Lakes_CCI+ - Phase 2   D5.3. User Workshop Document (UWR)

CHRONOLOGY ISSUES

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Checked by	Stefan Simis – PML J-F Cretaux - LEGOS	Stefan Simis – PML J-F Cretaux - LEGOS S. Simis
Approved by	Alice Andral - CLS	Alice Andral - CLS Pmourat
Authorized by	Clément Albergel - ESA	Clément Albergel - ESA clement.albergel

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1. Summary

This document is the final Report of the two User Workshops, the first organised as a sub-workshop of the "26th Annual International Workshop on Physical Processes in Natural Waters (PPNW2024)", held in Girona, Spain, from 1 to 5 July, and the second jointly organised with the "7th LAKES 2024 Workshop on Parameterisation of Lakes in Numerical Weather Prediction and Climate Modelling (for the sake of clarity here called LAKES NWP)", held in Milan, Italy, from 20 to 22 November.

This document summarises the results of the session held on the afternoon of Friday 5 July and the feedback collected during and after the PPNW2024 workshop, and presents some recommendations collected during the personal exchanges that took place during the workshop. It also summarises the three sessions held during the 7th LAKES NWP Workshop and the feedback received.

2. Objectives

As stated in the technical proposal for Work package 5 Product Assessment, the Climate Research Group (CRG) has the task of assessing and exploiting ECV Product fitness-for-purpose in climate applications and to organise a dedicated User Workshop (WP 5.5) to enhance exchange between the Lakes project team and the wider climate research community. Therefore, this document presents the workshop programme, the profiles of the participants, the results of the survey (only for the sub-workshop held in Girona) and our main conclusions from these events.

3. PPNW 2024 Lakes_cci workshop programme

Physical processes in inland and coastal waters and their interactions with atmospheric, biogeochemical, and groundwater processes are the main topics of the PPNW workshop. PPNW is an open workshop that actively seeks partnerships with related subjects including atmospheric sciences, engineering, and physical oceanography. The purpose of the moderately sized PPNW, which has 40–60 attendees, is to provide an environment with sufficient time for in-depth conversation and favour collaboration (https://esdeveniments.udg.edu/102710/detail/26th-annual-international-workshop-on-physical-processes-in-natural-waters-ppnw2024.html).

Held in Girona (Spain) from 1 to 5 July 2024, PPNW2024 welcomed 54 on-site participants from different countries, providing a good opportunity to meet the engineering, atmospheric and physical sciences community and promote Earth Observation (EO) data on global lakes, but also to get their feedback, ask their opinions on the data, if and how they use it, for what reasons, and what kind of input they would like to see in the future. Figure 1 reports the program of the PPNW2024.

PPNW24	Monday, July 1	Tuesday, July 2	Wednesday, July 3	Thursday, July 4	Friday, July 5
	Faculty of Arts	Education & Psychology Faculty	Education & Psychology Faculty	Faculty of Arts	Faculty of Arts
8:30-9:00		*Registration*	L. Ing		F.S. Sharifi
9:00-9:30		*Welcome*	B. Boehrer	W. Wang	I. Mammarella
9:30-10:00		M.V. Tenci	P.G.Grochocki	R. Valipour	B. Zamani
10:00-10:30		R. Katsman	E. Asirok	Y. Tong	A. Folkard
10:30-11:00	Coffee break				
11:00-11:30		M. de Vicenzi	M. Toffolon	D.F. McGinnis	P.G.Grochocki
11:30-12:00		M. Mancini	I. Dominovic	H. Shi	J. Vidal-Hurtado
12:00-12:30		*Iris Möller*	*Javier Sánchez-España*	*Rafael Marcè*	M. Fregona
12:30-13:00					*Closure*
13:00-14:00	Lunch				
14:00-14:30		Y. Amitai		M. Shikhani	
14:30-15:00		J. Ala-Köni		A. Lorke	Subworkshop Satellites**
15:00-15:30		W. Meredith	Free time	M. Wells	
15:30-16:00		R. Schwefel		Poster session*	
16:00-16:30		Coffee break		Coffee Break	Coffee
16:30-17:00		J. Jansen		S. Jamali	
17:00-17:30		C. Minaudo		M. Schmid	
17:30-18:00	*Welcome Aperitif*			L. Bryant	
18:00-18:30					
18:30-19:00			*Historical tour*		
19:00-20:00					
20:00-21:00			*Gala Diner* La Rosaleda		
21:00-22:00					

Keynote talk		*Poster session Thursday, July 4		**Subworkshop Satellite Friday, July 5	
		15:30-15:35	A .Rios	14:00-14:20	S. Simis
		15:35-15:40	P. Santoro	14:20-14:40	L. Carrea
		15:40-15:45	J. Mesman	14:40-15:00	P. Pastor
		15:45-15:50	J. Shan	15:00-15:20	M. Amadori
		15:50:15:55	M. Wells		

Figure 1. Program overview of the "26ᵗʰ Annual International Workshop on Physical Processes in Natural Waters (PPNW2024)".

On this occasion, a short sub-workshop on "Remote Sensing in Lakes" was held by PPNW2024. This short session took place in the afternoon of Friday 5 July and was chaired by Monica Pinardi (CNR-IREA) and Laura Carrea (University of Reading), with the presence of 25-30 participants (Figure 2).

Figure 2. Pictures of the PPNW2024- Remote sensing in Lakes workshop at the University of Girona.

Four oral presentations were scheduled for the "Remote Sensing in Lakes" session (or sub-workshop Satellite as reported in Figure 1), and a final slot was dedicated to collecting feedback from participants.

Two presentations were given to introduce the Lakes_cci dataset, in particular the essential climate variables Lake Water Leaving Reflectance (LWLR) and the related chlorophyll-a and turbidity products, Lake Surface Water Temperature (LSWT) and Lake Ice Cover (LIC). The list of the presentations included in the sub-workshop is given in Table 1.

