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Copernicus EO needs assessment for modellers and decision makers

Project Identification

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List of Acronyms	
APHRODITE	Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation
a_{phy}	Phytoplankton absorption coefficient
API	Application Programming Interface
ARC	African Rainfall Estimate Climatology
ASTER	Advanced Space Borne Thermal Emission and Reflection
ASTER GDEM	Advanced Space Borne Thermal Emission and Reflection Radiometer-Global Digital Elevation Model
AT	Air Temperature
a_{tot}	Total absorption coefficient
B_{bp}	Particulate Backscattering Coefficient
C3S	Copernicus Climate Change Service
CCS	Cloud Classification System
CDM	Coloured Dissolved Matter
CDOM	Coloured Dissolved Organic Matter
CDR	Climate Data Record
CGLS	Copernicus Global Land Service
CHIRPS	Climate Hazards Group InfraRed Precipitation with Stations
Chl-a	Chlorophyll-a
CLMS	Copernicus Land Monitoring Service
CMEMS	Copernicus Marine Environment Monitoring Service
CMFD	China Meteorological Forcing Dataset
CMORPH	Climate Prediction Center MORPHing technique
CNR-IREA	Italian National Research Council- Institute for electromagnetic sensing or the environment
CORINE	Coordination of information on the environment
CPC	Climate Prediction Center
DEM	Digital Elevation Model
DIAD	Design and Impact Assessment Dashboard
DOC	Dissolved Organic Carbon
DOI	Digital Object Identifier
EAWAG	Swiss Federal Institute of Aquatic Science and Technology
ECMWF	European Centre for Medium-Range Weather Forecasts
ECV	Essential Climate Variable
EGU	European Geosciences Union
EO	Earth Observation
EOMORES	Earth Observation-based Services for Monitoring and Reporting Ecological Status
ERA	ECMWF Re-Analysis
ESA CCI	European Space Agency Climate Change Initiative

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EWEMBI	Earth2Observe, WFDEI and ERA-Interim merged and bias-corrected
FAO	Food and Agriculture Organization
GFZ	German Research Centre for Geosciences
GLDAS	Global Land Data Assimilation System
GMTED 2010	Global Multi-resolution Terrain Elevation Data
GPCC	Global Precipitation Climatology Centre
GPCP	Global Precipitation Climatology Project
GPM	Global Precipitation Measurement
GSMaP	Global Satellite Mapping of Precipitation
GTOPO 30	Global Topography 30-Arcsecond
H-SAF	EUMETSAT Satellite Application Facility in Support of Operational Hydrology and Water Management
HydroSHEDS	Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales
IGRAC	International Groundwater Resources Assessment Centre
IJTSRD	International Journal of Trend in Scientific Research and Development
IMERG	Integrated Multi-satellite Retrievals for GPM
IOCCG	International Ocean-Colour Coordinating Group
IOP	Institute of Physics
ISPRS	International Society for Photogrammetry and Remote Sensing
ISRIC	World Soil Information as a result of international collaboration
IWT	Inland water temperature (IWT)
JRA-55	Japanese 55-year Reanalysis
K_d	Diffuse attenuation coefficient
LST	Land surface temperature
LSWT	Lake Surface Water Temperature
LU/LC	Land Use Land Cover
LULC	Land use land change
MCC	Mass concentration of clorophyll-a
MEERA-2	Modern-Era Retrospective Analysis for Research and Applications-2
MERIT	Multi-Error-Removed Improved-Terrain
MERRA-2	Modern-Era Retrospective analysis for Research and Applications
MH	Multi-Hydro Model
MODIS	Moderate Resolution Imaging Spectroradiometer
MSWEP	Multi-Source Weighted-Ensemble Precipitation
MSWEP	Multi-Source Weighted-Ensemble Precipitation

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NCEP CFSR	the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) Swat Database)
NLCD	National Land Cover Data
PERSIANN	Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks
PGF	Princeton University Global meteorological Forcing
PP CO2	Partial pressure of CO2 or CO2 concentration
RFE	Rainfall Estimate
Rrs	Remote Sensing Reflectances
RS	Remote Sensing
RSR	Remote Sensing reflectance
SAF	Satellite Application Facility
SDD	Secchi Disk Depth
SMC	Special monthly compensation
SM-DAS-2	Root zone soil moisture index in the root zone by scatterometer data assimilation
SMHI	Swedish Meteorological and Hydrological Institute
SM-OBS-1	Large-scale surface soil moisture by radar scatterometer
SM-OBS-2	Small-scale surface soil moisture by radar scatterometer
SMOS	Soil Moisture and Ocean Salinity
SPM	Suspended Particulate Matter
SPOT	“Satellite Pour l’Observation de la Terre’’, lit. "Satellite for observation of Earth"
SRTM	Spatial Information Shuttle Radar Topographic Mission
SST	Sea Surface Temperature
SWAT	Soil & Water Assessment Tool
TAMSAT	Tropical Application of Meteorology using SATellite
TanDEM-X	TerraSAR-X add-on for Digital Elevation Measurement
TN	Total Nitrogen
TP	Total Phosphorus
TRMM	Tropical Rainfall Measuring Mission
TSI	Trophic state index
TSS	Total Suspended Solids
TWS	Terrestrial Water Storage
UFZ	Environmental Research Centre Leipzig-Halle GmbH
USGS	United States Geological Survey
Water SA	Water South-Africa
WFDEI-CRU	Watch forcing data ERA-Interim – Corrected using Climatic Research Unit CRU data.

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WFDEI-GPCC	WATCH Forcing Data ERA-Interim (WFDEI) corrected using Global Precipitation Climatology Centre (GPCC) dataset
WL	Water levels in lakes and rivers
WLR	Water leaving reflectance
WP	Work Package
WPP	Water primary production
ZSD	Secchi Disk Depth

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Executive Summary

The Horizon2020 project Water scenarios For Copernicus Exploitation (Water-ForCE) will develop a Roadmap for Copernicus Inland Water Services. The Roadmap will assess the current state of water related services provided by six existing Copernicus Services and will provide an optimal way forward for satisfying different user and stakeholder communities.

The current report provides the current use of Remote Sensing data (RS) for modelling water quality and water quantity such that model outcomes are useful to decision makers. The aim of the report is to look at RS services in general, however the report gives special attention to Copernicus services, in order to better formulate recommendations for the Water-ForCE final roadmap.

The analysis carried out in preparing this report pointed out the following:

- Increase spatial coverage, as per recommended values in Section 3
- Provide the availability of datasets outside the European areas
- Reduce the differences in spatial and temporal data collection and the ones measured on the ground
- Provide API which will give the possibility to import real time data directly to models, especially in case of Early warning systems
- Create simpler search interface; provide guidance on novice users; organize training webinars
- Make standardised dataset formats
- Make the two datasets (RS and in-situ) comparable (possible validation), reduce uncertainty
- Make the accessibility to data quicker and less time-consuming
- Possibly enlarge the range of products to groundwater
- Give precise information to users about datasets and their uncertainty
- Add DOI to data, for easy referencing

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1. Introduction

1.1 Water-ForCE

Nowadays Remote Sensing (RS) technologies cover several applications in innovative research concerning different domains (environment, agriculture, land management, forestry, etc). One of the most important area to which RS data can contribute is water. In this field experts use RS data to obtain some of the parameters linked to water quality (Papathanasopoulou et al., 2019) and water quantity. In particular experts using RS target various objectives: operating with RS data for modelling (hydrological and hydraulic models); comparing RS data to modelling outputs for calibration and/or validation; using RS data as input to empirical predictions for extreme events, such as floods and droughts for decision making; etc. Remote Sensing Data Services need to be improved, implemented and consolidated considering users' needs. Increasing the reliability of RS data can lead to provision of more appropriate information about the upcoming disasters and consequently robust flood risk assessment (Stoleriu et al., 2020), or flash flood vulnerability maps and need assessment (Islam et al., 2022). These methodologies in fact can strongly contribute to the alarm systems and disaster management (Sarker et al., 2020). Other applications of RS technology are based on understanding the processes driving shoreline changes (Dada et al., 2018) or combining spatial datasets on forest loss from RS and spatially-explicit hydrological modelling to quantify the impact of deforestation on water-based ecosystem services (Netzer et al., 2019). An advantage of RS technology is that it does not need the direct contact to the surface of the Earth and in some particular areas, it is the unique solution to get the data. Remote Sensing methodologies have seen major improvements over the last decade, but their uptake is still limited, owing to a lack of skills within sectors that could benefit from Remote Sensing capability, limited confidence and overall lack of concerted effort to support their validation and integration. In EU the Copernicus programme was

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initiated to fill spatial and temporal gaps in availability of environmental data for management and decision making.

