
Geosat Follow On	Radar Altimeter					
Sentinel-1	C-band SAR					
Sentinel-2	MSI					
Sentinel-3A	SRAL					
	OLCI A/B					
	OLCI-SLSTR A/B					
Sentinel-3B	SRAL					
Landsat-4	MSS, TM					
Landsat-5	MSS, TM					
Landsat-7	ETM+					
Landsat-8	OLI					
Terra/Aqua	MODIS					
Suomi NPP	VIIRS					
ERS-1	RA					
	AMI					
	SAR					
ERS-2	RA					
	AMI					
	SAR					
	ATSR-2					
METOP-A/B	AVHRR					
Orbview-2	SeaWIFS					

3. Data description

3.1. Lake Water Level (LWL)

Lake water level information is traditionally obtained via ground-based observation systems and networks that suffer from well-known inherent problems: high cost, sparse coverage (often limited to political local/national instead of geographical/hydrological boundaries), slow dissemination of data, heterogeneous temporal coverage, destruction of the stations during floods, absence of stations in remote areas, absence of management strategy, etc.

Although originally conceived to study open ocean processes, the radar altimeter satellites have nevertheless acquired numerous useful measurements over lakes. This technique, that can complement ground-based observations systems, potentially provides a major improvement in the field of continental hydrology, due to the global coverage (however limited to Earth's portion at nadir of the orbital ground tracks), regular temporal sampling and short delivery delays.

Early studies rapidly demonstrated the great potential of satellite altimetry to monitor large continental water bodies such as the Caspian Sea or the East African lakes (Birkett, 1995; Birkett et al, 1998; Mercier et al., 2002). However, these studies also raised many important issues related to the need of a dedicated treatment and interpretation of the measurements acquired over continental waters. More specifically, the radar echoes (waveforms) returned by inland waters can strongly differ from those returned by the ocean (because of the contamination of the signal by reflections over emerged lands), thus altering the accuracy of the height retrievals.

However, the recognition of these systems by the hydrological community is increasing, and new altimeter sensors are currently being designed following the requirements expressed by hydrologists for scientific use but also for the water resources management operational services that are emerging. For the moment, the scientific use is preponderant (Crétaux et al, 2011) and mainly concerns the global scale: monitoring of large climatically sensitive lakes, or the study of the temporal water masses redistribution within a large basin.

3.1.1. Background

3.1.1.1. Satellite Radar Altimetry

Radar altimetry from space consists of vertical range measurements between the satellite and water level. Difference between the satellite altitude above a reference surface (usually a conventional ellipsoid), determined through precise orbit computation, and satellite-water surface distance, provides measurements of water level above the reference. Placed onto a repeat orbit, the altimeter satellite overflies a given region at regular time intervals (called the orbital cycle), during which a complete coverage of the Earth is performed.

Water level measurement by satellite altimetry has been developed and optimized for open oceans. Nevertheless, the technique is now applied to obtain water levels of inland seas, lakes, rivers, floodplains and wetlands. Several satellite altimetry missions have been launched since the early 1990s : ERS-1/RA (1991-1996), TOPEX/Poseidon (1992-2006), ERS-2/RA (1995-2005), GFO (2000-2008), Jason-1 (2001-2012), ENVISAT/RA-2 (2002-2012), Jason-2 (2008-), Cryosat-2 (2010-), HY-2A (2011-), SARAL/AltiKa (2013-), Sentinel-3A (2016-), Sentinel-3B (2018-). ERS-1, ERS-2, ENVISAT and SARAL have a 35-day temporal resolution (duration of the orbital cycle) and 80 km inter-track spacing at the equator. TOPEX/Poseidon, Jason-1, Jason-2 and Jason-3 have a 10-day orbital cycle and 350 km equatorial inter-track spacing. GFO has a 17-day orbital cycle and 170 km equatorial intertrack spacing. Sentinel-3A orbit has a revisit time of 27 days and its inter-tracking separation is 104 km. It has been reduced to 52 km in a two-satellite configuration (Sentinel-3A and B). Figure 1 shows the Jason passes over some Russian lakes. The combined global altimetry data set has more than 20 year-long history and is intended to be continuously updated in the coming decade. Combining altimetry data from several in-orbit altimetry missions increases the space-time resolution of the sensed hydrological variables.

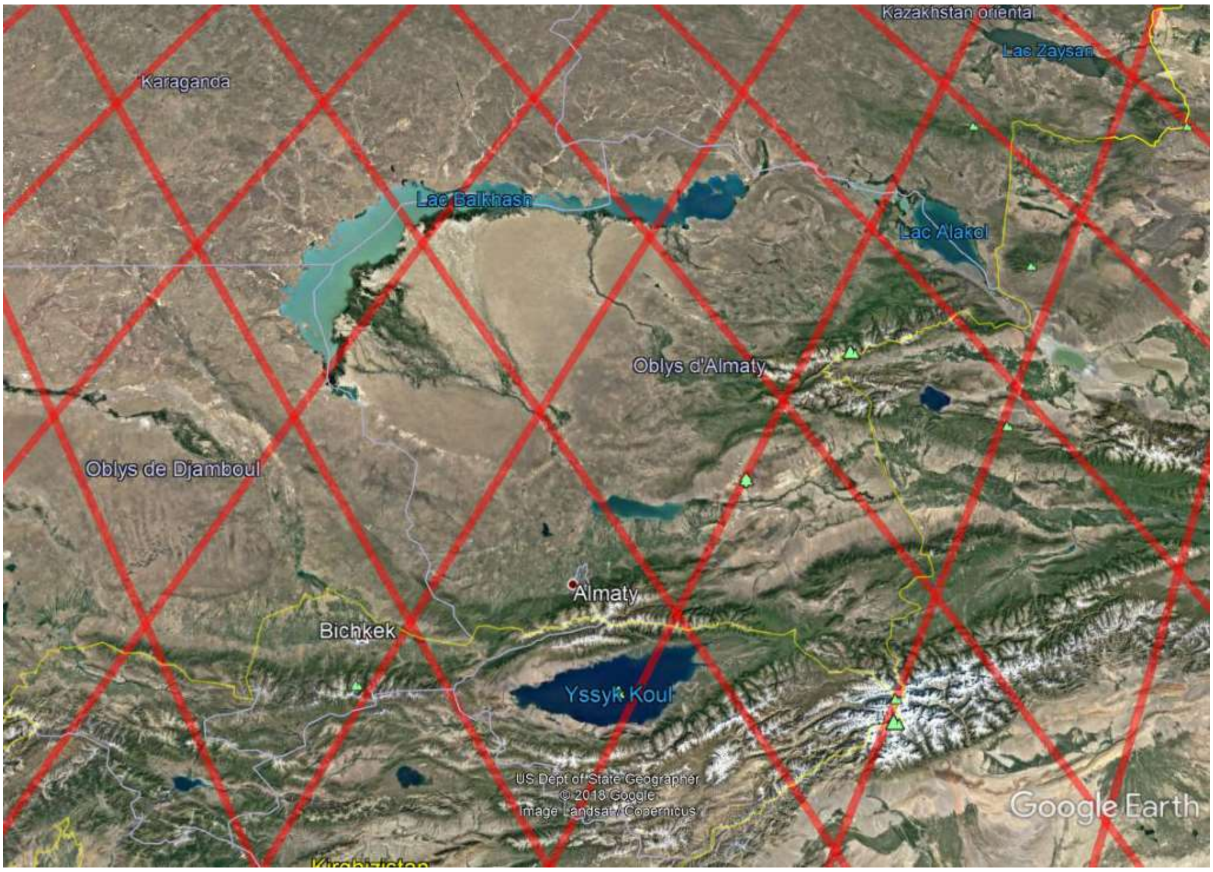

Figure 1 TOPEX/Poseidon (Jason1, Jason 2 and Jason 3) passes over the lakes Balkash, Yssik-Koul, Alakol and Saysan. Note that in between those passes, no measurements are made by these satellites.