Table 1. Presentations during the user workshop

Title	Presenter
Introduction to the Lakes Climate Change Initiative *Biogeochemical studies using the Lakes_cci climate data records*	Stefan Simis (PML, UK)
Global lake surface water temperature and ice cover for climate-related applications	Laura Carrea (University of Reading)
Monitoring cyanobacterial bloom and surface water temperature in protected areas by satellite images	Pilar Pastor (University of Madrid)
Sentinel Lakes of sub-Sahelian Africa: An assessment based on multivariate remote sensing data and numerical modelling	Marina Amadori (CNR-IREA, Milan)

The first presentation gave a general overview of the dataset and its limitations, followed by a description of the biogeochemical state variables, the performance of Chl-a, turbidity and CDOM products, and some case studies. Finally, it was communicated that the Lakes_cci team would like to continue to share, listen and work with the participants after this workshop. For example, by email for questions, as it is known that the data and documentation are not perfect, and for any remote sensing (RS) data useful for their scientific studies. We also suggested that they use this opportunity to communicate their satellite observation needs for their work.

The second presentation focused on LSWT and LIC dataset characteristics and validation, followed by some examples of use of LSWT for climate applications.

The third presentation was on the use of Sentinel-2 data and in situ data to retrieve phytoplankton and cyanobacteria abundances.

The fourth presentation was a good example of integrating different approaches to study the role of sub-Sahelian African lakes using remote sensing and modelled data, with the aim of identifying potential sentinel lakes for climate change.

Questions and open discussions took place between each presentation, giving the opportunity to collect end-user interests, and any technical, quality or format data needs from this community. Specific questions included:

- Is the Lakes_cci data available in near real-time?
- How long is the time series?
- What represents the de-gridded pixels?
- How do you select the pixel to create a product?
- Is it possible to have finer resolution (e.g. 30 m of Landsat)?
- Do you convert colour into transparency? (for the African case study)
- For equatorial lakes, is air2water suitable? (for the African case study)

Finally, an online survey was created using Google Form, titled "Feedback form to ESA Lakes_cci", consisting of three short sections (optional user information, questions on RS data requirements, usage specific questions) to collect feedback from users. Some participants completed the form at the workshop, others in the following days using the QR code or the link sent by email due to the timeless at the end of the session. The survey included several forward-looking questions to gauge the level of support and need for high-resolution observation time-series. The questions of the Feedback form are listed in Table 2.

Table 2. Feedback form of the Lakes_cci User Workshop

Section 1 - User information (optional)	1. Your name (optional) 2. Your affiliation (optional) 3. Your email address (optional) 4. May we contact you? • Yes, regarding this survey only • Yes, and add me to Lakes CCI quarterly newsletter distribution list • No, thank you
Section 2 - Specific questions on remote sensing data requirements	1. From your own perspective or that of your organisation, what are the priorities for remote sensing of lakes for (climate/other) modelling: consider observed variables, data format, data quality. 2. What are your preferences with regard to the scale of observation? E.g. temporal (timespan, daily, interannual, intra-annual, intraday) and spatial (single lake, regional, global)

3. How important is the creation of new satellite observation datasets at high-spatial resolution, including more smaller lakes, covering up to the last 10 years? From 1 (not important at all) to 5 (extremely important)
4. Which specific regions do you think should be covered with higher spatial resolution satellite observation?

	Higly unimportant	Somewhat unimportant	Neither important nor unimportant	Somewhat important	Highly important	Don't know
Non-specific: global	○	○	○	○	○	○
Specific regions exhibiting worrying climate trends	○	○	○	○	○	○
Specific regions exhibiting worrying water quality or quantity pressures	○	○	○	○	○	○
Specific regions with observation gaps	○	○	○	○	○	○
High altitude lakes	○	○	○	○	○	○
Arctic lakes	○	○	○	○	○	○

5. Please add any further comment on the above question
6. Gap-filled temperature and ice cover datasets will be created this year. For your application, would you need/prefer:
7. Gap filled dataset
8. Only observation dataset
9. Please add any further comment on the above question, for example any particular gap filling requirements or other variables you require.
10. Do you use/plan to use per-pixel uncertainty estimates?
    11. Yes
    12. No
    13. Maybe
    14. I don't know
15. Do you use/plan to use per-pixel quality flags (e.g. poor/fair/good/best)
    Appendix 1. Yes
    Appendix 2. No
    Appendix 3. Maybe
    Appendix 4. I don't know
16. Which of the following intended new products are you likely to use or recommend?

		Yes	No	Maybe
	Vertical diffuse downwelling irradiance attenuation [Kd]	◯	◯	◯
	Coloured Dissolved Organic Matter (CDOM)	◯	◯	◯
	Cyanobacteria pigment (phycocyanin)	◯	◯	◯
	17. Please add any further products that should be considered. Please describe your use case if relevant.			

Section 3 - Usage specific questions	18. Were you previously aware of the Lakes CCI products?
	    Appendix 5. Yes
	    Appendix 6. No
	    Appendix 7. Maybe
	    Appendix 8. I don't know
	19. Have you used any of the existing Lakes CCI products?
	    Appendix 9. Yes
	    Appendix 10. No
	    Appendix 11. Maybe
	    Appendix 12. I don't know
	
	20. If you used the Lakes CCI products, how useful were they to you? From 1 (not very useful) to 5 (very useful)
	21. How likely are you to use any of the Lakes CCI products in the next five years? From 1 (very unlikely) to 5 (very likely)
	22. Please add any comment on the previous two answers here, especially if you selected option 1 or 2.
	23. Please add any further comment below.			

4. PPNW2024 and User Workshop attendee profiles

From the PPNW2024 Proceedings book we know that 54 participants were present in Girona for the conference, of which approximately 25-30 attended the sub-workshop. Participants come from research institutes or universities. Regarding the nationalities of the affiliations of the attendees, 42 were based in the European continent (12 Spain, 7 Italy, 7 Germany, 5 UK, 4 Finland, 2 Sweden, 2 Switzerland, 1 Croatia, 1 Ireland, 1 France), with only 3 attendees from Canada, China, and South America (Uruguay and Brazil), 2 from Israel, and 1 from Australia, reflecting the facility to join a European location of the conference.