In this context the **Horizon 2020** project **Water-ForCE** (Water scenarios for Copernicus Exploitation) is developing a Roadmap to better integrate the entire water cycle within the [Copernicus services](), thereby addressing needs and requirements from the user community, the current disconnection between Remote Sensing / in-situ observations and upgrade of the modelling algorithms.

The Roadmap will contain:

- Analysis of user communities' landscape
- Analysis on how Copernicus water services can support policy development and monitoring of their implementation
- Gap analysis of the Copernicus water-related service portfolio
- Identification of future higher-level biogeochemical products
- Technical requirements for future Copernicus sensors to improve the water-related service portfolio
- Proposal for organising in situ measurement networks to validate Copernicus Remote Sensing and modelling products and to provide complementary data not collected by Remote Sensing
- Proposal on how to define relationships between Core Services and Downstream services
- Recommendation on the evolution of a water service (via the creation of a new service, or the improvement of water services under current Copernicus services, or through a better integration of water-related products)

The Water-ForCE project is coordinated by the University of Tartu (Estonia) with 20 participating organisations from all over Europe. It connects experts in water quality and quantity, in policy, research, engineering and service sectors. The project is divided into

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eight work packages (WP), each of them focusing on a specific problem and/or target of the Copernicus services. The project started on 1st of January 2021 with a duration of three years.

This report is part of Work Package 5 (WP5) “Modelling and data assimilation” which aims to augment the knowledge acquired in WP1-WP4 by identifying the potential for future use of different satellite EO in modelling of water resources for support of decision makers towards adaptive management of water resources and policy implementation.

1.2 Content of the Report

This document presents the needs assessment for Remote Sensing data in general for modelling water quantity and water quality, such that it will be used by decision makers. A special focus is given to Copernicus data services.

The report is structured in four main parts, followed by annexes. The first part, present chapter explains the background for the project and present report purpose. The second part explains the methodology adopted to collect data.

Section three of the report analyses the literature review and results obtained from specific questionnaires and interviews.

Section four of the report summarises the outcome of the analysis by recommending a set of possible improvements to current Copernicus services.

All gathered data through surveys, literature review and extracted information from literature review is available at the end of the report in annexes.

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2. Methodology

2.1 Approach

To achieve the objective of Work Package 5 of identifying the needs of EO data for modelling the methods used to collect data included the following steps:

- analysis of Water-ForCE previous workshops and outcomes of the deliverables D2.2 (2021) and D3.2. (2022); such that the main stakeholders, as identified and analysed in D1.1 contributed to the data collection and provided feedback on the use and needs from Earth Observation data in general and Copernicus data in particular.
- identification of current trends in use of Copernicus EO data in modelling in support of decision makers, by conducting a structured literature review. The literature review selection is based on keywords that were identified by deliverables D1.4 (2021), D2.2 (2021), D3.2 (2022), and outcomes of the Water-ForCE workshops, in particular Workshop of WP3 and WP4 from March 2021, and Workshop of WP2 and WP4 of April 2021.
- conducting online surveys based on the conclusions of the literature review. Two questionnaires were developed by the Work Package 5 (WP5) in close consultation with the other work packages of the project and feedback from the working group. The surveys were sent out to researchers, experts and end-users of Remote Sensing data in general and more specifically by Copernicus, to explore their current use of data in modelling and their future needs for data.
- conducting individual face to face interviews with researchers and consultants working with RS data. These interviews were carried out during the European Geosciences Union (EGU) General Assembly 2022, which took place on 23-27 May in Vienna, Austria.

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Data collection was done separately for water quantity and water quality. However, in the analysis the common elements to both were highlighted.

2.2 Data collection

The data collected for the needs assessment evaluation was a combination of quantitative, numerical data, and qualitative descriptive data. The aim of the literature review was to identify the challenges in using Remote Sensing data for modelling water quantity and water quality, while the conducted surveys and interviews aimed to identify suggestions and actions for implementation of the final Roadmap, in order to meet the needs of the users of EO Copernicus.

2.2.1. Literature review

The conducted structured literature review followed the guidelines, as highlighted in Moher et al., (2009) using the SCOPUS database, Web of Science, and Google Scholar. SCOPUS and Web of Science features the largest peer reviewed journal coverage (Mongeon and Paul-Hus, 2016) excluding grey literature. The search was limited to journal articles in English and the first search was in the title, abstract and keywords using a combination of keywords to describe the investigated EO and Copernicus data in the modelling context.

The full research methodology was stepwise. First queries of keywords were performed on the three selected databases. Search queries were as follows:

TITLE-ABS-KEY

(“modelling”)

AND (“remote sensing” OR “Earth observation”)

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AND/OR (“water quantity” OR “water quality”)

AND/OR (“rivers” OR “lakes”)

AND/OR (“inland waters”)

AND/OR (“water resources” OR “water allocation”))

AND (LIMIT-TO (SRCTYPE, “j”))

AND (LIMIT-TO (DOCTYPE, “ar”))

AND (LIMIT-TO (LANGUAGE, “English”))

In the second step duplicate papers were excluded. Third step referred to strict inclusion and exclusion criteria, established to keep the papers within the scope of this review. Papers were included if:

- their abstracts were about Remote Sensing and earth observation data, and if
- these studies were about water quality and water quantity.

Papers were excluded if:

- they were duplicates of an already selected paper
- the work was discursive, or if
- they were not selected by the VosViewer selection approach

The last eligibility was checked using the systematic scientometric software, VosViewer (www.vosviewer.com), developed by Leiden University (Van Eck and Waltman, 2011) in order to look for trends in the data in a quantitative manner. For example, the software was used to analyse where the studies were conducted (i.e. location) and to determine which studies address the identified keywords, during workshops with stakeholders. The software completes this analysis in a systematic, repeatable and robust manner. The output of a two-stage process which uses a refined second round to further

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categorise papers. This further round uses a user-defined thesaurus of similar terms, in order to screen for similarity and avoid double counting.

The initial search on the three databases was performed on 10 November 2021 and yielded 3043 articles matching the keywords. Next abstract screening, and availability check and full text screening as described above, which resulted in 114 papers that were included in the final analysis (please see References for a full list of articles).

All selected papers were analysed and categorised, describing bibliographical information, study design (e.g. spatial and/or temporal scale) and information regarding special parameters related to water quality and/or water quantity modelling, methods and concepts used, the location of presented case study and the type of inland water (i.e river, lakes, wetlands, etc) was generated.

Examples of type of Remote Sensing data considered are precipitation, evapotranspiration, flood extent, snow melt, soil moisture, in case of water quantity; and chlorophyll-a, turbidity and Total Suspended Solids (TSS), for water quality.

2.2.2. Surveys and interviews

The second type of investigation carried out was through surveys and face to face interviews of experts. One of the most used forms of needs analysis is the survey in the form of a questionnaire. The questionnaires were focussed at Copernicus data. Information which was obtained from it is tabulated and discussed in Section 3 of this deliverable.