3.1.1.2. Computing surface height

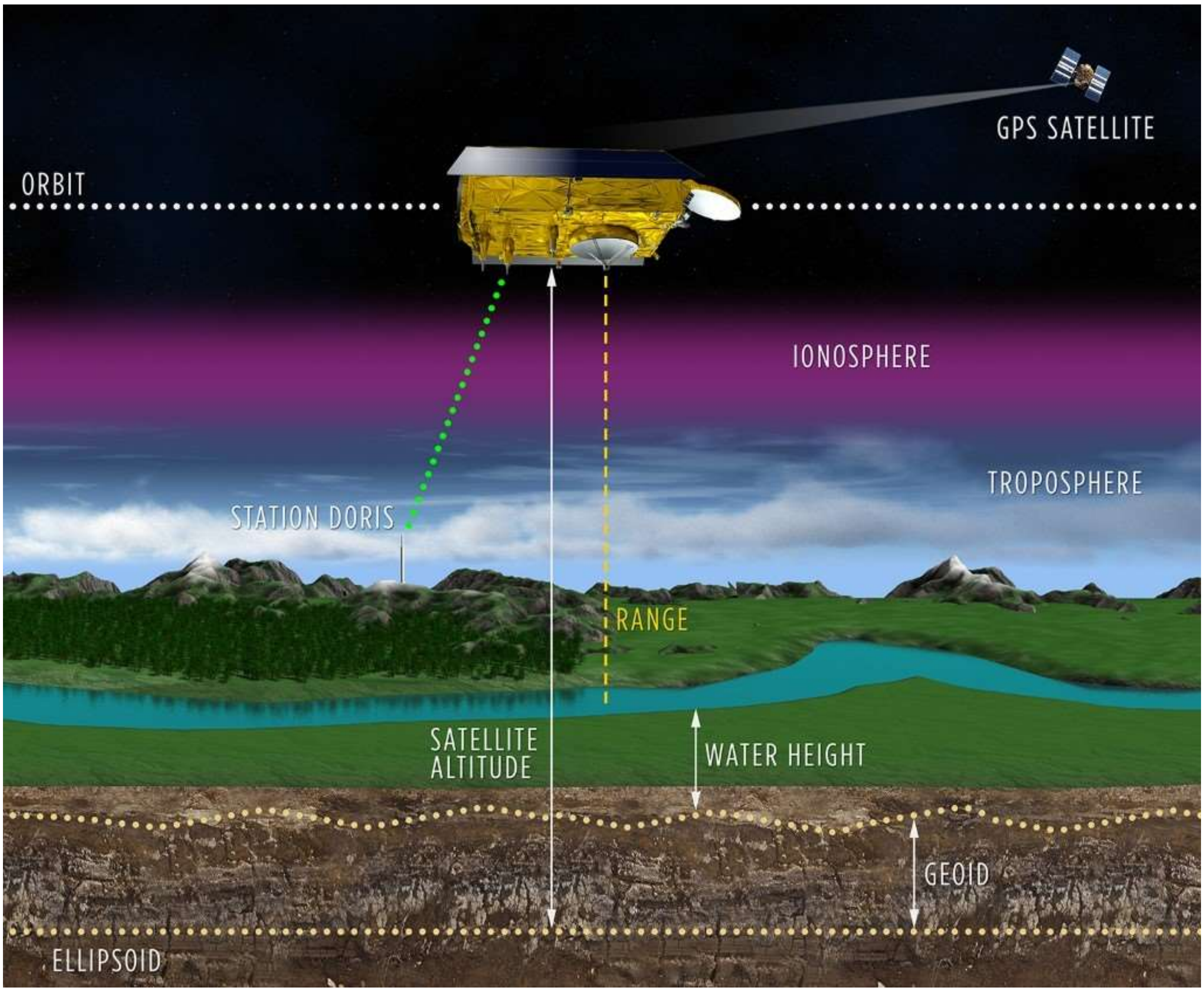

Figure 2. Altimetry principle (Credit CNES – Mira production)

For all satellites, the following operation is done:

Surface Height = altitude – corrected_range

With:

Corrected_range = range + Wet_tropo + Dry_ tropo + iono + polar tide + solid earth tide

"Wet_tropo" is a correction to account for the delay of the radar signal due the wet part of the atmosphere.
"Dry_tropo" is a correction to account for the delay of the radar signal due the dry part of the atmosphere.
"Iono" is a correction to account for the delay of the radar signal due the electronic content of the ionosphere.
"Polar Tide" and "Solid Earth Tide" are two corrections that account for the temporal deformation at the Earth' surface.

Note that for SARAL/AltiKa, ionospheric correction is not taken into account due to the frequency used for this mission (Ka-band), which is not sensitive to the ionosphere electron content.

Finally, the water surface height is expressed with respect to the geoid:

Water Surface Height = Surface Height – geoid

The geoid value considered here is extracted from a mean profile file over large lakes.

3.1.1.3. Processing

Altimetry missions used are repetitive, i.e. the satellite overflies the same point at a given time interval (10, 27, 35 days… depending on the satellite). The satellite usually does not deviate from more than +/- 1 km across its track.

A given lake can be flown over by several satellites, with potentially several passes, depending on its surface area and shape. Several passes can be used to derive the lakes' WSH timeseries according to their surface areas. The term "lakes" refers to lakes or reservoirs.

3.1.1.3.1. Input data

Lake Water levels are based on merged multi mission observations: TOPEX/Poseidon, Jason-1, Jason-2, Envisat, and SARAL data provided by ESA, NASA and CNES data centres. Updates include Jason-3 and Sentinel-3A respectively provided by CNES data centre and Copernicus Hub. The complete list of altimetric data and ancillary data for the whole period is described in the Data Access Requirement Document (DARD).

3.1.1.3.2. Method

The altimeter range measurements used for lakes consist of 20 Hz IGDR and GDR data. All classical corrections (orbit, ionospheric and tropospheric corrections, polar and solid Earth tides and sea state bias) are applied. Depending on the size of the lake, the satellite data may be averaged over very long distances. It is thus necessary to correct for the slope of the geoid (or equivalently, the mean lake level). Because the reference geoid provided with the altimetry measurements (e.g., EGM96 for T/P data or EGM2008 for Sentinel-3A) may not be accurate enough, we have computed a mean lake level, averaging over time the altimetry measurements themselves. Such mean lake level surface along each satellite track across the lake provides a better estimate of the model geoid. Mean profiles are therefore used for lake water level computations which are then referenced with respect to this estimate of the geoid. If different satellites cover the same lake, the lake water level is computed in a 3-step process:

- Extraction of input data: including an editing to remove erroneous measurement
- Lake water level computation and filtering
- Generation of output NetCDF files, including lake water level and the associated uncertainty

Each satellite data is processed independently. Potential radar instrument biases between different satellites are removed using T/P data as reference. We generally observe an increased precision of lake levels when multi-satellite processing is applied. The Algorithm Theoretical Basis Document (ATBD) contains a detail description of the algorithm used to estimate the LWL product.

3.1.2. Limitations of the product

The lake processing chain, initially developed at LEGOS, are based on the use of altimetry measurements from the CTOH database (Centre for Topography of the Oceans of LEGOS), including for Envisat GDRs. This database includes in addition some enhanced corrections that are not in the data sets of institutional suppliers (Aviso, ESA), such as for the wet and dry tropospheric as well as for the ionospheric corrections. As part of the online version of HYSOPE, these tailored corrections are replaced by default by their corresponding standard corrections included in the operational input products. On the other hand, a module for calculating the height of the geoid has been developed in the operational chain, starting from a grid provided by the LEGOS.

3.2. Lake Water Extent (LWE)

3.2.1. LWE definition and usage

LWE can be expressed as the presence of water (on a map), or as the total areal extent of a waterbody (a single number). Studying and monitoring variations and trends in lake area, or lake water extent (LWE) can be an important tool in identifying climatic variations over time since this physical parameter is regulated by changes in climate. Hence, changes in LWE can be indicators of climate variations since they are sensitive to changes in water and heat balance. LWE together with LWL can be utilized to assess the total volume of water in a lake.

It is practically impossible to determine lake extent variations from in situ measurements (and historic data are not available), therefore the only solution is to delineate lake shorelines from satellite imagery. To this matter, optical and SAR imagery will be exploited to generate LWE.

LWE will be combined with LWL (calculated using satellite altimetry) to determine the hypsometry relationship, which represents the variation of lake extent with respect to lake height. When hypsometry is established, using only satellite altimetry results, water height and extent of lakes may be measured from daily (for the biggest lakes like Caspian Sea or the Great lakes) to weekly or at worse monthly.

Optical and SAR LWE are complementary and are aimed to jointly feed the hypsometry relationship. Nevertheless, for the sake of comprehension, the following sections will be separately done for optical and SAR data.

3.2.2. LWE SAR data characteristics

SAR LWE are generated both as a geocoded binary map (water/non water) in geotiff and shapefile and as a single area value (in square kilometres) in a text file. Pixel size depends on the employed images. Uncertainty information will be provided with these products. At the present time the generation of this information is under development.

In order to better understand the SAR LWE product, it is worth mentioning some characteristics of the SAR images and the followed methodology (detailed in the ATBD document). This will be also useful when describing SAR LWE SAR limitations.

SAR images are acquired in native range-azimuth geometry. This can cause the appearance of geometric artefacts, especially if the area of interest (lake) is located at a steep topography area. These artefacts may introduce (in general with low probability but not fully excludable) some misclassifications.

The use of SAR data for water delineation is based on the analysis of the SAR backscatter image. In the case of still open water, strong specular reflection occurs at the surface, thereby returning little of the incident wave back to the radar. SAR backscatter from still water is therefore very low and water is distinguished in SAR backscatter images since it appears very dark. Therefore, land covers on the surroundings of the lake presenting similar (low) backscatter properties may induce misclassifications.

SAR images are affected by speckle noise. So, a filtering process is applied to them for a more accurate water class retrieval.

3.2.3. LWE SAR data sources

The SAR default sensor employed in this project is Sentinel 1. In any case, any SAR mission image can be used to retrieve LWE according to the methodologies developed and employed in the present project. Table 3 shows the most common SAR orbital missions and some of their main characteristics. Note that only one beam mode has been selected for each mission.

Table 3. Most common SAR orbital missions.