The fields of research of the workshop attendees includes all areas of physical limnology, including open-water and under-ice processes, sediment transport, modelling of physical dynamics, salt exclusion, suppression of turnover, salinity stratification, ebullition, and physical-biogeochemical interactions, in both natural and constructed water bodies as well as pollution in all aquatic ecosystems. A group of people is interested in lake/climate modelling, but few exploring RS data. In fact, during the conference, apart from the RS in lakes workshop, the other sessions were based on modelled or in situ data for different lake typologies, targeting for example biogeochemical processes (i.e. dissolved oxygen dynamics and greenhouse gas fluxes, also related to ice-cover phenology), lake warming and mixing regime, lake response to climate change, wave and lake hydrodynamics.

PPNW was quite informal. There were many discussions both after the presentations and at coffee and lunch. The community expressed concern (during the workshop, but also during the conference days) about the use of global datasets. They feel that this type of global research is leading to a proliferation of superficial studies and driving researchers away from in-depth investigations. Most of these scientists have long experience of specific case studies and detailed knowledge of the physical processes at their test sites, and therefore tend not to trust remote sensing data.

5. Results of the survey on Lakes_cci user experience and future needs

The online Feedback form was filled in by 13 people, who also gave their name and affiliation, with the possibility of being contacted again regarding this survey (2) or being added to the distribution list for the Lakes CCI quarterly newsletter (9). The affiliations of the users who completed the survey are from Spain, Italy, Sweden, Finland, Uruguay and China.

5.1 User requirement on resolution and data format

Following the other two sections of the survey, we report below the synthesis of responses to the question on remote sensing data requirements.

From your own perspective or that of your organisation, what are the priorities for remote sensing of lakes for (climate/other) modelling: consider observed variables, data format, data quality.
Data quality and atmospherically corrected data
Reliable chlorophyll and CDOM data
Survey and potential management tool.
Having a single database that integrates all the available variables and a simple system to download them by selecting an area or a single lake, and the time span.
High spatial resolution
Data quality
Cyanobacteria monitoring
Climate-driven changes in lake water temperature, ice cover and productivity. Also the (changes in the) timing of events that are not captured by sparse manual observations, such as ice-on and ice-off dates and algal blooms.
Surface water temperature, algae, CDOM, kd and suspended solids
Observed variables and data quality are my priorities.
Data quality
Water temperature, ice cover, ice quality (?); high-spatial resolution

About the priorities for RS of lakes for modelling different and specific answers were provided by the users, but data quality, phytoplankton related and CDOM data were found in more than one answer.

| What are your preferences with regard to the scale of observation? E.g. temporal (timespan, daily, interannual, intra-annual, intraday) and spatial (single lake, regional, global) |
|---|
| Daily, single lakes |
| Spatial within single lakes. No preference for time scales, but more often is better. |
| Low frequency, single lake/ reservoir regional. |

Single lake (but with the possibility to select multiple lakes at the same time), daily.
Single lake, weekly.
Single lake, intraday.
Daily for inland water-bodies in Israel.
Daily or weekly observations at single lake or regional scale.
Daily.
I need timespan and daily data over individual lakes across the globe.
Daily, regional.
Single lake, daily and intraday
Daily, both single lake and regional

Different needs emerged from this question, but in general it seems that in terms of the scale of observation, a preference was found for daily spatial data for individual lakes or at a regional scale.

How important is the creation of new satellite observation datasets at high-spatial resolution, including more smaller lakes, covering up to the last 10 years?

13 responses
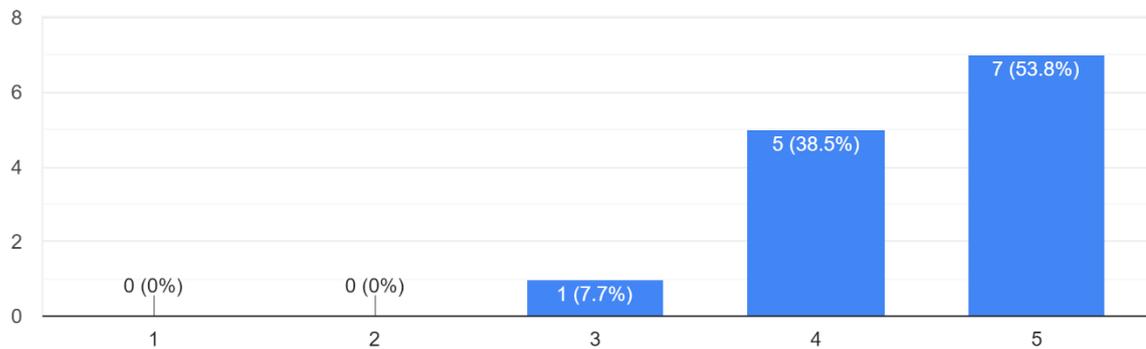
The majority of responses were '5' and '4', highlighting the importance of having high spatial resolution data.

Which specific regions do you think should be covered with higher spatial resolution satellite observation?
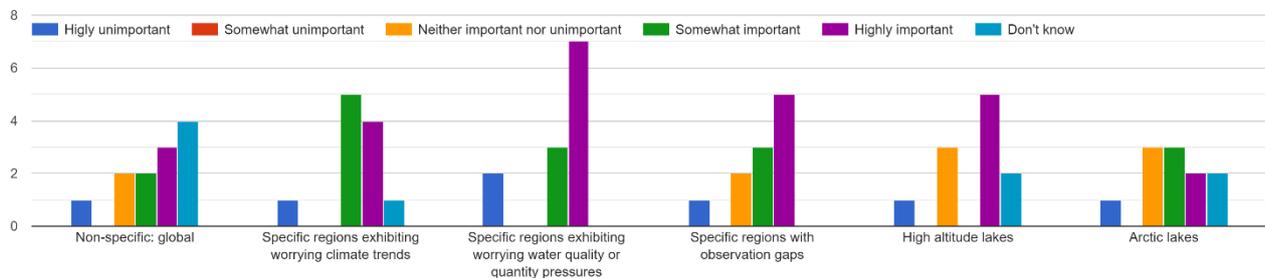
The regions of major interest for higher spatial resolution satellite observation are "Specific regions exhibiting worrying water quality or quantity pressures" and "Specific regions with observation gaps", as well as "High altitude lakes". Of some importance are "Specific regions with worrying climate trends". Two

users added these comments: "I would consider images with ground truth observations"; "I consider that it's important to search for collaborations in countries with observation gaps".
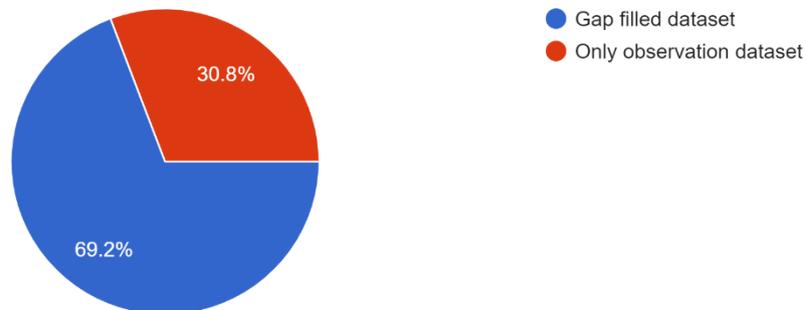
Gap-filled temperature and ice cover data sets will be created this year. For your application, would you need/prefer:

13 responses

The higher percentage of users chose the gap-filled dataset (70%), but two users added in the comment that it would be important to have access to both the original observation and the gap-filled dataset. Another user added that it depends on the accuracy of the gap-filling procedure.

Do you use/plan to use per-pixel uncertainty estimates?

13 responses
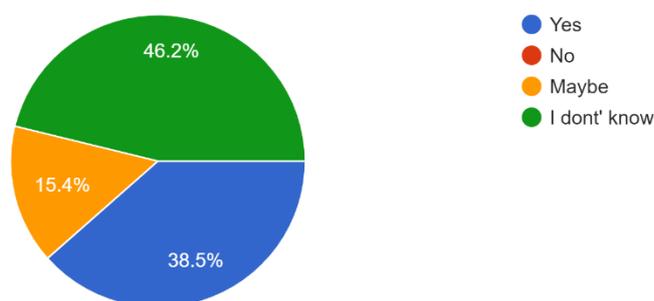
About 38% of users have used or plan to use per pixel uncertainty, and a slightly higher percentage "don't know", and the rest "maybe".

Do you use/plan to use per-pixel quality flags (e.g. poor/fair/good/best)
13 responses

- Yes
- No
- Maybe
- I don't know

38.5%

53.8%
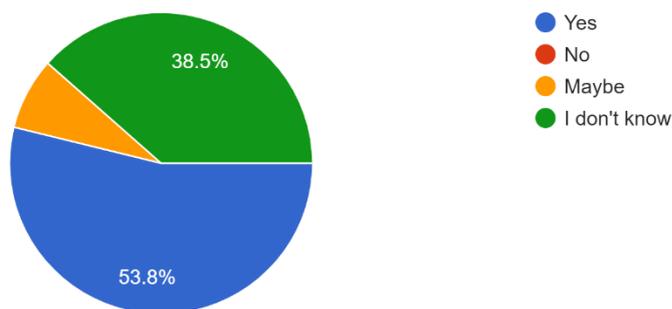
Up to 54% of responses indicated that users have used or plan to use quality flags, followed by a 38% who did not know.

Which of the following intended new products are you likely to use or recommend?
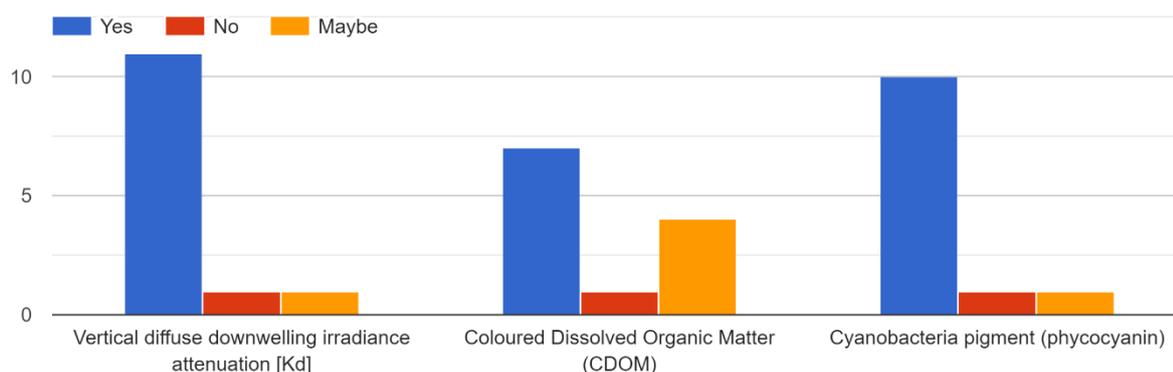
Coefficient of extinction (Kd) and Cyanobacteria pigment are the two main variables of interest, followed by CDOM.

Linked to this question, we asked if there were any other products that should be considered. The following comments were received from three users:: i) ice quality (depth of black ice, snow ice, snow); ii) surface water temperature as it drives blooms; iii) I want to use water clarity (optical depth) and water level (geometric water depth) daily data to analysis complex relationship between lake mixing regimes and lake "depths".

5.2 User experience feedback on Lakes_cci products and future needs

From the third section of the survey, the "Usage specific questions", we report below the synthesis of the responses.

Were you previously aware of the Lakes CCI products?

13 responses

- ● Yes
- ● No
- ● Maybe, not sure

38.5%

15.4%

46.2%
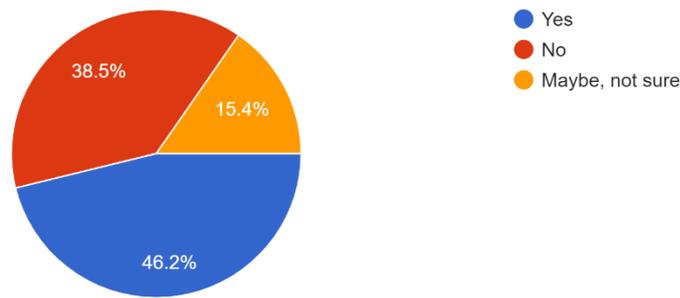
46% of the users had heard of Lakes_cci products before, while 38% had not.

Have you used any of the existing Lakes CCI products?