In this study, two questionnaires were developed, one for use of EO and RS for modelling water quality (Annex 1.1); and one for modelling water quantity (Annex 1.2). All project partners and working groups of the project registered in Hubspot were invited to fill in

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these two questionnaires, made available as a web-based format. The invitees were invited to complete the set of questionnaires of their choice; i.e either water quality, or water quantity, or both.

The main elements of the questionnaires were:

- Basic information regarding type of work, institution where the respondent works and experiences in using Copernicus EO data.
- Current use of Copernicus data.
- Identified needs for Copernicus data for the future.

Survey questionnaires were available for one month for answering, and apart from email invitation were also made available during two symposia: the Living Planet Symposium, Berlin, 2022; and European Geoscience Union, Vienna 2022.

A number of 25 survey were received for water quality and 21 for water quantity.

During the EGU 2022, a set of 17 face to face interviews were carried out. The base for these interviews were the survey questions.

During the surveys and interviews, structured questions also allowed for open ended answers with possibility to make comments, where the respondents could fill in their personal opinion.

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3. Results of Needs assessment

3.1. Literature review

The diversity in modelling inland water issues, as quantity and quality, is reflected by the fact that out of the 114 reviewed papers a total of 53 journals were checked. The most common journals were *Journal of Hydrology*, *Remote Sensing of Environment*, and *Water*. The list of consulted journals is available in Annex 2.1.

Table 1. Models' parameters considered for analysis in the reviewed papers

Selected parameters addressed by Remote Sensing	Where the modelling applies		Copernicus RS	Reviewed paper (as mentioned in Reference list)
	Water quantity	Water quality		
bathymetry	✓		✓	[40]
DEM	✓			[88]; [93]
drought	✓			[6]; [43]; [102]
evapotranspiration	✓		✓	[1]; [2]; [5]; [10]; [11]; [13]; [14]; [17]; [18]; [24]; [26]; [30]; [38]; [42]; [47]; [52]; [53]; [56]; [59]; [74]; [79]; [82]; [92]; [99]; [101]; [104]; [107]; [113]
flood extent	✓		✓	[7]; [16]; [25]; [43]; [44]; [58]; [63]; [65]; [68]; [75]; [80]; [84]; [85]; [87]; [89]; [102]; [103]
groundwater	✓			[24]; [35]; [65]
lake ice cover	✓		✓	[45]
land surface temperature	✓		✓	[26]; [78]; [114]
land use/land cover	✓			[4]; [16]; [19]; [33]; [34]; [42]; [77]; [88]
precipitation	✓			[1]; [10]; [24]; [38]; [42]; [46]; [54]; [57]; [59]; [62]; [70]; [83]; [99]; [104]; [107]; [110]
river discharge	✓			[24]; [37]; [48]; [51]; [70]; [110]
river width	✓			[41]; [51]
snowmelt	✓		✓	[9]; [12]; [24]; [38]; [42]; [51]; [59]; [72]; [91]; [105]; [106]; [109]; [113]

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soil moisture	✓		✓	[1]; [3]; [13]; [15]; [24]; [26]; [27]; [31]; [38]; [42]; [47]; [51]; [53]; [59]; [60]; [69]; [79]; [82]; [88]; [94]; [113]
terrestrial water storage (TWS)	✓			[97]; [111]
water levels	✓		✓	[26]; [42]; [51]; [65]; [73]
chlorophyll-a		✓	✓	[22]; [40]
aquatic habitats		✓	✓	[64]
Coloured Dissolved Organic Matter (CDOM)		✓	✓	[22]; [24]; [40]
Lake Surface Water Temperature (LSWT)		✓	✓	[40]
Secchi Disk Depth (SDD)		✓	✓	[22]
Total Suspended Solids (TSS)		✓	✓	[22]; [40]
trophic status		✓	✓	[40]
turbidity		✓	✓	[22]
vegetation products		✓		[29]; [86]; [100]

The frequency of papers per year of publication, for the last 5 years (2017-2020) is available on Figure 1.

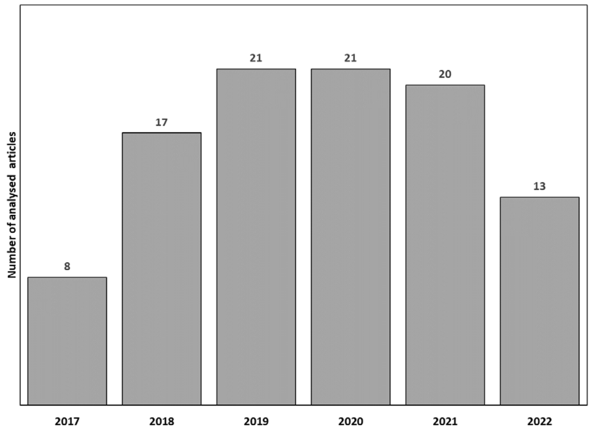

Figure 1. Yearly distribution of analysed articles

The review was done for both water quality and water quantity Remote Sensing parameters based on the processes that are described in models. The set of parameters selected for the review analysis, are defined in Table 1.

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Out of the analysed paper 16 of them specifically address Copernicus RS data, and the rest address RS data in general, including Copernicus data. The percentages of articles addressing just water quantity is 90%; 4% water quality; and 6% addressing both.

Water quality

The water quality parameters addressed in the reviewed paper are presented in Figure 2, and refer to Chlorophyll-a, Coloured Dissolved Matter, Suspended Particulate Matter and Turbidity.

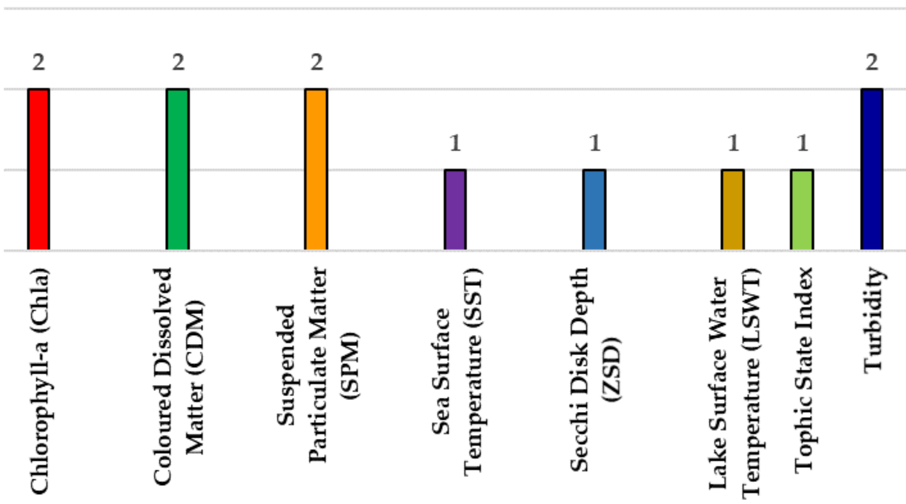

Figure 2. Water quality modelling parameters per journal paper mentioning

The water quality modelling papers that were in the list of selected papers to be reviewed initially are mainly addressing in-situ measurements. As this deliverable address's RS contribution to modelling, these were excluded from literature review. However, Work Package 4, of the Water-ForCE project, conducted a survey on data use and needs for in situ data for water quality modelling (Simis et al, 2021). Out of the 45 respondents to that questionnaire, 67% are using satellite data in their models. Moreover, they do consider that weather data are important for water quality modelling and monitoring, and weather variables are available (except evaporation). The main

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parameters lacking or not well known to be available are soil properties, hence it is recommended to look into this issue. In the end, the group was asked to answer if they are willing to use RS for data collection and 70% of them were positive about it. No mentioning of water quality parameters space and time resolution was found in Simis et al, (2021) data collection report.