CONSTELLATION	AGENCY	working since	working until	number of satellites	repeating cycle (each sat)	beam mode	polarization	res (rg x az) m	tile (rg x az) km
ERS	ESA	1992	2001	2	35	-	single	20 x 5	100 x 100
J-ERS	NASDA	Nov 1992	Dec 1998	1	44	-	single	18 x 18	75 x 75
ALOS-PALSAR	JAXA (Japan)	Jan 2006	May 2011	1	46	Fine Beam Single	single	8.3 x 3.3	55 x 75
ALOS-2	JAXA (Japan)	May 2014	active	1	14	Fine SM1	dual	3 x 10	50 x 70
ENVISAT-ASAR	ESA	Jan 2002	Oct 2010	1	35	S2	single	20 x 5	100 x 100
RADARSAT-1	CSA (Canada)	Jan 1998	Mar 2013	1	24	Standard	single	20 x 5	100 x 100
RADARSAT-2	CSA (Canada)	Jan 2008	active	1	24	Standard		20 x 5	100 x 100
TerraSAR-X/PAZ	DLR (Germany)	TSX Nov 2007, PAZ Sep 2019	active	1	11	stripmap	single	3 x 3	30 x 50
COSMO-SkyMED	ASI (Italy)	Jan 2008	active	4	16	stripmap	single	3 x 3	40 x 40
SENTINEL-1	ESA	1A Apr 2014, 1B Apr 2016	active	2	12	IW wide swath	dual	5 x 20	250 x 250

As they present different properties, these are the general aspects which have to be taken into consideration when planning or analysing a SAR LWE study:

- SAR data most common formats are Ground Range Detected (GRD) and Single Look Complex. C (SLC). GRD data products consist of focused SAR data that has been detected, multi-looked and projected to ground range using an Earth ellipsoid model. Level-1 Single Look Complex (SLC) products are images in the slant range by azimuth imaging plane. Both of them are considered as input to the LWE SAR methodologies.
- It is preferable to employ multi-polarization data (co-polar and cross-polar components) as they can be jointly used to increase accuracy. To this matter, the standard acquisition in Sentinel-1 is dual-pol (VV, VH). Full-polarization configuration is poorly populated on the SAR images catalogue.
- Different missions present different spatial resolutions. As a rule of thumb, the larger the spatial resolution (smaller pixel size) the better. To this matter it is important mentioning that images are speckle filtered during the LWE calculation processing, decreasing spatial resolution (larger pixel size).
- Different missions present different revisit times. Therefore, mission's acquisition frequency properties should be then considered depending on the LWE temporal monitoring requirements.
- Different missions have different spatial coverage. In most of the cases, the full lake is covered by a single frame, but it could happen that a single frame does not cover the full lake but a part of it. Total coverage could be achieved by using the contiguous track but this will be acquired at a different time.
- Ascending and descending orbit image acquisitions (when available) increase the revisit time. Furthermore, it increases the probability of fully covering the lake with a single frame.

3.2.4. LWE SAR data limitations

Some of the limitations are due to the SAR acquisition nature. Any significant modification of the low roughness condition of the water surface affects the LWE accuracy. The presence of ice/snow, strong wind and shallow waters causes that negative effect. Vegetation and high soil moisture along the shore line can also in some cases cause confusion. For example, in highly seasonal lakes ice/snow SAR images may be discarded for LWE generation since the uncertainty is higher. The presence of low backscatter land cover in the surroundings can also cause misclassification. Similarly, the averaging for speckle noise reduction can also introduce bias on the LWE estimation.

The employed methodology relies on thresholding and classification techniques. Therefore, depending on the water/non water contrast conditions misclassifications can be introduced.

3.2.4.1. LWE optical data characteristics

Optical LWE are generated both as a geocoded binary map (water/non water) in geotiff and shapefile and as a single area value (in square kilometres) in a text file. Pixel size depends on the employed images. Uncertainty information will be provided with these products. The production of this information is currently under development

In order to better understand the Optical LWE product, it is worth mentioning some characteristics of the optical images and the followed methodology (detailed in the ATBD document). This will be also useful when describing Optical LWE limitations.

The use of Optical data for water delineation is based on the analysis of the reflectance of water surfaces and their dynamics, quality and environment.

In the case of large open water body, classical case in public's mind, a case that did not occurred so often finally, water surfaces are characterized by a relative low signal in the VIS, decreasing in the NIR and trending towards zero in the SWIR spectral domain. Therefore, depending of the suspended materiel content, the depth of the water bodies, and the water flow, signal principally in the VIS and NIR bands is significantly modified. distinguished in SAR backscatter images since it appears very dark. plus land cover units on the surroundings of the lake could present similar (low) reflected signal, others one can also induce shadowing effects, that may induce misclassifications,

3.2.4.2. LWE Optical data sources

The Optical default sensor employed in this project is Sentinel 2, A and B. In absolute, any High Resolution image can be used to retrieve LWE according to the methodologies developed and employed in the present project. Therefore, Sentinel 2 like imagery is preferred due to the availability of SWIR bands, SPOT 4 &5, Landsat, Aster and Senintel2 A/B . Table 4 shows the classical most common optical orbital missions and some of their main characteristics. The list is not exhaustive (SPOT 6-7, DEIMOS, Rapid Eye missions are for example missing), are presented examples of Very High Resolution satellite and High Resolution satellites.

Table 3: Typical HR and VHR optical orbital missions

CONSTELLATION	AGENCY	working since	working until	number of satellites	repeating cycle (each sat)	beam mode	polarization	res (rg x az) m	tile (rg x az) km
ERS	ESA	1992	2001	2	35	-	single	20 x 5	100 x 100
J-ERS	NASDA	Nov 1992	Dec 1998	1	44	-	single	18 x 18	75 x 75
ALOS-PALSAR	JAXA (Japan)	Jan 2006	May 2011	1	46	Fine Beam Single	single	8.3 x 3.3	55 x 75
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RADARSAT-2	CSA (Canada)	Jan 2008	active	1	24	Standard		20 x 5	100 x 100
TerraSAR-X/PAZ	DLR (Germany)	TSX Nov 2007, PAZ Sep 2019	active	1	11	stripmap	single	3 x 3	30 x 50
COSMO-SkyMED	ASI (Italy)	Jan 2008	active	4	16	stripmap	single	3 x 3	40 x 40
SENTINEL-1	ESA	1A Apr 2014, 1B Apr 2016	active	2	12	IW wide swath	dual	5 x 20	250 x 250

As they present different properties, these are the general aspects which have to be taken into consideration when planning or analysing an Optical LWE study:

- Images are delivered most of the time in top of atmosphere luminance, level1. Only recent ones, i.e. Sentinel 2 over some places, are available at level 2, after receiving atmospheric corrections and providing top canopy reflectance. It must be noticed which level the exploited data are.
- A large amount of missions presenting different spatial resolutions can be exploited; as a rule of thumb, the larger the spatial resolution (smaller pixel size) the better. Therefore, in order to cover large lakes, sensors associating High resolution and large swath such as Sentinel 2 or Landsat are very valuable.
- Even if different missions present different revisit times, it is recommended to exploit their synergy in order to access to a sufficient amount of data to answer the LWE temporal monitoring requirements.

3.2.4.3. LWE optical data limitations

Some of the limitations are due to the optical acquisition nature. Of course, the first limitations, related to passive acquisitions characteristics corresponds to the meteorological conditions, presence of clouds, haze or fog, limit the observation of the surface earth and by the way the detection of water bodies. In some case, when sunlight reflects off the surface of water at the same angle that a satellite sensor views it, it induces a sunglint phenomenon. It produces visually-stunning images, the phenomenon can create problems for water bodies extraction as it obscures features that are usually visible. At the opposite, there are seasonality aspect in term of detection, data acquired in winter with low solar azimuth, more shadows are more difficult to be exploited compared to a spring or summer images.

As already mentioned, the case of shallow waters with the influence of the bottom of the lake, or the case of transportation of suspended sediments and others detrital materials can influence a lot the spectral answer of water bodies, making their extraction delicate.

The employed methodology relies on classification techniques and thresholding. Therefore, depending on the water/non water contrast conditions misclassifications can be introduced. Some neighbouring targets such as snow, wet soil, ice can disrupt the water contours extraction.

3.3. Lake Ice Cover (LIC)

3.3.1. LIC definition and usage

LIC refers to the extent (or area) of a lake covered by ice. Lake-wide ice phenology can be derived from LIC, including freeze onset to complete freeze over (CFO) dates during the freeze-up period, melt onset to water clear of ice (WCI) dates during the break-up period, and ice cover duration derived from number of days between CFO and WCI dates over an ice year (Duguay et al., 2015). For lakes that do not form a complete ice cover every year or in some years (e.g. Laurentian Great Lakes of North America), maximum ice cover extent (timestamped with date) is also a useful climate indicator that can be determined (Derksen et al., 2019). Similarly, minimum ice cover extent (timestamped with date) can be derived for High Arctic lakes that do not completely lose their ice cover in summer, although a recent study suggests that these lakes may be transitioning from perennially to seasonally ice-covered (Surdu et al., 2016). Knowledge of fractional lake-wide ice coverage (expressed in tenth or as a percentage of total area of a lake covered by ice) on a ca. weekly basis is also useful for improving numerical weather forecasting in regions where ice cover forms.

LIC is highly sensitive to changes in weather and climate. Documented trends and variability in ice dates have largely been attributed to air temperature changes (e.g. Duguay et al., 2006; Brown and Duguay, 2010). Investigations of long-term trends (observable from ground-based records) and short-term (also observable from EO data records) reveal increasingly later freeze-up and earlier break-up dates, closely corresponding to increasing air temperature trends. Broad spatial patterns in these trends and regime shifts have been associated with changes in major atmospheric circulation patterns originating from the Pacific and Atlantic oceans such as the El Niño-La Niña/Southern Oscillation, the Pacific North American pattern, the Pacific Decadal Oscillation, and the North Atlantic Oscillation/Arctic Oscillation (Bonsal et al., 2006; Prowse et al., 2011). LIC also plays an important role in weather and climate. The presence (or absence) and fractional coverage/concentration of ice cover on large lakes has a significant impact on regional weather and climate (e.g., lake-effect snowfall, thermal moderation effect).