13 responses

- ● Yes
- ● No
- ● I don't know

92.3%

7.7%
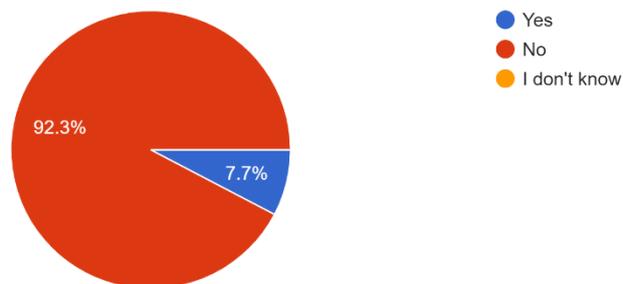
Only one user had used the Lakes_cci products before. However, four users responded to the usefulness of the dataset, ranging from 3 to 5, i.e. from medium to high usefulness, which could indicate they had witnessed the data being used by others.

How likely are you to use any of the Lakes CCI products in the next five years?
13 responses
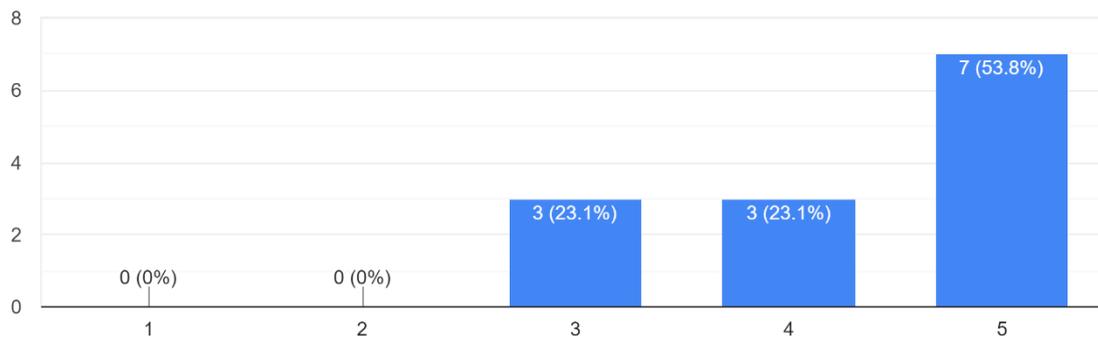
The majority of users are likely to use Lakes_cci products in the next five years. One user added that the data will be used for 3D model validation.

Other feedback from users gathered from the survey or during the conference is reported below:

6. There are multiple (and different) datasets available, but they are not connected with each other. It would be nice to have some links in the CCI webpage so that people are aware of them.
7. "Is there a detailed and regularly updated changelog that lists all the changes between versions? I've never been able to find this information on the CCI Lakes page, and the data lineage details on the CEDA Archive generally don't provide specific information on changes either. As a dataset user, it would be very helpful to have access to such information to stay informed about all the ongoing dataset changes.
8. "Flags type changed among versions makes it sometimes hard to download the entire timeseries".
9. "Webgis portal too slow and unusable even for a quick inspection of data availability in my lake".

In the recent updates of the Lakes_cci website, in the "Data" page, we have now published a section "Data access", which also reports the main improvements made to the ECV products compared to the previous dataset, responding to the first user request and using new flags to improve the knowledge and usability of the data, therefore more explanations on the data flags are available both on the website and in the document that accompanies the new version 2.1 of the dataset (e.g. Product Specification Document (PSD), Product User Guide (PUG).

Finally, we had few exchanges with the group that created the GLAST dataset (https://garslab.com/?p=650) which was created using FLake calibrated using Landsat data. We suggested to compare the dataset with Lakes_cci one to verify limitations/differences of the model used with respect to the satellite-derived observations. The GLAST group confirmed that they had a plan to perform the comparison. From our side we have already made some comparisons for lakes in Greenland and in the UK. For the Greenland lakes it is clear that the Flake model used to generate the GLAST dataset is not adequate for most of the lakes analysed, while for the lakes in UK the GLAST seems more in agreement with the satellite observations.

6. 7th LAKES Workshop on Parameterisation of Lakes in Numerical Weather Prediction and Climate Modelling programme

The local host and organizer of the 7th LAKE NWP Workshop was the Institute for Electromagnetic Sensing of the Environment of the Italian National Research Council (IREA CNR). The scientific committee consisted of the following scientists: Patrick Le Moigne (Météo France, France); Dmitri Mironov (Deutsche Wetterdienst, Germany); Homa Kheyrollah Pour (Wilfrid Laurier University, Canada); Claude Duguay (University of Waterloo, Canada); Laura Carrea (University of Reading, UK); Ekaterina Kurzeneva (Finnish Meteorological Institute, Finland); Marina Amadori and Claudia Giardino (IREA CNR, Italy).

In Figure 3 the whole programme of the 7th LAKES Workshop is reported.

The workshop was attended by 48 participants, of which six attended online, mainly from Europe, Canada and China. There were 14 oral presentations in the session "Lakes & Atmospheric Modelling", seven in the session "Ancillary data for modelling lakes" and five in the session "New frontiers for data assimilation from remote sensing". The poster session consisted of nine contributions. The photo of the participants is shown in Figure 4.

Other detailed information is reported in the workshop website (https://lakesmilan2024.irea.cnr.it/).