Water quantity

In case of water quantity, the analysed studies have been categorized according to study area sizes (micro, meso & macro) and purpose for which the remote sensed or satellite based global data products have been used in the hydrological models. Different authors in the literature have categorized the scale of catchments according to different sizes. For instance, the range for meso scale defined by Uhlenbrook et al., (2004), Singh and Stengar, (2018) and Becker et al., (2019) is 10 – 103 km^2

Figure 3 shows the different uses of RS in the hydrological modelling. Mostly the RS products have been used by researchers as an initial input to setting up hydrological models, also known as settings data. Some commonly used data products are related to meteorological data, digital elevation models (DEMs), Land use land change maps (LULC) and geological soil distribution information. Some researchers have used globally available data products for calibration of models in addition to in-situ stream flows while other researches are focused on use of these datasets for validation or evaluation of model performance such as actual evapotranspiration and soil moisture data products. Few studies also concentrated on the use of these products for updating the state of models for better simulation by techniques of data assimilations.

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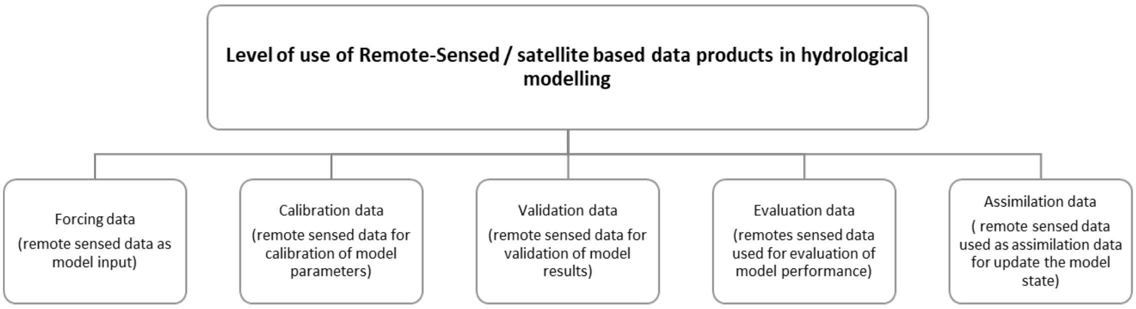

Figure 3. Use of Remote Sensing / satellite-based data products in hydrological modelling

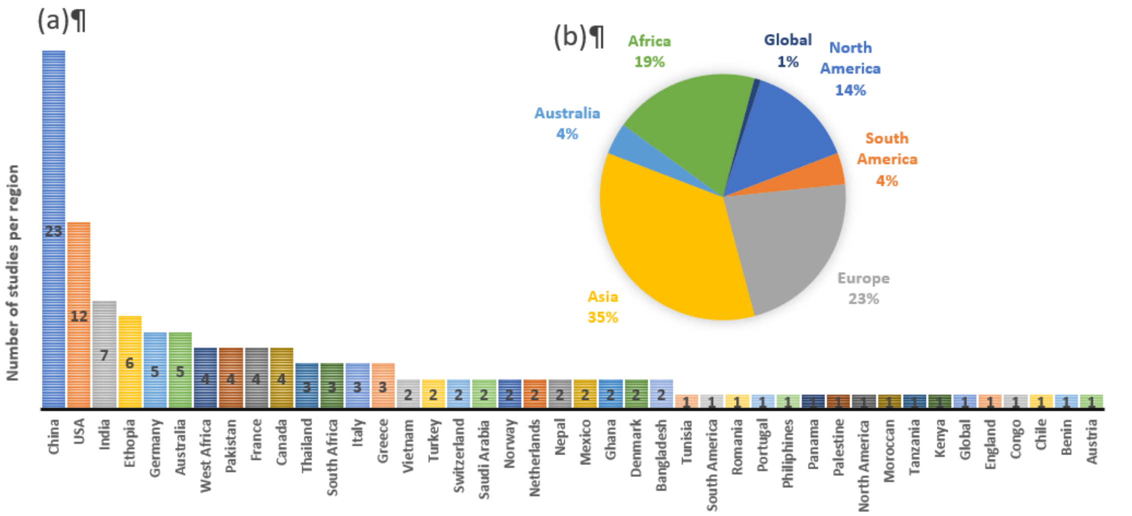

Figure 4.(a) Number of case study areas per country or region and (b) percentage contribution per continent.

As shown in Figure 4 out of total full text reviewed articles, most studies have been conducted in China (23), followed by USA (12) while continent wise most studies have been conducted in Asia followed by Europe. If we look into catchment scale wise contribution per continent then in Europe 13 out of 32 studies are at meso-scale, while macro scale catchments studies are from Asia followed by Africa (36 and 18 respectively).

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Precipitation is one of the main inputs in hydrological models. Mostly the in-situ data is used in the reviewed papers. Some articles have mentioned the use of satellite data products in addition to local gauge data, while in few others the gauge data have been used for evaluation of satellite-based products or for correction of satellite-based products before using in the models. Annex 2.2 Table 2.2.1, presents the different rainfall data products used by different researchers. TRMM (Tropical Rainfall Measuring Mission TMAP 3B42) is the most used rainfall product by the researchers followed by MSWEP (Multi-Source Weighted-Ensemble Precipitation), CMORPH (Climate Prediction Center (CPC) MORPHing technique), CHIRPS (Climate Hazards Group InfraRed Precipitation with Stations), GSMaP (Global Satellite Mapping of Precipitation, IMERG (Integrated Multi-satellite Retrievals for GPM).

Dembele et al., (2020) used 17 different rainfall products in combination with 6 temperature products to test the hydrological process in Volta river basin, Africa. Qi et al., (2016) compared six rainfall products statistically with gauge station data and also with respect to hydrological simulation in the area of Biliu basin, China by the (i) fully distributed and (ii) semi-distributed hydrological models. Lakew et al., (2020) and Pakoksung & Takagi, (2016) evaluated the performance of five rainfall data products for catchments in Ethiopia and Thailand respectively. Khairul et al, 2018 evaluated four rainfall products (TRMM TMPA, CHIRPS, MSWEP & GSMaP) statistically with gauge data and found that all products are weak in apprehending the magnitude and spatial distribution but good in capturing events. Similarly, Singh and Saravanan, (2020) evaluated four rainfall products for catchment in India and found that GPCP, TRMM and APHRODITE are more suitable products for simulation of hydrological processes in India. Mao et al., 2019 evaluated three rainfall products (GLDAS, TRMM, MERRA-2 and CMFD: China Meteorological Forcing Dataset) and assessed that, for runoff simulation MERRA-2 has performed better. To conclude, it is difficult to clearly identify a single better

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performing product from all perspectives. It varies from catchment size to size, region to region and depends a lot on evaluation criteria either is it a direct comparison with in-situ data, or is it a capacity of a product to simulate the runoff.

Topography defined by DEMs, is an important factor for the generation of overland flow in hydrological models. Among the global DEMs, SRTM (Spatial Information Shuttle Radar Topographic Mission) is the mostly used product (in 28 articles) followed by ASTER GDEM (Advanced Space Borne Thermal Emission and Reflection Radiometer-Global Digital Elevation Model), HydroSHEDS (Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales), GTOPO 30: Global Multi-resolution Terrain Elevation Data 2010, GMTED 2010: Global Multi-resolution Terrain Elevation Data 2010; MERIT: Multi-Error-Removed Improved-Terrain DEM (1 article) and TanDEM-X: TerraSAR-X add-on for Digital Elevation Measurement . Annex 2.2.2, presents the DEM products used in the studies of the literature review.