Given the importance of ice cover in lake-atmosphere interactions, the LIC ECV will be of interest to users who wish to: 1) examine short-term trends and interannual variability in ice cover globally (ca. 20 years); 2) investigate the impact of changing ice cover conditions on other variables covered in Lakes_cci, such as Lake Surface Water Temperature (LSWT); 3) conduct data assimilation experiments using state-of-the-art numerical weather prediction systems to demonstrate the impact of better consideration of LIC on, for example, improving predictions of lake-effect snowfall; and 4) evaluate lake models (e.g. FLake) used as lake parameterization schemes in numerical weather prediction and climate models. Finally, from a socio-economic perspective, the LIC variable may also serve to examine the impact of changing ice conditions on winter transportation (shipping, ice roads) and food security (access to resources by northern communities via ice roads).

3.3.2. LIC data characteristics

The LIC product consists of two variables (bands): 1) lake ice cover and 2) the uncertainty associated with the retrieval of LIC (see Table 5 under section 4.4.3). For the LIC variable each grid cell falling within a lake, as determined by the input lake mask, is assigned one of four possible values: water (value=1), ice (value=2), cloud (value=3), and bad (value=4; case where a retrieval was not possible due to poor data quality). For the uncertainty variable grid cells take one of three possible values (expressed as a percentage): water (1.15), ice (8.29), and cloud (4.37). Uncertainty for each category has been determined from accuracy assessment (confusion matrix) through independent statistical validation (see End to End ECV Uncertainty Budget, E3UB, document for details).

For CDRP V1.0, the LIC product is generated on a daily basis using MODIS data acquired from multiple Terra and Aqua satellite overpasses on each day as to maximize the number of cloud-free observations. The product, which covers a 20-year period (2000-2019), is merged with the other lakes thematic products on the common (harmonized) grid described in section 4.

3.3.3. LIC data sources

The LIC product is generated from all MODIS observations available from both the Terra (since 24 February 2000) and Aqua (since 4 July 2002) satellite missions. Hence, for the period between 24 February 2000 and 3 July 2002, only Terra observations were ingested for LIC product creation.

The primary input data source is the MODIS Terra/Aqua Atmospherically Corrected Surface Reflectance 5-Min L2 Swath (MOD09/MYD09), Collection 6 product (Vermotte et al., 2015). MODIS surface reflectance and brightness temperature bands are used for feature retrieval (i.e. for labelling as water, ice, or cloud). The surface reflectance bands are available at 250 m (QKM) and 500 m (HKM) resolutions. Brightness temperature bands are available in 1 km (1KM) resolution. Geolocation is provided at 1 km resolution and is interpolated to 250 m. The second data source for LIC product generation is the maximum water extent observed in ESA CCI Land Cover (v4.0) at 150-m resolution.

Details regarding the processing steps and the retrieval algorithm are described in the Algorithm Theoretical Basis Document (ATBD). Briefly, the processing steps consist of:

1) Loading MODIS MOD09/MYD09 surface reflectance (bands 2, 3, 4, 6/7), brightness temperature (bands 20, 31, 32), and geolocation (latitude and longitude) bands.
2) Identifying lake (water) pixels of interest based on maximum water extent from ESA CCI Land Cover (v4.0) 150-m resolution product.
3) Identifying pixel quality and label pixels of interest from application of a threshold-based retrieval algorithm applied to Terra and Aqua data separately for the detection of clouds, ice and open water.
4) Resampling labelled pixels acquired in a day from individual swaths to the output grid at 1/120 degrees resolution and perform temporal (daily) and spatial aggregation (combining Terra and Aqua retrieved classes) in terms of each cell in the output grid.
5) Filtering the output grid to discard cells (1/120 degrees resolution) which contain land pixels using maximum water extent observed in ESA CCI Land Cover (v4.0) 150-m resolution product.
6) Writing and exporting the daily LIC product in the required format (NetCDF) with metadata.

3.3.4. LIC data limitations

The LIC daily product has been created using the longest possible MODIS time series (2000-2019) and with the intent of maximizing the number of clear-sky observations within each day. This is made feasible through the combination of multiple acquisitions from Terra and Aqua overpasses. While this approach increases the likelihood of detecting a larger number of grid cells containing ice cover or open water, the presence of cloud cover over extended periods of time across the northern hemisphere remains the greatest limiting factor for the generation of a spatially and temporally contiguous lake ice cover product from MODIS or any other optical satellite dataset.

In addition to the impact of cloud cover, users should be aware that other factors may also affect the quality of the LIC CDRP V1.0 (see E3UB document for greater details). They include, in no particular order of importance:

1) High solar zenith during fall freeze-up and early winter at high latitudes (i.e. polar darkness). For example, LIC retrieval is not possible from MODIS above ca. 61 degrees N latitude at winter solstice. In such instance the data is flagged as “bad”.
2) Use of the maximum water extent mask derived from ESA CCI Land Cover v4.0 at 150-m resolution product (secondary input data) to determine MODIS pixels falling within a lake. Since this mask represents maximum water extent, it can introduce some misclassification errors along the shoreline of lakes (i.e. mask spilling over land so that some MODIS land pixels may be incorrectly flagged as lake ice pixels) or for entire lakes or lake sections that dry up in summer. Other lake mask options will be examined leading to second release of the LIC product.
3) The quality and temporal continuity of the MOD09/MYD09 surface reflectance products used as the primary input data source.

- Although detector noise/sensor degradation and observation noise have been relatively well characterized (see E3UB document for details), there are few documented cases where noise has been found to lead to false negatives (e.g., detection of ice instead open water).
- Regarding temporal continuity, a few years have been found not to provide data from either Terra or Aqua on some days (missing days: 12 in 2000, 17 in 2001, 19 in 2002, 7 in 2003, 2 in 2008, and 9 in 2016).

4) Reporting of uncertainty. The assessment of uncertainty in the LIC CDRP V1.0 was performed through computation of a confusion matrix built on independent statistical validation. Uncertainty was not assessed at a per-pixel level, but rather from overall classification error calculated from multiple samples/images for each of three classes (ice, water, cloud). Every pixel belonging to a class was assigned the same overall % classification error under the LIC uncertainty variable. Efforts will be placed in identifying additional metrics for consideration and possible implementation for per-pixel uncertainty assessment leading to LIC v2.0 production.

3.4. Lake Surface Water Temperature (LSWT)

3.4.1. LSWT definition and usage

LSWT is the surface expression of the thermal structure of lakes and is changing in response to climatic trends. LSWT is needed for climate change studies, water budget analysis (linked to evaporation), lake physical and ecological modelling.

Lake surface water temperature (LSWT) is the temperature of the upper layer of lake water. In the case of a satellite observation of LSWT, the obtained value is sensitive to the skin temperature of the water, which is the temperature of a layer <0.1 mm thick from which thermal radiation is emitted by the lake. In Lake CCI products, the LSWT is an estimate of this skin temperature, which may differ from the temperature as measured by a thermometer a few centimetres below the water-air interface. Typically, the temperature difference between skin and sub-skin LSWT is of order –0.2 K (meaning, the skin temperature is on average cooler). However, the difference depends on meteorological conditions. Although the skin effect is variable, the satellite LSWT is nonetheless tightly coupled to the LSWT as measured conventionally, and satellite LSWTs have been used to quantify worldwide aspects of lake thermal dynamics such as seasonal cycles (Maberly et al., 2020), onset of summer stratification (Woolway and Merchant, 2018), lake mixing dynamics (Woolway and Merchant, 2019), over-turning behaviour (Fichot et al, 2019) and several other aspects of lake-climate interactions.

3.4.2. LSWT data characteristics

Users of the Lake products will note that the LSWT fields are not in general spatially complete. This arises because the LSWT estimation process (MacCallum and Merchant, 2012) is valid only for cloud-free views of the water surface from space, since the satellite sensors rely on infrared wavelengths to which clouds are opaque. The degree of "gappiness" is therefore variable in time and space, according to the weather conditions. Some lakes in cloudy regions are observed relatively rarely (many days between cloud-free measurements).

The primary LSWT variable is the lake surface water temperature field itself. Two other LSWT variables should be considered by users. (1) An estimate of uncertainty is provided per datum. The provided uncertainty field is an evaluation of total standard uncertainty (so-called "1-sigma"), and is estimated within the LSWT retrieval process. The uncertainty arises from a range of sources, some of which are independent between data, while other sources cause errors that are correlated to other nearby data. (2) A quality level is provided per datum. This is an index ranging from 2 (suspect/marginal quality) to 5 (best quality). "Quality" here means the level of confidence that the LSWT value and its evaluated uncertainty are both valid (Merchant et al., 2017). For climate applications, we recommend use of quality levels 4 and 5. However, LSWT with quality levels = 2 and 3 are present in the product, and users can assess their usefulness for their own application. Quality levels 1 (bad) and 0 (unprocessed) are never valid.

The provided data are on a regular latitude-longitude grid (see section 4), which means they have been regridded from the less regular pixel locations originally observed by the satellite sensors.

3.4.3. LSWT data sources

As background information, the basis on which LSWT data are obtained is summarised in this section.

1.1 The retrieval methodology

For full details of the basis of the data, refer to the Algorithm Theoretical Basis Document.

The algorithms to derive LSWT products aim to retrieve the LSWT from the observed reflectance and brightness temperature for only inland water pixels. The core retrieval is the Optimal Estimation (OE) of LSWT, which is a form of Bayesian inference of the LSWT given the difference between the satellite observations and simulations of those observations made for an assumed LSWT (the prior value). The other components of the algorithm prepare the inputs for the retrieval, namely they classify a satellite pixel as water or non-water. Finally, the observations are gridded and a cross-sensor adjustment is estimated and applied in order to obtained a harmonized result across the several sensors that contribute.

