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Copernicus Europe's eyes on Earth

In Situ

European Environment Agency

Review of global in situ data for lakes and reservoirs

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List of abbreviations

Abbreviation	Name	Reference
COINS	Copernicus In Situ Observations consortium	https://insitu.copernicus.eu
EEA	European Environment Agency	www.eea.europa.eu
EFAS	European Flood Awareness Service	www.efas.eu
EO	Earth Observation	
GCOS	Global Climate Observing System	https://gcos.wmo.int/en/home
GloFAS	Global Flood Awareness System	https://www.globalfloods.eu
GLWD	Global Lakes and Wetlands Dataset	https://www.worldwildlife.org/pages/global-lakes-and-wetlands-database
GOODD	Global Georeferenced Database of Dams	https://www.globaldamwatch.org/goodd
GRanD	Global Reservoir and Dam	https://www.globaldamwatch.org/grand
GTN-H	Global Terrestrial Network – Hydrology	https://www.gtn-h.info
USGS	United States Geological Survey	https://www.usgs.gov
WHOS	WMO Hydrological Observing System	https://wmo.int/activities/wmo-hydrological-observing-system-whos
WMO	World Meteorological Organisation	https://wmo.int

Executive Summary

Lakes and reservoirs are vital components of global water resources. Yet, the persistent lack of comprehensive data on their water storage over time is due to limited access to in situ measurements. This data is essential for accurate modelling of hydrological systems, simulation of current operations, and forecasting future water demand and use. In recent years, Earth observations (EO) have emerged as a promising solution to enhance our understanding of various environmental phenomena, including hydrological processes and water resource management. However, the full potential of EO is hindered by limitations in accessing and collecting data from remote and inaccessible regions.

This report provides a comprehensive overview of the undertaken task, which aimed to identify and catalogue associated metadata and access requirements for various readily available in situ data sources related to water body levels and/or storage. In response to the increasing utilization of EO-derived water body data in hydrological research, the task also includes relevant portals and links designed to facilitate access to this specific data category.

A total of 95 websites and data sources were initially investigated. However, 35 were classified as having 'no data' due to either providing only summary statistics of aggregated reservoir metrics, or having no reservoir data available at all. An additional 9 entries were recorded as having 'other data,' where water body-related information was available, but no actual water storage or levels data. A few portals also required log-in credentials to access data records. Furthermore, 10 satellite-derived data portals were documented.

Future steps for this task could involve expanding the catalogue with input from the hydrological community, adding information about the time periods covered by lake records and extracting further details about individual lakes covered, along with links to other lake and reservoir databases. Additionally, efforts could be made to standardise the time-series data from these links into a common file format and centralise them in a repository, all while considering licensing agreements and best practices for data citation.

1. Introduction and rationale

Lakes and reservoirs play an integral part in the water resources of many countries around the world. However, despite their importance and impact on the hydrological system, there remains a lack of information on the amount of water being stored within these water bodies over time (Busker et al. 2019), largely as a result of limited access to in situ data around water levels and storage (Yunus D. Salami, 2012).

Such data is often a requirement for the parameterisation of lakes and reservoirs in hydrological models. The accurate representation of these water bodies within models is key to both simulate present day operations, and to forecast water demand and water use under future scenarios to allow for improved mitigation and adaptation to changes in water demand (Horan et al. 2021). However, due to a lack of observed in situ data, anthropogenic alterations to the hydrologic cycle are not always captured or accounted for in current hydrological and earth system models.

River flow-based products from the Copernicus Emergency Management Service (e.g. EFAS / GloFAS) and Copernicus Climate Change Service rely heavily on hydrological modelling, often calibrating and validating models against in situ measures of river flow. However, information on the impact of lakes and reservoirs, in particular the human management of these water bodies, has been identified as a limitation within the modelling approach.

There is also a growing requirement for water body data to facilitate the validation of Earth observation (EO) products, such as water level products from Copernicus Global Land Management Service. The ability of EO data is supporting the capture of hydrological variables on a wider spatial scale, often for inaccessible regions of the world or in areas where human capacity and the ongoing maintenance and cost of water monitoring programs hamper the collection of hydrological data (Lorenz and Kunstmann, 2012; Avisse et al., 2017; Solander et al. 2016). Copernicus In Situ, in its review of in situ hydrological data requirements (Fry et al. 2019) describes the limitations of the datasets currently available for validation of these water level products.

The locations of large reservoirs and their purpose is well documented, such as in the Global Reservoir and Dam (GRanD) dataset (Beames et al., 2019), the Global Lakes and Wetlands Database (GLWD) (Lehner and Döll, 2004) and the Global Georeferenced Database of Dams (GOODD) (Mulligan et al., 2020). In contrast, consistent observations of reservoir storage are limited. Where records do exist, they are often difficult to locate and access due to geographic remoteness and closed data policies. Existing datasets have also traditionally focused on larger water bodies like lakes and major rivers, neglecting smaller bodies of water. Although there are recent efforts to address this data gap (Donchyts et al., 2022), the insufficient long-term data for small and medium lakes and reservoirs has made it challenging to comprehensively study and manage these important water resources. This lack of water body level and storage datasets poses a particular challenge to those working in the field of hydrology, and specifically water resources, and makes the modelling and forecasting of river flows and water budgets extremely challenging.