Few researchers used multiple data product for the required utility like Ayala et al., (2020) who used local 55-meter contour lines, STRM and TanDEM-X for DEM extraction for year 1955, 2000 and 2013 respectively for glacier change and run-off study in the region of Maipo river basin, Chile. Siqueira et al., (2018) used SRTM for DEM and Hydroshed for flow accumulation data. Bech et al., (2020) used MERIT DEM for global scale hydrological modelling on distributed HBV model while Chalkidis et al., (2016) derived the DEM for Strymonas River catchment from SPOT-5 satellite images (10 m x 10 m). One study, Pakoksung & Takagi, 2021, compared the runoff and inundation area simulation performance of five satellite products (SRTM, ASTER GDEM, GMTED 2010, GTOPO 30 & Hydroshed) for a 2011 flood event in Nan river basin, Thailand through distributed hydrological modelling. For simulation of run-off GMTED 2010 performed comparatively better while SRTM gave highest accuracy for inundation. Although the

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GMTED 2010 has a coarser resolution it performed better in run-off simulation as compared to other finer resolution data products while SRTM performed better for inundation area. However, no one commented or analysed the performance of these data products for detailed distributed hydrological modelling.

Similarly, for the land use / land cover (LULC) maps, local or data products from national agencies are used. The most frequently used regional or global data product is CORINE land cover map (Cenci et al., 2016; Hebe et al., 2017; Hollering et al., 2017). For the US region studies in the region of USA the mostly used dataset is NLCD (National Land Cover Data developed by USGS; Gleason et al 2016., Rajib et al., 2018). Landsat 8 and SPOT-5 satellite images based derived LULC maps have been used by Gampe et al., (2016), respectively. None of the studies reports concern the performance evaluation of these products on the hydrological modelling simulation.

For the soil distribution maps, mostly the local or national information or maps have been used. The global data products mentioned to be used were: Digital Soil Map of the World FAO (Macalalad et al., 2021), Harmonized World Soil Database FAO (Appel et al., 2019) and SoilGrids by ISRIC (World Soil Information as a result of international collaboration; Chen et al., 2016).

Soil moisture satellite products are used for model calibration and data assimilation. Rajib et al, (2018) used the gridded soil moisture product, Aqua daily level-3 version 2 having a resolution of 25 km for calibration of a SWAT model for two catchments in the USA (one meso scaled and another macro scaled). Khan et al., (2018) used surface soil moisture data product from European Space Agency Climate Change Initiative (ESA CCI) for a SWAT model evaluation. Cenci et al., (2016) used three soil moisture products by "EUMETSAT Satellite Application Facility in Support of Operational Hydrology and Water

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Management" (H-SAF): SM-OBS-1 (25 km resolution data product), SM-OBS-2 (1 km resolution data product) and SM-DAS-2 (25 km root zone soil moisture data product). In the same time Laiolo et al., (2016) used four soil moisture data products: SM-OBS-1, SM-OBS-2, SM-DAS-2 products from H-SAF and SMC Level 2 (L2) product by European Space Agency SMOS mission for testing the effect of soil moisture data assimilation into physically based distributed hydrological model. The previous mentioned authors use the soil moisture products for calibration and for data assimilation, while quality of product by comparing them with in-situ data before using for other purposes has not been analysed by any of the author from the reviewed articles. Only actual evapotranspiration data product from MODIS (MOD16) has been evaluated against the value calculated by models by Abiodun et al., (2018) and Bugan et al., (2020).

The modelling tools used in the studies presented in the literature review show that the most commonly used physically based fully distributed models are Continuum (Cenci et al., 2016; Laiolo et al., 2016), Liuxihe (Chen et al., 2021; Macalalad et al., 2019) and MH (de Souza et al., 2018). At the same time SWAT is the mostly used semi-distributed model (Andualem et al., 2020; Rajib et al., 2018; Jaiswal et al., 2020; Abiodun et al., 2018).

The use of remote sensed data in different studies showed their potential, however this is still limited. Moreover, performance evaluation is quite limited, especially for physically based distributed hydrological modelling at meso-scale level. There is a need for further exploration and in-depth performance analysis.

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3.2. Surveys

One of the actions to determine the EO needs assessment was to collect Copernicus RS data users' feedback about different aspects of modelling by distributing two surveys; one for water quantity modelling and another one for water quality modelling. Members of the Water Force Community and other identified experts were directly contacted and asked for feedback. In total, more than 250 specialists were contacted from the project community. A number of 46 respondents filled in the on-line surveys.

The two surveys consisted of a set of sixteen (16) questions, and they started on 25th April 2022 and finalised on 9th of June. A total of twenty-five (25) filled-in forms were received for water quality and twenty-one (21) filled-in forms for water quantity.
The outcomes of these surveys are analysed in this section of the deliverable.

The types of organizations for which the respondents work are presented for both water quality and water quantity surveys in Figure 5. In case of water quality, the majority of respondents are researchers or academics and use modelling for their case studies. In the case of water quantity 19% of them work in water management organisations, hence just take decision based on advice of modellers, rather than using models. An important number of respondents are from non-profit organisations and private companies (approx. 15%).

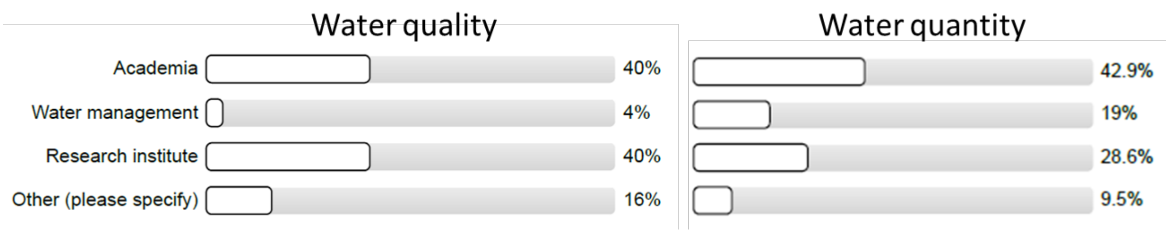

Figure 5. Respondents' organisation type

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Institutions represented in answering the questionnaires are:

- Confederación Hidrográfica del Ebro
- CNR-IREA
- EAWAG
- Federal Waterways Engineering and Research Institute
- German Research Centre for Geosciences (GFZ Potsdam)
- Griffith University
- IGRAC
- IHE Delft Institute for Water Education
- National Institute for Marine Geology and Geoecology GeoEcoMar Romania
- Plymouth Marine Laboratory
- Russian State Hydrological institute
- SMHI
- Sorbonne University
- TU Vienna
- University of Bari
- University of Coimbra (Portugal)
- Terrasigna
- UFZ Magdeburg
- Vrije University Brussels
- Water Resources Management Authority
- Wageningen University

In order to assess the answers to survey from modelling needs point of view respondents were asked to select their position in the organisation. Majority of them consider themselves researchers while only 16% of the water quality respondents consider themselves modellers, and 23% of water quantity (Figure 6).

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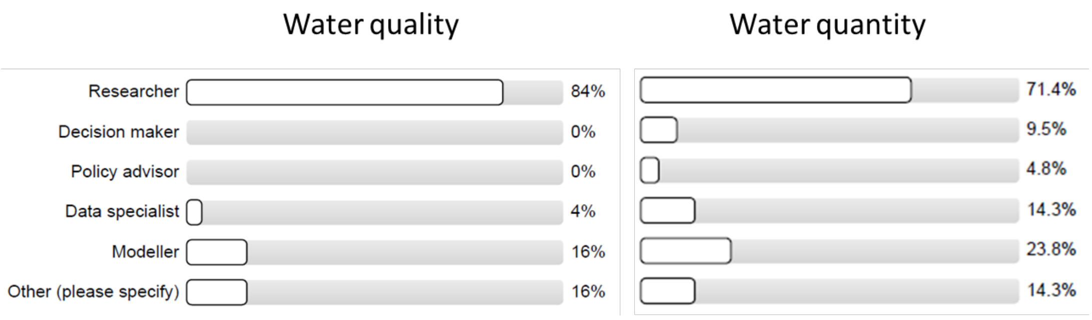

Figure 6. Respondents' position in their institutions

The survey looked first at their current use of Copernicus data followed by their intent to the future use of services.