Preparatory processing: This includes orbit file reading, validity checks, association of auxiliary information to the orbit file being processed (including prior fields from numerical weather prediction, where relevant), and any pre-processing adjustment to the data themselves.

Classification: It identifies valid pixels for LSWT retrieval. Although sometimes referred to as cloud detection, this also involves identifying which image pixels cover only lake water (no coast or islands within the pixel), and exclusion of pixels affected by ice (for which LSWT cannot be obtained). Valid LSWT is estimated only for pixels that are fully water and free of cloud) The algorithm for the discrimination of water and non-water pixels in presence of clouds is based on threshold tests on the Visible (VIS), Near-InfraRed (NIR), and Short-Wave-InfraRed (SWIR) channels of the ATSR and AVHRR instruments. The water detection algorithm is applied only to candidate pixels identified as potential inland water in the water-bodies identifier mask [Carrea et al., 2015] built from the ESA CCI Land Cover Project.

Retrieval of LSWT (geophysical inversion): For pixels classified as water, LSWT is calculated dynamically given prior information with the Optimal Estimation technique [MacCallum and Merchant, 2012]. The prior information comprises NWP fields as inputs to a radiative transfer model, whose simulations in comparison to the observations are used in the retrieval. The LSWT is estimated for each (clear-sky) water pixel using joint optimal estimation of surface temperature and Total Column Water Vapour (TCWV) given the simulations and observations. The form of OE used is to return the Maximum A-posteriori Probability (MAP) assuming Gaussian error characteristics. OE also gives an uncertainty estimate for each retrieval. Quality levels are also estimated which reflects the degree of confidence in the validity of the uncertainty estimate (not the magnitude of data uncertainty).

Gridding/averaging: The algorithm grids the irregular swath-based imagery into the regular grid.

Daily collation: The complete 14-15 orbits each day per sensor stored are collated to produce one data layer for each 24-hour period, corresponding to day-time observations. The average of the best quality observations from all available sensors is used as the combined gridded LSWT for each grid cell.

Inter-sensor adjustment: To stabilise the record for changes in satellite sensor, an adjustment using overlaps of sensors is made, using as the (unadjusted) reference the LSWTs from the AVHRR on MetOpA.

3.4.4. LSWT data limitations

The classification algorithm relies on threshold tests, using one generic set of thresholds for all the lakes (although some in reality have different reflectivity). For any classification scheme, some water pixels may have not been detected as water and some non-water pixels may have been included in the set of pixel where the retrieval has been applied. The classification scheme is “fuzzy”: the confidence of the water detection is captured in a water detection score which is used (together with other parameters) to set the value of the LSWT quality levels.

The emissivity assumed in the LSWT retrieval is always set to that of fresh water, and for highly saline lakes, this may introduce some small bias (whose magnitude is yet to be assessed, and may be negligible). The retrieved LSWT reflects the skin temperature of the lake (the radiating layer of surface water), and a cool offset of order 0.2 K should be expected relative to sub-surface water temperature measurements.

The temporal density of observations of any particular quality varies greatly between lakes. Lakes that are narrow (only a couple of kilometres across) generally obtains few water-only pixels with these sensors (whose best resolution is 1 km), even if the lake is extensive and its area overall is large. Some lakes that are targeted in the products, but whose geometry is unfavourable, may have associated with them few or no high quality LSWTs.

Prior to the availability of global 1-km resolution AVHRR (MetOpA) satellite observations (2006 onwards), the temporal density of observations is generally lower because of the lesser coverage from the earlier ATSR series instruments used. This will be addressed partly in a future version by developing the means to obtain and include more sources of 1-km data.

3.5. Lake Water-Leaving Reflectance (LWLR)

3.5.1. LWLR definition and usage

Lake Water-Leaving Reflectance (LWLR), also referred to as water colour, is the measurement of the quantity of sunlight reaching the remote detector after interaction with the water column. The maximum depth from which the reflected signal is observed depends on the optical properties of the water column, is dependent on the colour band (waveband) considered and, in natural waters, can range from tens of meters (up to nearly 100 m in the clearest ocean waters) to just centimetres in highly absorbing and/or turbid waters. The colour of water is retrieved using imaging or line-scanning optical detectors on satellites. Each sensor offers a specific trade-off between the observation time (longer periods yielding lower instrument noise) and the spatial resolution as well as the number of discrete wavebands in which reflectance is measured. Because relatively small changes in absorption by, for example, phytoplankton pigment need to be distinguishable, an adequate signal-to-noise of an ocean-colour sensor for the signal received at the top of the atmosphere should be at least 1000:1 (IOCCG 2012). Correspondingly, the spatial footprint of such sensitive detectors on modern polar-orbiting satellites which scan the entire Earth every 2-3 days (a speed-over-ground exceeding 25,000 km/h) is around 300m at the equator. For previous sensors with less advanced detectors, which may also have been limited by downlink capacity, the spatial resolution tends to be 1km or coarser while the number of discrete wavebands has increased from eight (at 10 bits digitization) on SeaWIFs (1997-2010) to 21 (using 12-bit precision) on OLCI (2016-present).

Lake Water-Leaving Reflectance (LWLR) is the result of atmospheric correction of top-of-atmosphere radiance over water pixels. This correction is the result of model optimization and subject to the possibility of ambiguous solutions. The main effects that introduce uncertainty are mixing of reflectance from water and nearby land in the atmosphere, bottom effects, in-water bio optical model ambiguities and limited sensor band configurations to help bound the mentioned numerical optimisation.

Once LWLR is obtained, several optical-biogeochemical characteristics of the lake may be determined from its colour. Main quantities of interest are:

- the concentration of phytoplankton pigment, particularly chlorophyll-*a*, which is found in all species as the major photosynthetic pigment
- vertical transparency, for submerged vegetation habitat mapping or primary production models when combined with chlorophyll-a and temperature observations or models
- the concentration of (coloured) dissolved (organic) matter as a proxy for the dissolved organic Carbon pool, as well as the quality of underwater light.
- the total amount of suspended sediment (TSM), either expressed as equivalent particulate dry weight or as Turbidity.

Currently, globally validated algorithms to retrieve such quantities are available for chlorophyll-*a* and TSM or Turbidity, and vertical transparency, with by far most of the attention in scientific literature dedicated to the retrieval of chlorophyll-*a.*

3.5.2. LWLR data characteristics

The daily observations used for CDRP V1.0 are obtained from the MERIS and OLCI satellites onboard the Envisat (2002-2012) and Sentinel-3 (2016-present) platforms. They are provided on a common grid with the other Lakes Essential Climate Variables. Both sensors offer a native 300 m resolution, although for MERIS the 1km reduced resolution data provide better spatio-temporal coverage.

The data will not be available for each of the included lakes at every daily aggregation interval. This is due to a combination of satellite overpass limitations (more frequent with OLCI than with MERIS, particularly for 2019-present when two OLCI sensors were in simultaneous operation) and removal of pixels affected by cloud (including edges and shadows) or ice.

The LWLR is presented in a number of discrete wavebands corresponding to the frequency or wavelength of light across the visible to near infra-red spectrum. The number of wavebands differs per sensor and each sensor has variations in where the bands are centred. This has not (at least in CDRP v1.0) been harmonized, because doing so would require making assumptions on the true shape of the LWLR, which cannot be known – particularly in optically highly diverse inland waters.

In addition to LWLR the CDRP V1.0 includes estimates of chlorophyll-*a* (mg m^{-3}) and turbidity (NTU). For a detailed overview of the algorithms and correction used to obtain these estimates please refer to the ATBD. Each product also comes with an associated per-pixel product uncertainty estimate, as long as sufficient in situ reference observations were available for the product, observed value range and lake optical type. The procedure used to determine product uncertainties is defined in the E3UB document.

3.5.3. LWLR data sources

The full observation archive from Envisat-MERIS and Sentinel-3 OLCI-A/B is used, which contain observations from April 2002 until April 2012 and June 2016 to December 2019, respectively. MERIS satellite passes identified as invalid (A list from ESA is available through this link) were omitted. The MERIS data are the L1B Reduced Resolution from the 3rd reprocessing by ESA. The OLCI source data are L1B at full resolution.

The observed area per lake is defined by the maximum water extent following the ESA Land Cover CCI v4.0 water mask. Within this water extent, land/water/ice/cloud classification is performed. Areas outside the maximum water extent are not considered here.

3.5.4. LWLR data limitations

The LWLR data set is provided for every pixel recognised as water. However, at the spatial resolution of the satellite sensor (nominally 300-1km) there is a risk of 'mixed pixels': water in which small fractions of land, cloud, ice or vegetation are included. The water classification is set up to be restrictive: when classified as water, other influences are likely to be minor. However, given the difference in optical contrast between water and other features even minor differences can lead to large estimation errors. Users are advised to consider their application of the data with care, and e.g. consider removing data near shorelines to answer questions about long-term change.

It is known that the major source of uncertainty in lake optical water quality estimation is the separation of water and atmospheric effects. The latter increase in severity nearby land and this 'adjacency effect' can, depending on the state of the atmosphere, extend several kilometres. This has two major influences on the observations:

- Longer wavebands tend to be more affected by mixing of reflectance from land and water, because the contrast in reflectance from these features is largest in these wavebands. This affects particularly the retrieval of turbidity (which relies on near-infrared reflectance) and chlorophyll-a at concentrations > 10 mg m^{-3} (which uses red and near-infrared wavebands).
- Elevated near-infrared reflectance introduced from nearby land may lead to over-correction of LWLR at shorter wavebands.