The WMO and GCOS established the Global Terrestrial Network – Hydrology (GTN-H) to coordinate global data centres of hydrological observations, including Hydrolare for global lake and reservoir levels. However, Hydrolare contains a catalogue of 1069 lakes and reservoirs but has fundamental limitations for use for Copernicus product calibration and validation in that most of the datasets for lakes outside the Russian Federation do not have time series data beyond circa 2012, and most data is at monthly resolution and represented as a monthly mean level only. There is, therefore, an ongoing requirement for in situ lake and reservoir data, and for this to be made easily accessible to the hydrological modelling community. The focus of this task was to locate freely available in situ data for water body levels and/or storage, and to catalogue the associated metadata and access requirements. Due to the increasing use of EO-derived water body data in hydrological research, portals and links for these data types were also included.

2. Methods

Searches were initially conducted based on National Hydro-Meteorological Organisation websites and portals, as set out in the Copernicus In Situ Global Hydrological In Situ Data Review (Fry and Nash, 2021). Further searches were conducted via keywords in the Google and Google Scholar search engines, whilst some entries were included based on a previous knowledge of relevant datasets. Of the 95 data sources initially investigated, 35 were classified as having "no data" due to there either being only summary stats of aggregated reservoir metrics available, or because no reservoir data were available at all. A further 9 entries were recorded as having 'other data', where water body-related information was available e.g. properties, shapefiles etc, but no actual data for water storage or levels. A total of 10 satellite-derived data portals were recorded.

For the 41 in situ data sources identified, metadata were catalogued in a spreadsheet provided with this report (Global catalogue of water body data version 1.0) which included the following columns, as set out in Table 1:

Table 1 – Information in metadata catalogue

Continent	Continent the water body is located in
Country	Country the water body is located in
Notes	General info on data availability, accessibility, limitations etc
Website	Link to the data
Number of water bodies	The number of water bodies that data exist for
Proprietor	Owner of the data
How monitored	Whether in-situ or satellite
Reservoir name	Name of reservoir(s). Water bodies names have been omitted where records hold data for multiple sites
Start year	Start year of timeseries
End year	End year of timeseries
Temporal resolution	Data timestep
Data presented as	How the data is displayed on the website/portal
Ongoing record	Whether or not storage/level data are still being recorded and updated
Downloadable	Whether or not the data are downloadable
File type	The file type of the downloadable data

3. Results

A total of 41 different data sources were input to the catalogue, which represents over 5000 records of in situ water body data, in some cases going back as far as the year 1900. This figure does not include those datasets where only satellites were used to record water body storage and/or height, nor where a mixture of both gauged and satellite data are used. Some records for water body storage are also listed from more than one data source.

Exact counts for a total of 5 records could not be established due to their presentation on the respective website/portal, frequently through a map format that did not permit a definitive tally or include an associated tabular data format. As such, their numbers have been conservatively estimated.

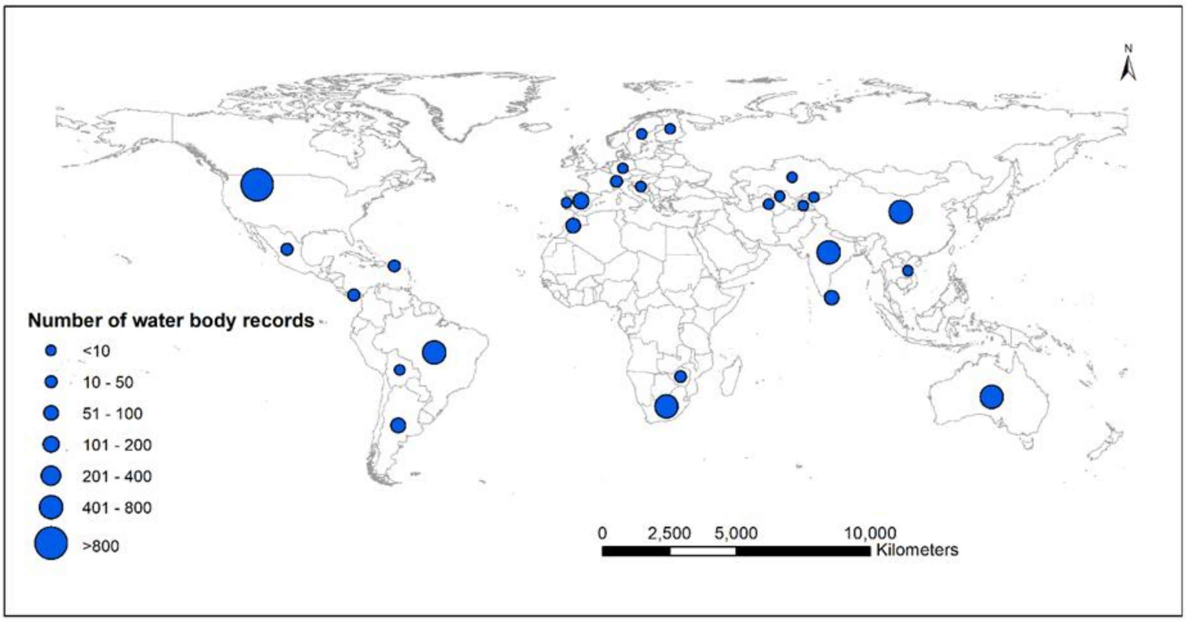

Figure 1 – Water body records per country that were added to the data catalogue

Table 2 – Details of water body records per continent

Continent	No. of records	No. of countries
Africa	289	3
Asia	582	9
Central America	43	2
North America	2408	1
Oceania	685	1
South America	818	4
Europe	182	7