The main Copernicus services used are coming from the Land services, followed by Climate Change, as shown in Figure 7.

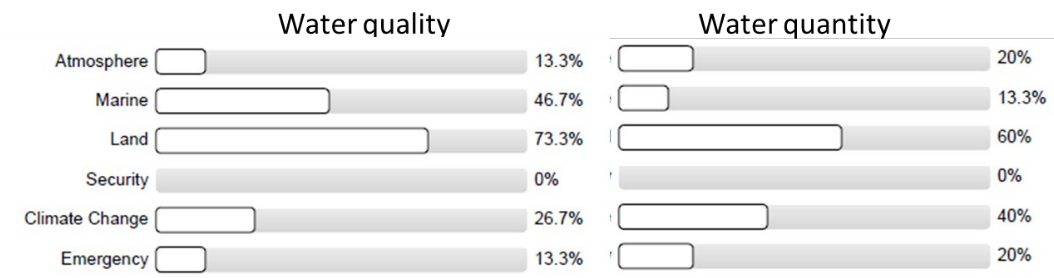

Figure 7. Use of Copernicus services

The experience of researchers is mainly up to 10 years, very few have more than 10 years of experience in using Copernicus services.

A 40% proportion of respondents consider that Copernicus data are easy to use in a model and easy to find, however there are some problems in accessing it, such as:

- no uniform data access
- no harmonisation of data formats for different services
- data have no DOI to be referenced
- no clear location of virtual stations for river altimetry for example
- some data are not free, for example DIAD collected data

The current use of data and the preferred needs for the future are highlighted below, as resulted from each of the surveys.

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Water quality

Majority of respondents for the water quality survey, 84% of them, are using Remote Sensing data in general; and 64% of them use Copernicus data services. The ones who do not use the services commented that they do not have enough knowledge on how to access these data, because they do not have the time to learn how to access it, or because they were not aware if such data would be relevant for their models. One researcher mentioned that while trying to access the CLMS data set, there were so many products available that overwhelmed him/her, and could not find exactly what s/he was looking for (see annex with all responses, for reference).

Current spatial resolution in use by the respondents, for each identified water quality parameter is presented in Table 2.

As seen from Table 2 spatial resolution most used is the one of 200 m x 200 m. The respondents state that it is used in modelling to do calibration and validation mainly.

In terms of temporal resolution, the water quality parameters are mainly used as daily (see annex with all responses, for reference).

Table 2. Used spatial resolution for water quality parameters

Parameter	Spatial resolution (answers in %)				
	200m x 200m	500 mx 500m	2km x 2km	10 kmx 10 km	Other
Chlorophyll-a (Chla)	38.5	7.7	7.7	23.1	23.1
Phytoplankton absorption coefficient (a_{phy})	50	16.7	16.7	16.7	0
Total absorption coefficient (a_{tot})	75	0	0	0	25
Coloured dissolved matter (CDM)	50	0	0	25	25
Suspended Particulate matter (SPM)	44.4	22.2	11.1	22.2	0
Diffuse attenuation coefficient (K_d)	60	20	20	0	0
Sea Surface temperature (SST)	37.5	12.5	0	25	25
Particulate Backscattering Coefficient (B_{bp})	50	0	0	25	25

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Secchi Disk depth (ZSD)	50	50	0	0	0
Remote Sensing Reflectances (R_{rs})	37.5	25	12.5	12.5	12.5
Lake surface water temperature (LSWT)	50	25	0	12.5	12.5
Trophic state index (TSI)	50	25	0	0	25
Water leaving reflectance (WLR)	42.9	42.9	0	14.3	0
Mass concentration of chlorophyll-a (MCC)	37.5	37.5	0	25	0
Remote Sensing Reflectance (RSR)	50	25	12.5	12.5	0

A majority larger than 45% of respondents consider that Copernicus data portals are easily accessible, and easy to find. They use it in models, however they do have problems while using these services, such as:

- Though services are great, such as C35 API, there is no uniform data access;
- Data formatting is not harmonised for all products, hence sometimes difficult to use.
- Not all datasets are having DOI, and as such cannot be easily referenced.

All Copernicus services are mainly used for calibration and validation (53.3% of respondents) while the main limitations users have in using them for modelling are data quality as compared with quality of in-situ measurements (60% of respondents).

The survey identified what would be the preferred improvements for the Copernicus services, with most respondents finding it as the most important thing to improve the Remote Sensing data quality and reduce the uncertainty (60% of respondents).
In terms of spatial needs per each parameter, including new proposed parameters, the choice of the respondents is given in Table 3.

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Table 3. Recommended spatial resolution for water quality modelling parameters

	Preferred spatial resolution (answers in %)				
Parameter	50m x 50m	100m x 100m	200m x 200m	1 km x 1Km	Others
chla	38.9	33.3	5.6	5.6	16.7
a_{phy}	35.7	28.6	7.1	0	28.6
a_{tot}	35.7	28.6	7.1	7.1	21.4
CDM	35.7	35.7	7.1	7.1	14.3
SPM	41.2	41.2	0	11.8	5.9
K_d	30.8	38.5	0	7.7	23.1
SST	31.3	31.3	12.5	12.5	12.5
B_{bp}	30.8	46.2	0	0	23.1
ZSD	30.8	46.2	0	15.4	7.7
R_{rs}	33.3	33.3	0	13.3	20
LSWT	44.4	22.2	11.1	11.1	11.1
TS	42.9	21.4	0	14.3	21.4
Turbidity	63.2	15.8	0	10.5	10.5
WLR	40	33.3	0	6.7	20
MCC	37.5	37.5	0	12.5	12.5
RSR	47.1	29.4	0	5.9	17.6
WPP	42.1	21.1	5.3	21.1	10.5
TN	44.4	16.7	5.6	16.7	16.7
TP	44.4	16.7	5.6	16.7	16.7
DOC	38.9	22.2	5.6	16.7	16.7
PP CO2	35.7	7.1	21.4	14.3	21.4

In terms of time resolution, the majority of parameters are recommended to be daily, by over 85% of respondents. (see answers in annex)

A series of free text observations were inserted by respondents, a selection of them is listed below. The suggestions are included in the concluding section of this report as well.

Suggestions are:

- Simpler search interface when lots of variables are on offer by any Copernicus Service.
- Guidance for novice users on how to choose the best parameter for their needs (e.g. tutorials, or onboarding).

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- DOIs and clear citation guidelines for every dataset.
- I think it would be nice for me to learn how to bridge the gap between modellers and Remote Sensing and vice versa.
- I wonder if the products suggested are also suitable to be used in groundwater assessments, or if this is only focused on surface water. More products dedicated to groundwater are needed.
- Validated EO data.
- Please also provide uncertainty bands around the values, and technical reports on how the processing was done that we can refer to.

Water quantity

Majority of respondents for water quantity, 85.7%, are using Remote Sensing data in general; and if they are not using it, in general is because their colleagues are using it and provide them with end processed data. A majority (71.4 % of them) use Copernicus data services. The ones who do not use the services are not doing so because others are providing them with data coming from Copernicus services. This is a different approach than in the case of water quality where some of the researchers were not aware of the data availability for their modelling needs.

Current spatial resolution in use by the respondents, for each identified water quantity parameter is presented in Table 4.