Overall, validation results to date suggest that atmospheric correction procedure yields a systematic under-estimation of LWLR. This effect has not been corrected for because the validation itself is uncertain due to limited availability of in situ reference data. It is anticipated that this affects the retrieval of lake colour intensity more than lake hue. Chlorophyll-a and turbidity estimates are not equally affected by this issue, because their retrieval is calibrated directly against in situ reference measurements.

Per-pixel uncertainty estimates for chlorophyll-a and turbidity are currently modelled as a function of algorithm performance per optical water type (see the E3UB document for details). Other effects such as proximity to land have not yet been modelled, but will likely explain a significant fraction of the overall product uncertainty. This implies that the uncertainties in open water are likely to be a worst-case estimate at present.

Given the perceived systematic negative bias in LWLR, per-pixel uncertainty estimates for each LWRL waveband for which in situ data are available, are provided both as the relative difference (which includes the negative bias) and the un-biased relative difference. The latter provides a better estimate of the effect of other sources of uncertainty in LWLR on downstream biogeochemical retrieval algorithms, if these are individually calibrated against in situ reference measurements such as done in the Lakes_cci.

4. Lakes ECV Dataset

4.1. Definition

The CDR (Climate Data Record) ECV Lake dataset is a merged product composed of the thematic products described in the previous sections:

- Lake water level (LWL)
- Lake water extent (LWE)
- Lake Ice Cover (LIC)
- Lake Surface Water Temperature (LSWT)
- Lake Water Leaving Reflectance (LWLR)

4.2. Main characteristics

Data generated in the Lakes_cci project is derived from data from multiple sensors and satellites (for details see the Product Specification Document (PSD)) and consequently different temporal and spatial resolutions. One of objectives in Lakes_cci project is the harmonisation of the different products in a single dataset with the following characteristics:

- Daily aggregation interval (products are specified as 12:00:00 UTC).
- 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 in the grid for the area given under the nominal spatial delineation of that lake.
- Common 0,0083333 (1/120) degree grid (latitude and longitude)
- Common regions of interest. A set of priority lakes is defined (Annex A). The mask of this lakes, provided with the product as ancillary data, contains this land mask based on maximum water extent V4.0 maps from ESA LC This file also contains the distance to the nearest land for each lake.
- Extent: -180 to 180 degrees longitude, -90 to 90 degrees latitude, where positive signs point north and east. The pixel coordinate is the centre of the pixel.

Uncertainty estimates are provided for each product. Procedures to derive uncertainty estimates are provided in the End-to-End Uncertainty Budgets report (E3UB). Where uncertainties cannot be provided for a given pixel these are marked as Infinity (Inf) or not a number (NaN).

The identification of lakes (Annex A) follows the Global Lakes and Wetlands Database and Hydrolakes databases, respectively. Where these databases overlap or where there delineations of water bodies is incomplete, the numbering follows the provenance of projects where they were initially defined (Table 4), so that users can combine old and new datasets.

Table 4 Provenance of lake identifiers

ID	Provenance
0 - 99999999	Global Lakes and Wetlands Database
100000000 – 199999999	GloboLakes project
200000000 – 299999999	Copernicus Land Monitoring Service
300000000 – 399999999	Hydrolakes

4.3. Nomenclature

The nomenclature of the files in the Lakes_cci follows the CCI data standards:

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

Where:

Processing Level:L3S, meaning that the Lakes_cci is super-collated: observations from multiple instruments and observation times are combined into a common spatiotemporal grid.

Data type: LK_PRODUCTS

Product String: MERGED, meaning data are combined from more than one platform and/or sensor

Indicative Date: YYYYMMDD format, the date of the observations.

Version: V1.0

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

ESACCI-LAKES-L3S-LK_PRODUCTS-MERGED-20190214-fv1.1.nc

4.4. Format

The Lakes_cci dataset is stored in the NetCDF 4 classic format (Network Command Data Form) using the CF (Climate and Forecast) metadata convention (v1.8) and CCI Data Standards (v2.1).

The following sections describe the components of each NetCDF.

4.4.1. Global attributes

The global attributes provide general information about the product. The Lakes_cci global attributes are those recommended in the CF standards (Table 5)

Table 5. CF Global Attributes

Attribute Name	Attribute description
title	description of the dataset
institution	where the data were produced
source	original data source
history	processing history of the dataset
references	reference website
comment	any additional information

Additionally, the NetCDF files contain the recommended global attributes for dataset discovery and additional attributes defined in the CCI data standards v2.1 (Table 6).

Table 6. CCI Global Attributes

Attribute Name	Attribute description
tracking_id	Universal Unique Identifier (Random)
conventions	CF and CCI Data Standards
product_version	Lakes_cci merged product version
summary	description of the dataset
keywords	list of keywords
id	filename.nc
naming authority	lakes.esa-cci
keywords_vocabulary	science keywords
cdm_data_type	Grid
date_created	Date of the file creation
creator_name	ESA Lakes_cci
creator_url	http://cci.esa.int/lakes
creator_email	lakes_cci@groupcls.com
Project	Climate Change Initiative - European Space Agency
geospatial_lat_min	-90.0
geospatial_lat_max	90.0

Attribute Name	Attribute description
geospatial_lon_min	-180.0
geospatial_lon_max	180.0
geospatial_vertical_min	NA
geospatial_vertical_max	NA
time_coverage_start	First date available in the dataset
time_coverage_end	Last date available in the dataset
time_coverage_duration	P1D
standard_name_vocabulary	NetCDF Climate and Forecast (CF) Metadata Convention version 1.7
License	ESA CCI Data Policy: free and open access
Platform	list of satellites used in this data file
Sensor	list of sensors used in this data file
spatial_resolution	1 km at Equator
key_variables	water_surface_height_above_reference_datum, lake_surface_water_extent, lake_ice_cover, lake_surface_water_temperature, chla_mean, turbidity_mean, Rw900, Rw620, Rw709, Rw885, Rw754, Rw443, Rw681, Rw665, Rw779, Rw560, Rw412, Rw510, Rw490
geospatial_lat_units	degrees north
geospatial_lon_units	degrees east
geospatial_lat_resolution	0.0083333
geospatial_lon_resolution	0.0083333
doi	doi of the dataset

Annex A contains an example of these global attributes.

4.4.2. Dimensions

Following the CCI data standards, the gridded products of the Lakes_cci have three dimensions: time, latitude and longitude. As indicated in chapter 4.2, for reasons of consistency, all the included variables share the same dimensions.

4.4.3. Variables

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

- standard_name: standard name following CF conventions
- long_name: description of the variable in human-readable format
- units: units of the variable
- valid_min: smallest value to be considered valid
- valid_max: largest value to be considered valid
- _FillValue: the value used to indicate lack of data
- scale_factor (optional): multiplicative factor for packing data
- add_offset (optional): additive offset for packing data
- comment (optional): Miscellaneous information for the user, such as the meaning of product quality flags

The variables included in the dataset are listed in Table 7

Table 7. List of variables in the NetCDF file

Variable Name	Lakes_cci product
water_surface_height_above_reference_datum	LWL
water_surface_height_uncertainty	LWL
lake_surface_water_extent	LWE
lake_surface_water_extent_uncertainty	LWE
lake_ice_cover	LIC
lake_ice_cover_uncertainty	LIC
lake_surface_water_temperature	LSWT
lswt_uncertainty	LSWT
quality_level	LSWT
Rw[xxx]*	LWLR
Rw[xxx]_uncertainty*	LWLR
chla	LWLR
chla_uncertainty	LWLR
turbidity	LWLR
turbidity_uncertainty	LWLR

* Rw = lake_water_leaving reflectance where xxx is one of 412, 443, 490 , 510, 560, 620, 665, 681, 709, 754, 779, 885, 900 nm. Not all bands contain values for each product/period.

5. Software Tools

The Lakes_cci data are stored using the NetCDF format. A wide choice of software packages can be used to visualise or manipulate the NetCDF data. A list of software is provided on the Unidata web site (https://www.unidata.ucar.edu/software/netcdf/software.html).

The Lakes_cci files can be visualised with the Climate Analysis Toolbox (Cate), the reference software for visualising data developed within the CCI Program funded by ESA.

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Annex A. Example of global attributes

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
	LSWT: University of Reading
	LIC: H2O Geomatics
	LWLR: Plymouth Marine Laboratory
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), Indian Space Research Organisation (ISRO)
	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)
	LIC: European Space Agency (ESA), National Aeronautics and Space Administration (NASA)
	LWLR: European Space Agency (ESA), National Aeronautics and Space Administration (NASA)
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
	LSWT: created with collate_10DAYS_onMASK_RES120_new_unc.py
	LIC: Lake ice cover processor by H2O Geomatics
	LWLR: Calimnos processor by Plymouth Marine Laboratory, including calls to Idepix (SNAP) and POLYMER (Hygeos) algorithms
references	http://cci.esa.int/lakes
tracking_id	f5170cc0-0da7-4b2b-b829-93e485aa451a
conventions	CF-1.7
product_version	V 1.0
Format_version	CCI Data Standards v2.1