As can be seen in Figure 1 and Table 2, the catalogued in situ records cover 27 countries in total, although nearly half of all data are for water bodies in the USA. This is largely due to the records held by the United States Geological Survey (USGS). South America has more than 700 records, and Asia more than 500. Oceania has 685 records, all for water bodies located in Australia.

Catalogued entries for European water bodies are relatively limited in number. Many of Europe's lakes and reservoirs are extensively monitored, although data availability is somewhat sporadic depending on the ownership of the water bodies and the country in which they're located. For this reason, search efforts were focussed outside of Europe for this task.

Of the 41 entries, 11 are not currently available to download in full, although full records appear to be held by the data proprietors. Of the remaining 30 where time series data are downloadable, the majority are available as csv or xlsx files.

The catalogue also documents 10 portals for satellite-derived water body levels, surface areas or storage. From these, 8 have downloadable storage and/or level data. These portals offer a more extensive spatial coverage of reservoirs than the in situ records, although it may be the case that not all of the satellite data have been validated. However, different methodologies exist between portals to derive storage data in water bodies, and some of these may offer suitable alternatives to in situ water body data where observations are not available. It should be noted that the majority of satellite datasets entered into the catalogue primarily focus on large water bodies, and also display large variations in temporal coverage and resolution. For example, of the 6 satellite portals that have ongoing records of waterbody storage, only 1 contains timeseries data pre-2013.

4. Discussion, limitations and next steps

The catalogue described here is a first step towards a global collation of metadata and links to in situ data for water body levels and storage. Overall, the number of lake and reservoir records represented is significant, and would be of substantial benefit to hydrological modellers and EO product developers.

As previously mentioned, due to the nature of water body data, and in particular that of reservoirs, its acquisition can be more problematic than that of other hydrological variables, such as river flow for example. This was reaffirmed at various stages throughout this task, where data either seemed not to exist for a particular water body or country, links to datasets and downloads were no longer working, or data existed but were not available to the public. Some data were also only accessible behind a pay wall, and as such these records were not included in the catalogue.

A number of portals also required log-in credentials to access data records, although this was not seen to be a major obstacle and accounts were set-up where necessary to obtain access to data.

Some storage timeseries were only presented graphically via dashboards and the associated timeseries data were often unavailable for download, or limited to the previous 3-7 days of recorded data, for example. Future steps should include follow-up correspondence with the data owners to ascertain whether these records could be made available in full for the purpose of research.

Alongside this, a more extensive search of academic studies containing timeseries of water body storage data should be conducted. Although such data may have limited temporal and spatial coverage, it still has the potential to be used for the calibration and validation of historical model runs and EO images.

To this end, expansion of the catalogue could be expedited with input from the hydrological community, to include records from their own research. A model similar to that used by the CAMELS dataset (Newman et al., 2014; Coxon et al., 2020) could be adopted to achieve this, although such an approach would require further exploration. Further enhancements could include the addition of information about the time periods covered by lake records, and further extraction of information on the individual lakes covered and links to other lake and reservoir databases.

The collation of links to water body data is a first and ongoing step in giving greater access of hydrological data to academics and practitioners alike. Future steps could also look to standardising the actual timeseries data from these links into a common file format, and placing them into a central repository, taking into account licensing agreements and data citation.

The collation and updating of data from multiple sources is not a trivial task and ideally a mechanism for this activity should be in place through a global data centre, or within Copernicus if this data is considered suitably valuable (though the products benefitting from this data are developed across a number of different services). A one-off effort to collate data may be of immediate benefit to hydrological modellers and EO product developers but it will not form a sustainable solution to production of a maintained dataset. The COINS project, on behalf of EEA, will liaise with potential Copernicus users to ascertain if this would be an effective activity to undertake in future phases. Copernicus In Situ has an active engagement with WMO and the GTN-H network and will highlight the limitations of Hydrolare and the need for provision of data services suitable to the requirements of a real-time data and EO era. In addition, it will highlight the value of this data to the WMO WHOS developers, to ensure lake and reservoir levels are fully considered for incorporation within WHOS services. The WHOS system may, in the long-term, offer the most potential for a “bottom-up” approach to provision of real-time, up-to-date, and standardised lake and reservoir level data.

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Annex: Global catalogue of water body datasets

Spreadsheet provided separately (WB_data_catalogue_reservoirs_v1.xls).