Wednesday	20		Authors
Session			LAKES & ATMOSPHERIC MODELLING (Chair: Dmitrii Mironov)
14:00		14:30	**Welcome & opening (Claudia Giardino, Francecso Soldovieri)**
14:30		14:50	Lijuan Wen
14:50		15:10	Maarten Boonekamp
15:10		15:30	Gelito Inacio Franco Sululu (remote)
15:30		16:00	Coffee
16:00		16:20	Elena Shevnina
16:20		16:40	Marco Papetti
16:40		17:00	Francesca Hinegk
17:00		17:20	Tatiana G. Smirnova
17:20		18:00	Session discussion
			Free time in Milano
Thursday	21		Authors
Session			LAKES & ATMOSPHERIC MODELLING (Chair: Patrick Le Moigne)
09:00		09:20	Cesar Ordonez
09:20		09:40	Claude Duguay
09:40		10:00	Damien Bouffard
10:00		10:20	Homa Kheyrollah Pour
10:20		10:50	Coffee
10:50		11:10	Pengfei Xue
11:10		11:30	Patrick Le Moigne
11:30		11:50	Alexander Smirnovsky (remote)
11:50		12:30	Session discussion
12:30		14:00	Lunch & Group photo
Session			ANCILLARY DATA FOR MODELING LAKES (Chair: Homa Kheyrollah Pour)
14:00		14:20	Galina Zdorovennova (remote)
14:20		14:40	Irina Fedorova
14:40		15:00	Margarita Choulga
15:00		15:20	Ekaterina Kurzeneva
15:20		15:40	Sebastiano Piccolroaz (remote)
15:40		16:10	Coffee
16:10		16:30	Miguel Potes
16:30		16:50	Laura Carrea
16:50		17:30	Session discussion
17:30		18:00	Poster Session
			Joint dinner
Friday	22		Authors
Session			REMOTE SENSING (CHAIRS, TBD)
09:30		09:50	Gary Free
09:50		10:10	Daniel Odermatt
10:10		10:30	Monica Pinardi
10:30		10:50	Coffee
10:50		11:10	Giacomo De Carolis
11:10		11:30	Gianfranco Fornaro
11:30		12:00	CCI_lakes project: exploring satellite dataset
12:00		12:30	Session discussion
12:30		12:50	Workshop Wrap-up & next edition
12:50		13:00	**Closing and farewell**

Figure 3. Programme of the 7th LAKES NWP Workshop held in Milan from 20 to 22 November 2024.

Figure 4. Participants of the 7th Lakes Workshop held at the CNR in Milan from 20 to 22 November 2024.

7. Overview of the 7th LAKES Workshop and user recommendations

This section provides a summary of the presentation titles with the presenting authors, followed by the key takeaways that emerged during the session discussions and as final notes from the Scientific Committee after the workshop.

7.1 Session: Lakes & Atmospheric Modelling (November 20st 14:00 18:00)

- Simulation of potential impacts of lakes on glacier over the Tibetan Plateau in summer. Lijuan Wen, Chinese Academy of Sciences
- The influence of a land use change scenario on climatic suitability for mosquitoes in the Netherlands. Maarten Boonekamp, TU Delft/KNMI
- Gender mainstreaming. Gelito Inácio Franco Sululu (remote), Commonwealth Youth Climate Change Network (online but with poor connection)
- Evaporation over glacial lakes in the Schirmacher oasis, East Antarctica. Elena Shevnina, Finnish Meteorological Institute
- Effect of coarse climate model resolution on lake temperature simulation. Marco Papetti, Università degli Studi di Brescia
- Response of lake ice cover to water level and air temperature variations in two Norwegian hydropower reservoirs. Francesca Hinegk, University of Trento
- Implementation of the Community Land Model (CLM) 4.5 Lake Model in the US NOAA Unified Forecasting System (UFS). Tatiana G. Smirnova, CIRES, University of Colorado Boulder

The main points that emerged from the presentations and the discussion are set out below:

- Many researchers are concerned about the overestimation of the modelled lake surface temperature in warming regime. The most likely reason for this deficiency is an underestimation of the mixed layer depth, which in turn is due to an underestimation of the momentum transfer from the atmosphere to the lakes. In fact, the NWP community has excellent observational datasets and should make considerable progress towards improved surface layer parameterisations for lakes. Another possible reason for the overestimation of lake surface temperature is the use of a too large, fixed reference value for the solar radiation extinction coefficient for all lakes, regardless of the actual lake water transparency. **The use of more realistic estimates of the extinction coefficient can improve the situation. Satellite data on lake water transparency are very useful. In fact, the development of a global water transparency (Kd, extinction coefficient) dataset based on satellite data now seems quite possible and should be a subject of future work in this lake community. As also observed at the 6th NWP Workshop that was combined with the first Lakes_cci User Workshop, such a dataset will be of considerable use for NWP and climate studies (among other applications).**
- Another issue relevant to the modelling of shallow lakes is the interaction of lake water with bottom sediments. A simple parameterisation of the heat flux at the water-sediment interface is available in the Flake model. This parameterisation should be extensively tested and improved where necessary. A more sophisticated parameterisation may be required for specific applications.
- There is a growing interest in modelling/parameterising **saline lakes and reservoirs**. One straightforward approach is to use advanced and well-tested ocean models and adapt them to lakes, although caution should be exercised.
- Further development of the datasets used to generate external parameter fields for NWP and climate models (lake fraction, lake depth) is an ongoing task, such as the inclusion of dynamic (time-dependent) features (i.e., temporary lakes and flooded areas). **A lake-water transparency dataset with global coverage would also be of considerable utility for NWP, climate studies, and related applications.** Development of such dataset should be undertaken by the lake parameterisation community.
- Predicting extreme, high-impact/extreme events is an increasingly important part of the NWP and climate modelling agenda. High-impact lake-related events include lake-induced storms, pollution dispersion, and phytoplankton blooms, which often lead to water quality degradation. Modelling and prediction of lake-related extreme events requires the use of advanced hydrodynamic lake models coupled with atmospheric models and models of lake ecosystems.
- There are many sensitive issues associated with the use of ocean models/parameterisation schemes in fine-resolution atmospheric prediction systems over lakes. A tricky and largely unresolved issue is the verification of model results obtained with tiled surface layer schemes against observational data.
- Some lake models/parameterisation schemes do not explicitly treat snow over lake ice, which is desirable. This requires credible formulations of snow density and thermal conductivity.