Attribute	Value
Summary	This dataset contains L3S daily ECV Lakes products: Water Level (LWL), Water Extent (LWE), Ice cover (LIC), Surface Water Temperature (LSWT) and Water Leaving Reflectance (LWLR). 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
id	ESACCI-LAKES-L3S-LK_PRODUCTS-MERGED-20190214-fv1.0.nc
naming_authority	lakes.esa-cci
keywords_vocabulary	inspire: INSPIRE spatial data themes, gcmd: NASA Global Change Master Directory (GCMD) Science Keywords, gemet: GEMET keywords
keywords	Satellite, Lake, Climate Change, Lake Water Level, Lake Water Extent, Lake Surface Water Temperature, Lake Ice Cover, Lake Water Leaving Reflectance, Orthoimagery, EARTH_SCIENCE-OCEANS-OCEAN_OPTICS-WATER-LEAVING RADIANCE, EARTH_SCIENCE-TERRESTRIAL_HYDROSPHERE- WATER_QUALITY_WATER_CHEMISTRY-CHLOROPHYLL, SUSPENDED_SOLIDS, TURBIDITY, 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,
cdm_data_type	Grid
comment	These data were produced for the ESA Lakes_cci project
date_created	2020-01-20
creator_name	ESA Lakes_cci
creator_url	http://cci.esa.int/lakes
creator_email	lakes_cci@groupcls.com
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	19920101T120000Z
time_coverage_end	20191231T120000Z
time_coverage_duration	ISO8601
time_coverage_resolution	P1D
standard_name_vocabulary	CF Standard Name Table v72
license	ESA CCI Data Policy: free and open access

Attribute	Value
platform	LWL: TOPEX/Poseidon, Jason-1, Jason-2, Jason-3, Envisat, SARAL, GFO, Sentinel-3A
	LWE: Landsat-<4,5,7,8>, Sentinel-1A
	LSWT: ERS-2, Envisat, Metop-A, Metop-B
	LIC: Aqua, Terra
	LWLR: Aqua, Envisat, Sentinel-3A, Sentinel-3B, Orbview-2, Suomi NPP
sensor	LWL: Poseidon-1, Poseidon-2, Poseidon-3, RA, RA-2, AltiKa, SRAL
	LWE: MSS, TM, OLI
	LSWT: ATSR-2, AATSR, AVHRR-3
	LIC: MODIS
	LWLR: SeaWifs, MODIS, MERIS, VIIRS, OLCI
spatial_resolution	1 km at Equator
key_variables	water_surface_height_above_reference_datum, lake_surface_water_extent, lake_ice_cover, lake_surface_water_temperature, chla_mean, turbidity_mean, Rw412, Rw443, Rw490, Rw510, Rw560, Rw754, Rw620, Rw665, Rw681, Rw709, Rw779, Rw885, Rw900
Ancillary_variables	water_surface_height_uncertainty, lake_surface_water_extent_uncertainty, lswt_uncertainty, lswt_quality_level, lake_ice_cover_uncertainty, chla_uncertainty, turbidity_uncertainty, Rw412_uncertainty_relative, Rw443_uncertainty_relative, Rw490_uncertainty_relative, Rw510_uncertainty_relative, Rw560_uncertainty_relative, Rw754_uncertainty_relative, Rw620_uncertainty_relative, Rw665_uncertainty_relative, Rw681_uncertainty_relative, Rw709_uncertainty_relative, Rw779_uncertainty_relative, Rw885_uncertainty_relative, Rw900_uncertainty_relative Rw443_uncertainty_relative_unbiased, Rw490_uncertainty_relative_unbiased, Rw510_uncertainty_relative_unbiased, Rw560_uncertainty_relative_unbiased, Rw754_uncertainty_relative_unbiased, Rw620_uncertainty_relative_unbiased, Rw665_uncertainty_relative_unbiased, Rw681_uncertainty_relative_unbiased, Rw709_uncertainty_relative_unbiased, Rw779_uncertainty_relative_unbiased, Rw885_uncertainty_relative_unbiased, Rw900_uncertainty_relative_unbiased Rw900_uncertainty_relative_unbiased, Rw620_uncertainty_relative_unbiased, Rw709_uncertainty_relative_unbiased, Rw885_uncertainty_relative_unbiased, Rw754_uncertainty_relative_unbiased, Rw443_uncertainty_relative_unbiased, Rw681_uncertainty_relative_unbiased,

Attribute	Value
	Rw665_uncertainty_relative_unbiased, Rw779_uncertainty_relative_unbiased, Rw560_uncertainty_relative_unbiased, Rw412_uncertainty_relative_unbiased, Rw510_uncertainty_relative_unbiased, Rw490_uncertainty_relative_unbiased
geospatial_lat_units	degrees_north
geospatial_lon_units	degrees_east
geospatial_lat_resolution	1/120 degrees
geospatial_lon_resolution	1/120 degrees

Annex B: List of lakes

Name	Latitude	Longitude	GLWD + HYLA unified Ids
Aksai Chin	35,20	79,85	GLWD00001096
Alakol	45,11	81,73	GLWD00000058
Albert	1,66	30,92	GLWD00000030
ALBUFERA	39,34	-0,36	GLWD00010679
Almendra	41,26	-6,28	GLWD00001562
Altevatnet	68,59	19,39	HYLA00001038
Amadjuak	64,93	-71,15	GLWD00000056
Angostura	16,08	-92,50	GLWD00000234
Aral Est	45,13	60,80	GLWD00000004
Aral Nord	45,13	60,80	GLWD00000004
Aral Ouest	45,13	60,80	GLWD00000004
Aral South	45,13	60,80	GLWD00000004
Argentino	-50,25	-72,49	GLWD00000117
Assad	36,00	38,17	GLWD00000279
Athabasca	59,32	-109,38	GLWD00000023
Ayakum	37,55	89,35	GLWD00000312
Aydar	40,86	67,08	HYLA00000138
Aylmer	64,15	-108,46	GLWD00000226
Baikal	53,53	108,21	GLWD00000008
Baker	64,13	-95,28	GLWD00000097
Balaton	46,88	17,83	GLWD00000310
Balbina	-2,44	-58,25	GLWD00000359
Balkhash	46,32	74,47	GLWD00000017
Bangweulu	-11,19	29,76	GLWD00000081
Beysehir	37,77	31,52	GLWD00000267
BOGORIA	0,27	36,10	GLWD00004953
Bolmen	56,93	13,70	GLWD00001028
Bosten	41,99	87,02	GLWD00000181
Boye So	70,11	-50,63	GLWD00003211
Branched-Oak	40,98	-96,86	GLWD00214687
Bratsk	56,24	101,75	GLWD00000039
Buyo	6,33	-7,07	GLWD00000182
Cabora Bassa	-15,73	31,63	GLWD00000042
Caniapscau	54,29	69,84	GLWD00000168
Caspian	42,08	50,55	GLWD00000001
Cedar	53,33	-100,14	GLWD00000057
Chad	13,15	14,32	GLWD00000014
Champian	44,50	-73,31	GLWD00000165
Chany	54,87	77,56	GLWD00000092
Chapala	20,21	-103,05	GLWD00000153
Chardarinskoye	41,15	68,17	GLWD00000296
Chenghai	26,55	100,67	HYLA00015455
Chilwa	-15,30	35,72	GLWD00000256
Colhue Huapi	-45,54	-68,75	GLWD00000219
Constance	47,59	9,45	GLWD00000352

Name	Latitude	Longitude	GLWD + HYLA unified Ids
Cuerda del pozo	41,90	-2,75	GLWD00008527
Dagze	31,70	88,00	GLWD00000744
Dead Sea	31,53	35,48	GLWD00000244
Dogai Coring	34,57	89,02	GLWD00000725
Dogaicoring Quang	35,27	89,25	GLWD00001891
Dongting	28,83	112,66	GLWD00000620
Douglas	45,58	-84,71	GLWD00013377
Dubawnt	63,10	-101,50	GLWD00000049
Eagle-Creek	39,85	-86,30	GLWD00215339
Ebi/Ebinur	44,89	82,97	GLWD00000297
Edward	-0,39	29,61	GLWD00000069
Egirdir	38,01	30,89	GLWD00000390
Ennadai	60,00	-100,50	GLWD00000254
Erie	42,21	-81,25	GLWD00000012
Erken	59,84	18,57	GLWD00006785
Erne	54,45	-7,76	GLWD00001526
Erne-Lough	54,21	-7,51	GLWD00004947
Eyre	-28,45	137,36	GLBL00000002
Fort Peck	47,68	-107,29	GLWD00000201
Fureso	72,03	-26,29	HYLA00000185
Garda	45,61	10,63	GLWD00000505
Geist	39,94	-85,94	GLWD00215311
General Carrera /Buenos Aires	-46,66	-72,50	GLWD00000094
George	0,01	30,22	GLWD00000687
Glan	58,62	15,96	GLWD00002358
Grande-3	53,83	-75,38	GLWD00000063
Great Bear	66,02	-120,61	GLWD00000009
Great Salt Lake	41,14	-112,50	GLWD00000026
Great Slave Lake	61,58	-114,20	GLWD00000011
Guri	7,74	-63,00	GLWD00000154
Hartbeespoort	-25,75	27,86	GLWD00010694
Hongze	33,34	118,53	GLWD00000109
Hubsugul	51,07	100,48	GLWD00000059
Hulun	48,97	117,43	GLWD00000075
Huron	44,92	-82,46	GLWD00000005
Idro	45,78	10,51	GLWD00015600
Ijsselmeer	52,82	5,38	GLBL00000012
Ilha Solteira	-19,83	-50,58	GLWD00000129
Ilment	58,28	31,30	GLWD00000192
Imja	27,90	86,92	HYLA01382089
Iseo	45,74	10,07	HYLA00014185
Issyk-Kul	42,41	77,28	GLWD00000025
Itaipu	-25,31	-55,16	GLWD00000065
Itaparica	-8,87	-38,61	GLWD00000216
Ivoesjoen	56,11	14,44	HYLA00013156
Izabal	15,51	-89,17	GLWD00000245