Table 4. Spatial resolution used for water quantity parameters

	Spatial resolution (answers in %)				
PARAMETER	200 m x 200 m	500 m x 500 m	2 km x 2 km	10 km x 10 km	Other
Precipitation	0	8.3	8.3	58.3	25
Soil moisture	0	10	0	70	20
Evapotranspiration	25	12.5	0	37.5	25
Surface runoff	0	0	0	50	50
River discharge	0	25	0	0	75

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Flood extend	14.3	0	14.3	14.3	57.1
Inland water temperature (IWT)	0	0	0	33.3	66.7
LU /LC	36.4	9.1	0	18.2	36.4
Land surface temperature (LST)	0	16.7	0	50	33.3
Air temperature (AT)	0	0	0	66.7	33.3
Bathymetry	0	0	33.3	33.3	33.3
DEM	0	14.3	0	0	85.7
Water levels in lakes and rivers (WL)	25	12.5	0	12.5	50

Concerning the spatial resolution, the most used Copernicus products resolution is the one of 10 km x 10 km which is quite coarse. The respondents state that the parameters are mostly used as modelling inputs (66.7%), followed by calibration and validation. Similar to water quality, the main limitations found in using the data are the data quality followed by the insufficient spatial resolution.

Temporal resolution usage is presented in Table 5, where it is seen that except LU/LC, the most often used temporal resolution is the daily one.

Table 5. Temporal resolution for water quantity modelling parameters

	Temporal resolution (answers in %)				
Parameter	Annual	Monthly	Daily	Hourly	Others
Precipitation	0	9.1	54.5	18.2	18.2
Soil moisture	0	0	88.9	0	11.1
Evapotranspiration	0	12.5	75	0	12.5
Surface runoff	0	0	25	25	50
River discharge	0	0	50	25	25
Flood extend	0	14.3	28.6	14.3	42.9
IWT	0	0	33.3	0	66.7
LU /LC	72.7	0	18.2	0	9.1
LST	0	0	83.3	0	16.7
AT	0	16.7	50	16.7	16.7
Bathymetry	33.3	0	33.3		33.3
DEM	14.3	0	14.3	0	71.4
WL	0	12.5	25	25	37.5

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The survey found out that on what would be the preferred improvements for the Copernicus services all respondents considered the most important improvement to be the Remote Sensing spatial coverage, data reliability, update frequency and reducing uncertainty. In terms of spatial needs per each parameter, the choice of the respondents is given in Table 6.

Table 6. Recommended spatial resolution for water quantity modelling

	Preferred spatial resolution (answers in %)				
Parameter	50 m x 50 m	100 m x 100 m	200 m x 200 m	1 km x 1 Km	Others
Precipitation	12.5	37.5	6.3	37.5	6.3
Soil moisture	31.3	25	12.5	31.3	0
Evapotranspiration	33.3	20	20	26.7	0
Surface runoff	26.7	26.7	13.3	33.3	0
River discharge	28.6	21.4	7.1	28.6	14.3
Flood extend	23.1	38.5	15.4	7.7	15.4
IWT	44.4	22.2	0	8.3	16.7
LU /LC	33.3	41.7	0	0	23.1
LST	35.7	35.7	7.1	21.4	0
AT	22.2	44.4	0	33.3	0
Bathymetry	50	25	0	12.5	12.5
DEM	62.5	12.5	0	12.5	12.5
WL	56.3	12.5	0	12.5	18.8

For the most respondents, the preferred temporal resolution is for the majority of parameters, the one already in use, i.e daily. However, hourly resolution is preferred for some of the parameters, such as river discharge (see Table 7).

Table 7. Recommended temporal resolution for water quantity parameters

	Temporal resolution (in %)		
PARAMETER	Daily	Hourly	Others
Precipitation	56.3	43.8	0
Soil moisture	82.4	11.8	5.9
Evapotranspiration	73.3	26.7	0
Surface runoff	56.3	43.8	0
River discharge	46.7	53.3	0
Flood extend	42.9	50	7.1

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IWT	45.5	45.5	9.1
LU /LC	50	16.7	33.3
LST	60	40	0
AT	50	50	13.3
Bathymetry	55.6	22.2	22.2
DEM	75	12.5	12.5
WL	64.7	35.3	0

In case of water quantity modelling parameters, there were only few suggestions mentioned in the surveys:

- Copernicus data service for the ECV (Essential Climate Variable) groundwater storage are needed.
- Copernicus data service for the ECV (Essential Climate Variable) terrestrial water storage (TWS) are needed as well.
- DOI and clear dataset citation.
- I think that more products related to groundwater are needed (e.g. groundwater storage change, or even total water storage change).

All the suggestions and outcomes of the survey and are captured in recommendations in section 4 of this deliverable.

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3.3. Interviews

Seventeen interviews involving researchers, consultants, and PhD students working with RS data were carried out at EGU General Assembly 2022 in Vienna. The majority of those who answered the interview, mainly use Copernicus data for water quantity modelling (58.8%), and secondly for water quality modelling (23.5%) (Figure 8).

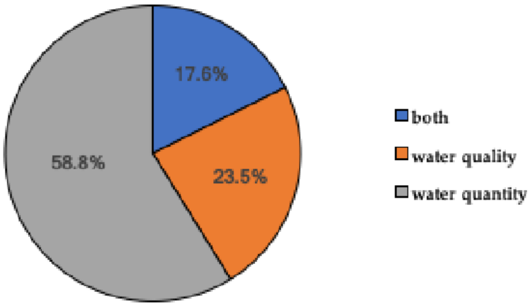

Figure 8. Type of modelling addressed by the interviewed specialists

Out of the 17 persons interviewed 50% use Copernicus data for their modelling needs. However, the main limitations of RS Copernicus data services detected during the interviews consist of:

- an insufficient spatial and temporal resolution (e.g. no sub-hourly dataset is available);
- the discrepancies identified with the real time data;
- the data latency. Concerning this, some of the people interviewed would appreciate the possibility to import real time data (not available right now) directly to models for Early warning systems;
- the temporal and spatial coverage of the datasets. In particular, the interviewees mostly found that an important limitation of Copernicus Data involves the availability of datasets exclusively for European areas.

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4. Conclusions and Recommendations

The main recommendation for the Roadmap is to highlight the need of EO and RS for modelling water quantity and water quality in support of decision making, while a special emphasis should be made on the Copernicus data. Some of recommendations are summarised in Table 8 below.

Table 8. List of recommendations for the Water ForCe Roadmap

ID	Needs	Recommendation
1	Higher spatial coverage of datasets	Increase spatial coverage, as per recommended values in Section 3
2	Spatial coverage all over the world	Provide the availability of datasets outside the European areas
3	Higher update frequency of datasets	Update frequency of data collection to match the ones measured on the ground
4	Importing data into models	Provide API which will give the possibility to import real time data directly to models,
5	Make easier processing, interpreting the data by the non-specialists	Create simpler search interface; provide guidance on novice users; organize training webinars
6	Harmonization of products from different services in terms of data format	Make standardised dataset formats
7	Improve data quality (as compared to in situ data)	Make the two datasets (RS and in-situ) comparable (possible validation), reduce uncertainty
8	Make easier the accessibility to data	Make the accessibility to data quicker and less time-consuming
9	More products dedicated to groundwater (groundwater storage change or total water storage change)	Possibly enlarge the range of products to groundwater

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10	Provide uncertainty bands around the values and technical reports on how the processing was done	Give precise information to users about datasets and their uncertainty
11	DOI	Add DOI to data, for easy referencing
12	Uncertainty bound of data	Provide data quality assessment more easily findable, and provide uncertainty bounds of data

A series of hydrological models, distributed or lumped, which are widely used by modellers, such as Mike Zero, Delft3D, are not mentioned in the revised paper, because they do not rely on RS data. Moreover, the Surface Water Ocean topography (SWOT) mission (Biancamaria et al, 2016), which is due to be launched in November 2022 (swot.jpl.nasa.gov/mission/overview/) is not presented as a need by respondents, however it is well represented in the literature review by different authors. This shows that it is not well known yet by all users.