7.2 Session: Lakes & Atmospheric Modelling (November 21st 09:00 12:00)

- The Influence of Climate Change, Solar Brightening, and Water Clarity on Thermal Structure in Lake Hallwil, Switzerland. César Ordóñez, University of Geneva
- A Deep Learning Model for Lake Ice Cover Forecasting. Claude R. Duguay, H2O Geomatics/University of Waterloo

- ALPLAKES: advancing lake research and management through open integration of remote sensing and hydrodynamic products. Damien Bouffard, Eawag/University of Lausanne
- Advancing Modeling of Lake Ice Dynamics and Phenology in High-Latitude Regions. Homa Kheyrollah Pour, Wilfrid Laurier University
- Enhancing Winter Climate Simulations of the Great Lakes: on the Importance of Integrating 3D Hydrodynamics with a Regional Climate Model. Pengfei Xue, Michigan Technological University
- Overview of lake-related activities at Météo-France. Patrick Le Moigne, Météo-France/CNRS
- The influence of water transparency on the development of radiatively driven convection in lakes under ice. Alexander Smirnovsky (remote), Peter the Great St. Petersburg Polytechnic University

The key points that emerged from the presentations and the ensuing discussion are summarized below:

- It's important to consider **trophic state dynamics** in lake management strategies, particularly in the context of climate change.
- 3D hydrodynamic models allow to properly capture the main processes in large lakes (as opposed to 1D models) and their use can significantly reduce biases (e.g., cold climate).
- Deep learning models can be more efficient as compared to physical models, like for instance for lake ice cover forecasting. However, **there is a need to continue developing physical models and hybrid approaches** such as the lake ice model for simulating daily ice thickness and phenology.
- **Transparency plays a key role in the development of the convective mixing layer under ice.** In this context the use of large-eddy simulations (LES) shall be encouraged.
- The use of observational datasets would be beneficial to test and further develop parameterisation scheme. Measurements through the entire column, including the atmosphere, snow, ice, and lake water are of particular value. From the viewpoint of lake physics, of great interest are spatially distributed measurements that should allow to quantify horizontal heterogeneity in ice-covered lakes.
- Advanced atmosphere-lake coupled prediction systems, possibly also including models of surface waves, will surely become increasingly popular in lake studies. One interesting task is the development of advanced turbulence closure models capable of describing intermittent, stably-stratified turbulence in lake thermocline.
- High-resolution, eddy-resolving numerically simulations, e.g., LES and direct numerical simulations (DNS), are commonly used in meteorology and oceanography over many decades to generate numerical datasets, supplement observational data, and gain better insight into the structure and transport properties of atmospheric and oceanic flows. The use of LES and DNS in lake research is still in its infancy, but their application in the future is highly encouraged.

7.3 Session: Ancillary data for modelling lakes (November 21st 14:00 17:30)

- Parameterisation of lake ice structure: the role of precipitation and air temperature. Galina E. Zdorovennova (remote), Northern Water Problems Institute
- Small alpine Armenian lakes degradation under climate warming and anthropogenic impact. Irina Fedorova, Institute of Botany after A.Takhtadjan
- Time-varying lake surface cover for reanalysis application. Margarita Choulga, ECMWF
- Status and Progress of Globlal Lake Database developments. Ekaterina Kurzeneva, Finnish Meteorological Institute
- A simple model for predicting ice formation timing, thickness, and quality in lakes. Sebastiano Piccolroaz (remote), University of Trento

- Heat and carbon fluxes over a large Mediterranean reservoir. Miguel Potes, University of Évora
- Towards the Development of Global Gap-Filled Lake Surface Water Temperature and Ice Cover Products. Laura Carrea, University of Reading

Key points from the presentations and subsequent discussion are summarised below:

- The integration of meteorology, limnology, and climatology provides deeper insights into lake systems under environmental stress.
- Armenian alpine lakes serve as a valuable microcosm for studying climate impacts, emphasizing the need for localized conservation strategies.
- Changes in ice dynamics in boreal and temperate zones underline the importance of implementing safety measures in vulnerable regions.
- **Advancing dynamic lake shapefiles for reanalysis models holds significant promise for improved NWP. The level of detail required in lake water masks, especially for seasonally dynamic lakes, needs careful consideration to optimize into NWP models. CCI Land Use Land Cover was one of the sources, along with the JRC Global Lake Explore so that the LWE from Lakes_cci might be of great interest for this community.**
- There is a need for increased international collaboration to leverage datasets like the GLDB and platforms such as ALPLAKES. Strengthening interdisciplinary collaborations is essential to bridge research gaps.
- **Development and accessibility of global datasets, such as those for lake surface temperature, wind, snow on ice, and fluxes, are critical for supporting model schemes and remote sensing algorithms, However, significant gaps remain between data collectors, model developers, and the remote sensing community. A concerted effort is necessary to better connect these groups and foster collaboration.**

7.4 Poster presentation (2' talk)

Before the poster session the authors had the opportunity to present their studies with a short talk to better introduce their posters and stimulate the discussion.

- Dynamic of horizontal structures in lakes and impact on horizontal heterogeneity. Anne Leroquais, Eawag
- Spatially Distributed Modelling of Ice Thickness on Small and Medium Sub-Arctic Lakes. Gifty Attiah, Wilfrid Laurier University
- Improved thermal structure and lake-surface temperature simulation for Lake Superior using a data assimilative model. Chuyan Zhao, Michigan Technological University
- Environmental Factors Influencing Temperature Variation in Small Reservoirs (<14,000 m³): Insights from Experimental Monitoring of Temperatures, Flow Rates, and Weather Conditions in three small reservoirs. Clemence Houpert, INRAE
- Evaluating the Results in Tibetan Plateau Lakes Using LakeEnsemblR. Yifan Xie, Wuhan University
- Modeling Hydrodynamics in Great Bear Lake Using AEM3D. Kirin Lorente, Wilfrid Laurier University
- Water retention technologies to promote slow hydrology in an intermittent river. Miguel Potes, University of Āvora
- Overview of the ESA Lakes Climate Change Initiative. Stefan Simis, Jean-Francois Cretaux, et al., Marina Amadori
- Lake-climate interactions in African sub-Sahelian lakes: a continental-scale assessment based on multivariate remote sensing and modeling data., Anne Joelle Greife et al.

The last two posters were related to the Lakes_cci project. One was dedicated to the objective of the project, the dataset and tools, together with the link to the last survey on the water transparency product. The second one focused more on the results of the first part of the work on the Africa option.