Name	Latitude	Longitude	GLWD + HYLA unified Ids
Jingyu	36,32	89,45	GLWD00001044
Kainji	10,43	4,56	GLWD00000116
Kamilukuak	61,40	-102,20	GLWD00000264
Kaminak	62,10	-95,60	GLWD00000246
Kangaarsuup Tasersua	62,52	-49,61	HYLA00003969
Kaptchagayskoye	43,82	77,73	GLWD00000131
Kara-Bogaz-Gol	41,23	53,54	GLWD00000197
Karakaya	38,52	38,41	GLWD00000542
Kariba	-17,23	27,60	GLWD00000035
Kasba	60,34	-102,27	GLWD00000124
Kasumigaura	36,05	140,37	GLWD00001204
Khanka	45,00	132,39	GLWD00000045
Khar-Us	48,10	93,21	GLWD00000142
Khyargas	49,16	93,38	GLWD00000121
Kinneret	32,81	35,59	GLWD00001196
Kivu	-2,04	29,93	GLWD00000067
Kokonor/Qinghai	36,92	100,17	GLWD00000041
Krasnoyarskoye	54,84	90,94	GLWD00000093
Kremenshugskoye	49,28	32,62	GLWD00000087
Kuybyshevskoye	54,54	48,65	GLWD00000033
Kyoga	1,48	32,96	GLBL00000013
Ladoga	60,83	31,58	GLWD00000016
Leman	46,46	6,53	GLWD00000327
Lixi'Oidain	35,75	90,18	GLWD00000812
Llanquihue	-41,14	-72,81	GLWD00000209
Loskop	-25,45	29,29	GLWD00007840
Lough-Mourve	54,76	-5,81	GLBL00000004
Lumajangdong	34,01	81,64	GLWD00000592
Macnean-Lough	54,29	-7,83	GLWD00018089
Maelaren	59,42	17,24	GLWD00000163
Maggiore	46,00	8,68	GLWD00000948
Malawi	-12,00	34,48	GLWD00000010
Managua	12,37	-86,33	GLWD00000176
Manasarovar	30,70	81,50	GLWD00000439
Manitoba	50,54	-98,33	GLWD00000037
Mantua	45,15	10,81	GLWD00208840
Mar Chiquita	-30,52	-62,57	GLWD00000084
Maracaibo	9,72	-71,53	CGL200000072
Mead	36,33	-114,39	GLWD00000278
Melvin	54,43	-8,15	GLWD00007889
Mendota	43,11	-89,41	GLWD00004503
Michigan	43,86	-87,09	GLWD00000006

Name	Latitude	Longitude	GLWD + HYLA unified Ids
Migriggyangzham	33,48	90,32	GLWD00000520
Milh	32,78	43,66	GLWD00000173
Mingechaurskoye	40,93	46,79	GLWD00000328
Moeckeln	56,68	14,20	HYLA00013104
Mohave	35,44	-114,65	HYLA00009360
Mono	38,00	-119,00	GLWD00000883
MORSE-Reservoir	40,12	-86,03	GLWD00215215
Mossoul	36,67	42,86	GLWD00000576
Muggelsee	52,44	13,65	HYLA00165102
Mweru	-9,01	28,74	GLWD00000036
Naivasha	-0,76	36,35	GLWD00001659
Nam Co	30,72	90,61	GLWD00000091
Nasser	22,86	32,58	GLWD00000048
Nassuttuutaata tasia	67,61	-52,43	HYLA00002545
Neagh	54,62	-6,41	GLWD00000481
Nettiling	66,42	-70,28	GLWD00000032
Nezahualcoyoti	17,16	-93,65	GLWD00000477
Ngangla-Ringco	31,56	83,05	GLWD00000354
Ngangze	31,00	87,10	GLWD00000444
Ngoring	34,93	97,71	GLWD00000300
Nicaragua	11,53	-85,37	GLWD00000021
Nipissing	46,26	-79,60	GLWD00000198
NN-Glacial-lake	65,09	-50,04	GLWD00001099
NN-Glacial-lake	77,03	-20,34	HYLA00000182
NN-Glacial-lake	79,59	-22,54	HYLA00001744
NN-Glacial-lake	80,16	-22,10	GLWD00002540
NN-Glacial-lake	67,00	-51,89	HYLA00002685
NN-Glacial-lake	65,62	-50,32	GLWD00003219
NN-Glacial-lake	66,28	-49,86	HYLA00002892
North Caribou	52,79	-90,74	GLWD00000516
Novosibirskoye	54,37	82,03	GLWD00000190
Nueltin	60,25	-99,40	GLWD00000083
Oahe	45,49	-100,38	GLWD00000122
Oestra Ringsjoen	55,87	13,55	HYLA00013182
Ohrid	41,03	20,72	GLWD00000526
Okanagan	49,83	-119,54	GLWD00000565
Onega	61,75	35,41	GLWD00000018
Ontario	43,64	-77,73	GLWD00000015
Opinaca	52,50	-76,30	GLWD00000159
Oulu	64,45	26,97	GLWD00000202
PÄIJÄNNE	61,60	25,48	GLWD00000157
Patos Lagoon	-31,18	-51,36	CGL200000071

Name	Latitude	Longitude	GLWD + HYLA unified Ids
Patzcuaro	19,62	-101,64	HYLA00009739
Peipus	58,65	27,49	GLWD00000050
Poopo	-18,81	-67,06	GLWD00000133
PORTMORE-Lough	54,56	-6,28	GLWD00164651
Poyang	29,04	116,35	GLWD00000078
Pung-co	31,52	90,97	GLWD00001432
PYHÄJÄRVI	63,58	25,90	GLWD00001240
Pyramid	40,03	-119,57	GLWD00000411
Qadisiyah	34,31	42,30	GLWD00000484
Rakshastal	30,65	81,24	GLWD00000676
Razlem Sinoe system	44,79	29,00	GLWD00000358
Rihpojavri	69,21	20,61	HYLA00134644
ROSARITO	40,10	-5,31	GLWD00018140
Roseires	11,79	34,41	GLWD00000274
Rukwa	-7,84	32,16	GLBL00000011
Rusken	57,24	14,38	HYLA00013043
Rybinskoye	58,49	38,13	GLWD00000047
Saint Clair	42,41	-82,72	GLWD00000146
Sakakawea	47,81	-102,32	GLWD00000110
Salton Sea	33,32	-115,81	GLWD00000194
Sandy	53,00	-93,40	GLWD00000356
Saratovskoye	52,74	48,36	GLWD00000113
Sarykamyshskoye	41,88	57,61	GLWD00000241
Sasykkol	46,57	81,05	GLWD00000247
Saysan	48,00	83,93	GLWD00002637
Sebago	43,85	-70,54	GLWD00001498
Seneca	42,66	-76,90	HYLA00000773
Sevan	40,39	45,29	GLWD00000135
Simcoe	44,46	-79,36	GLWD00000236
Skadar	42,19	19,30	GLWD00000488
Sobradino	-9,73	-41,67	GLWD00000019
Soungari	43,60	126,93	HYLA00001297
SQUAM	43,75	-71,53	GLWD00006561
St. Jean	48,66	-72,02	GLWD00000158
St. John	30,03	-81,68	GLWD00000507
Superior	47,95	-87,32	GLWD00000002
Tahoe	39,10	120,02	GLWD00000380
Taihu	31,21	120,24	GLWD00000066
Tana	11,95	37,31	GLWD00000055
Tanganyika	-6,26	29,55	GLWD00000007
Tangra	31,05	86,59	GLWD00000215
Tapajos	-2,37	-54,94	CGL200000013

Name	Latitude	Longitude	GLWD + HYLA unified Ids
Taro-co	31,12	84,12	GLWD00000383
Tasersuaq	66,75	-50,94	GLWD00002199
Tharthar	34,11	43,17	GLWD00000077
Titicaca	-15,84	-69,35	GLWD00000020
Todos los Santos	-41,14	-72,29	HYLA00000991
Toktogul	41,76	72,91	GLWD00000729
Torrens	-31,00	137,85	HYLA00000177
Trasimeno	43,14	12,11	GLWD00001529
Tres Marias	-18,65	-45,21	GLWD00000188
Tsimlyanskoye	48,05	42,98	GLWD00000071
Tucurui	-4,57	-49,49	GLWD00000052
Turkana	3,51	36,10	GLWD00000022
Tuz	38,76	33,35	HYLA00000140
Ulan Ul Hu	34,85	90,40	GLWD00000456
Ulungur	47.275	87.269	GLWD00000239
Urmia	37,64	45,49	GLWD00000034
Urru	31,71	87,96	GLWD00000543
Uvs	50,33	92,74	GLWD00000053
Vaettern	58,33	14,54	GLWD00000095
Valencia	10,19	-67,73	GLWD00000515
Van	38,63	42,96	GLWD00000051
Vanern	58,88	13,22	GLWD00000029
Victoria	-0,98	32,98	GLWD00000003
Vidoestern	57,01	14,00	HYLA00013070
Volta	7,63	0,11	GLWD00000024
Vorstjarv	58,30	26,03	GLWD00000679
Williston	55,95	-123,91	GLWD00000103
Winnipeg	52,42	-97,68	GLWD00000013
Winnipegosis	52,74	-99,88	GLWD00000031
Wood	49,38	-94,91	GLWD00000044
Xuelian-hu	34,09	90,25	HYLA00015002
Yellowstone	44,43	-110,39	GLWD00000572
Zeyskoye	54,26	127,80	GLWD00000088
Zhari-namco	30,90	85,61	GLWD00000179
Zige-tangco	32,06	90,85	GLWD00000989
Ziling, Xining	31,80	89,04	GLWD00000105