7.5 Session: New frontiers for data assimilation from remote sensing (November 22st 9:30 13:00)

- Climate change and ecological assessment in Europe – using remote sensing and climate data to contextualize change. Gary Free, European Commission, Joint Research Centre
- Remote sensing of tipping lakes. Daniel Odermatt, Eawag
- New insights from the Lakes_cci project on satellite-derived lake variables for climate studies. Monica Pinardi, CNR-IREA
- Achievements, Developments and Perspectives of the SARLAKES Project. Gianfranco Fornaro, CNR-IREA
- CosmoSkyMed SAR observations of wind and surface currents over the Garda Lake. Preliminary results from the SARLAKES project. Giacomo De Carolis, CNR-IREA
- CCI_lakes project: exploring satellite dataset, Monica Pinardi and Alessandro Scotti, CNR-IREA

The last session of the workshop focused more on the remote sensing studies related to lakes, and the main results are as follows:

- The study of tipping points in lakes will benefit from remote sensing data although discerning changes from irreversible changes is a challenging task, also because a tipping point is not necessarily abrupt.
- Many lake variables (and derived variables) regridded at the same resolution are available from the ESA CCI project for validation/calibration of models including lake water transparency.
- A lake-water transparency dataset with global coverage would be of great utility for NWP, climate studies, and related applications.
- Wind measurements at high resolution can be useful to drive lake circulation models and to assess the model results. The wind fields used as forcing for modelling lake circulation are often too smooth, and the lack of small-scale spatial variability results in insufficient mixing within lakes.
- And finally, it was noted that for IMHO, Lake Garda should be used as a show case, where observations and modelling are used in a mutually fertilizing way to excel in lake research.

The presentation on the use of the Lakes_cci dataset focused on three main questions:

1.   Where and how to download the dataset?

2.   How to download the dataset for a lake and a variable?

3.   How to visualise and query the dataset?

For the first point an overview of the CEDA Archive website was given, while for the second point a more detailed application using Jupiter notebook and Binder was shown. Finally, the Webgis portal and the global climate dashboard were presented.

The community showed interest in the new version of the dataset, and we will leave the tutorial for the participants of the Milan workshop.

7.6 User Feedback

The 7th LAKES NWP workshop followed the 6th NWP workshop Toulouse in 2019, where one of the needs collected from the NWP community was the water transparency product. Following this feedback, among others, the Lakes_cci team is now working to develop a Kd product derived from remote sensing reflectance at a global level. The ongoing task of filling the LIC and LSWT data gaps was also appreciated by the lake modelling community.

During the workshop, in almost all sessions, the great usefulness for NWP, climate studies and related applications to have a global lake water transparency dataset, changing lake by lake and during the season from remote sensing observations emerged. The extinction coefficient could improve the model estimation of lake surface temperature in the lake warming regime, as noted in the first session of the workshop. However, there was also some interest in Secchi disk depth as a proxy for water transparency. It was also emphasised that transparency plays a critical role in the development of the convective mixing layer under the ice. Finally, more generally, consistent products are needed by this community that, for several reasons might look at similar products provided by other initiatives (e.g. CCI LULC for the water body mapping and the CCI Ocean Color that provide water transparency for some of the largest water body).

Another request relates to the possibility of having lake variables as aggregated data and the Fore Ule classification for lakes (Daniel Odermatt). In addition, a near-real-time service could be useful, for example, for mapping algal blooms in Chinese lakes such as Taihu, to be integrated with in situ data collected near the shore (Lijuan Wen). The integration of in situ and model data, as shown for example in the presentation of Alexander Smirnovsky and Damien Bouffard, but also with remote sensing data, is a key point to be further developed in the next future. In addition, a temporal dynamic mask of lakes to face the changes in drying and flooding of water bodies is still a need to improve NWP and climate models.

8. Synthesis and recommendations

The opportunity to participate in the Lakes_cci user workshop at PPNW2024 and the 7th LAKES Workshop on Parameterisation of Lakes in Numerical Weather Prediction and Climate Modelling, the latter in continuity with the previous exchange held in Toulouse in 2019, allowed for an in-depth discussion between Lakes_cci data providers and potential end-users. Such interactions were needed both to clarify data characteristics and limitations of the dataset, and to get feedback from end-users on their awareness of the Lakes_cci products, their research needs, and needs for new products that could be improved in the next phase of the project.

PPNW and the 7th LAKES workshop were quite informal. There were lots of conversations over coffee and lunch and after the presentations. We noticed that many PPNW attendees were not planning to attend the workshop as they felt it was just a general introduction to the dataset and basic instructions on how to download time series. Instead, people were interested in the dataset and wanted to know not so much how to download the data, but what the data looked like and said. Many of them eventually decided to stay, knowing that interaction with the data producers would have been possible and appreciating the personal presence of the ECV science leaders. Instead, the programme of the 7th LAKES Workshop was planned together with the lake NWP and climate modelling communities, facilitating interaction between the remote sensing and modelling communities. There was quite a lot of interest in the explanation of the CCI tool.

During both workshops ,we had a fairly homogeneous end-user community under the umbrella of physical limnology and processes and of NWP and atmospheric modelling, respectively.

Some members of the PPNW community expressed concerns about the use of global datasets and the use of satellite derived data. However, it is likely that part of this community will use high quality Lakes_cci data for individual lakes in the near future, with particular interest in temperature, water quality, lake level and ice cover data. The NWP modelling community expressed fewer concerns on the use of RS data. Another important feedback was the interest in high spatial resolution products. In fact, behind the different scale of observation needs, it emerged that daily spatial data for individual lakes or at a regional scale were preferred. Participants agreed on the need for validation and interaction on individual case studies. From the Feedback form we can also summarise that the priorities for RS of lakes for modelling are data quality, phytoplankton and cyanobacteria pigments, extinction coefficient (Kd) and CDOM data. In addition, the NWP and climate modelling communities highlighted the potential usefulness of having a global coverage of lake water transparency. From both communities reached in the two workshops, we can highlight a strong interest in gap-filled temperature and ice cover data, and that uncertainty and quality flags are useful.

Finally, mainly from the experience of the PPNW2024 we can draw some lessons for future user workshops. This type of event should focus more on the interaction between data producers and the scientific community. In this respect, following the example of CCI SST, we could consider adding a short 'Quick Start Guide to ESA Lakes_cci products' at the beginning of the PUG (cf. https://climate.esa.int/media/documents/SST_CCI_D4.2_PUG_v1.1.pdf) or on the project website. One possibility is to divide the workshop into 2 parts: presentations and discussions. Regarding the content of the presentations, it worked quite well to show: 1) what the dataset contains (showing variables, quality flags and uncertainties); 2) how good the dataset is (showing validation and/or comparison with other datasets); 3) what can be done with the dataset (showing some applications/case studies). As for the discussion part, breakup groups could be a strategy.