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References

Remark: The list of references contains a list of references that are not part of the literature review, however part of the deliverable work, hence referenced in text; and a numbered list of papers that are part of the reviewed literature. Reviewed literature is numbered, for the use of it in tables of the literature review.

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Annexes

Annex 1

1.1. Water quality

Survey for end-users, stakeholders and decision makers about the use of Copernicus Remote Sensing data for modelling inland water

Water-ForCE is a EU Horizon 2020 Coordination and Support Action (2021-2023) dedicated to developing a roadmap for the water component for the future Copernicus services. Our goal is to address the current disconnects between Remote Sensing and in situ observation research, deliver clarity in terms of the needs and expectations of the public and private sectors of the core Copernicus Program and the wider research and business innovation opportunities. Work Package 5 of the project aims to explore what are the needs for modelling water systems and aquatic environments when using satellite EO data and improving the interaction with the water modelling community even if they are not using Copernicus EO. We are kindly asking for your input with the present survey about the use of Copernicus Remote Sensing data for modelling inland water – water quantity. The survey has 3 parts (intro, current use, future needs). It will take max 15 minutes of your time, and will help us identifying the needs of Copernicus Services for modelling. Thank you for taking the time to answer the survey questions.

Intro Data

- **In which organisation are you working?**
    - academia
    - water management
    - research institute
    - consultancy
    - others (Please specify) ....
- **What is the name of your organisation?** (optional) ....

- **What is your position in the organisation you are working in?** (Please select up to three options)

    - researcher
    - decision maker
    - policy advisor
    - data specialist
    - modeller
    - others (Please specify) ....

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Current Use of Copernicus Remote Sensing Data

INFO: Copernicus data = (Remote Sensing + Derived data from RS) services

- **Do you use any type of Remote Sensing Data? Yes/No**

(If the answer is Not)

  - **Could you please elaborate briefly why not?**

(If the answer is Yes, the following set of questions will appear)

• What Copernicus service(s) are you using in your work? (Please mention the 2 ones mostly used)

  - Atmosphere
  - Marine
  - Land
  - Security
  - Climate Change
  - Emergency

• How many years of experience do you have in using Copernicus EO for modelling?

  - < 2 years
  - 2 – 5 years
  - 5 – 10 years
  - > 10 years

For the following statements please select what is applicable for you.

• Copernicus data portals are easy to find

(1)	(2)	(3)	(4)	(5)	
Totally disagree				Totally agree	I do not know

• Copernicus data are accessible

(1)	(2)	(3)	(4)	(5)	
Totally disagree				Totally agree	I do not know

• Copernicus data are easy to use for modelling

(1)	(2)	(3)	(4)	(5)	
Totally disagree				Totally agree	I do not know

Remarks: Please provide any feedback you might have:

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- **What parameters are you using in your work? Please mention only the 3 most often used.**

	SPATIAL RESOLUTION	TEMPORAL RESOLUTION
Copernicus Marine (CMEMS)		
Chlorophyll-*a* (Chla)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annual • Monthly • Daily • Hourly • Others ....
Phytoplankton Absorption Coefficient (aphy)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annual • Monthly • Daily • Hourly • Others ....
Total Absorption Coefficient (atot)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annual • Monthly • Daily • Hourly • Others ....
Coloured Dissolved Matter (CDM)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annual • Monthly • Daily • Hourly • Others ....
Suspended Particulate Matter (SPM)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annual • Monthly • Daily • Hourly • Others ....

Water-ForCE is a CSA that has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101004186.

Diffuse Attenuation Coefficient (K_d)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Sea Surface Temperature (SST)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Particulate Backscattering Coefficient (B_{bp})	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Secchi Disk Depth (ZSD)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Remote Sensing Reflectances (R_{rs})	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....

Water-ForCE is a CSA that has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101004186.

Copernicus Global Land Service (CGLS) & Climate Change Service (C3S)		
Lake Surface Water Temperature (LSWT)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Trophic State Index	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Turbidity	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Water leaving reflectance	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Mass concentration of chlorophyll-a	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Remote Sensing reflectance	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km	• Annually • Monthly • Daily • Hourly

Water-ForCE is a CSA that has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101004186.

	• Others	• Others ....
others (please specify)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
others (please specify)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
others (please specify)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
	•	•

- **How are the previous parameters used? (Please select as many as used)**

  - modelling inputs (hydrological, hydraulic models etc)
  - to compare to modelling outputs for calibration and/or validation
  - input to empirical predictions (monitoring/predicting extreme events – floods and droughts, etc) for decision making
  - others (please specify) ....

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Current needs for Copernicus data services for modelling:

• Which are the main limitations and gaps you can highlight? (Please select up to 4 most important ones)

- difficulties in processing/interpreting the data by the non-specialists (validation, data format, etc)
- data quality (as compared with in-situ data)
- reliability of the data (regular, consistent availability)
- insufficient temporal resolution
- insufficient spatial resolution
- insufficient temporal coverage
- insufficient spatial coverage
- data latency (delayed availability)
- others (please specify) ....

- **Please state your interest for the following options of improved Copernicus Data Services.**

	Not important	Not very important	Important	Very important	Extremely important	Not applicable
1. Higher spatial coverage						
2. Processing, interpreting the data by the non-specialists						
3. Remote Sensing data reliability						
4. Remote Sensing data quality						
5. Higher update frequency						
6. Higher spatial resolution						
7. Higher temporal resolution						

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- **What would be your preferred spatial and/or temporal resolution and update frequency for Copernicus Data Services?**

	SPATIAL RESOLUTION	TEMPORAL RESOLUTION	UPDATE FREQUENCY
Copernicus Marine (CMEMS)			
Chlorophyll-*a* (Chla)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Phytoplankton Absorption Coefficient (aphy)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Total Absorption Coefficient (atot)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Coloured Dissolved Matter (CDM)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Suspended Particulate Matter (SPM)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………

Water-ForCE is a CSA that has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101004186.

Diffuse Attenuation Coefficient (Kd)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Sea Surface Temperature (SST)	• 50 × 50 m	• Daily	• Monthly
	• 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Hourly • Others ………………………	• Daily • Others ………………………
Particulate Backscattering Coefficient (Bbp)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Secchi Disk Depth (ZSD)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Remote Sensing Reflectances (Rrs)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Copernicus Global Land Service (CGLS) & Climate Change Service (C3S)			
Lake Surface WaterTemperature (LSWT)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………

Water-ForCE is a CSA that has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101004186.

Trophic State Index	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others	• Daily • Hourly • Others	• Monthly • Daily • Others ....
Turbidity	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others	• Daily • Hourly • Others	• Monthly • Daily • Others ....
Water leaving reflectance	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km	• Daily • Hourly • Others	• Monthly • Daily • Others ....
	• Others		
Mass concentration of chlorophyll-a	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others	• Daily • Hourly • Others	• Monthly • Daily • Others ....
Remote Sensing reflectance	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others	• Daily • Hourly • Others	• Monthly • Daily • Others ....
others (please specify)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others	• Daily • Hourly • Others	• Monthly • Daily • Others ....
others (please specify)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others	• Daily • Hourly • Others	• Monthly • Daily • Others ....

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others (please specify) ………………………………………………	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………

- **New water quality products, as listed below, are developed by Copernicus. What would be your ideal spatial, temporal resolution and update frequency for them?**

	SPATIAL RESOLUTION	TEMPORAL RESOLUTION	UPDATE FREQUENCY
Water primary production	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Total Nitrogen	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Total Phosphorus	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Dissolved organic carbon .	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Partial pressure of CO2 or CO2 concentration	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………

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1.2. Water quantity

Survey for end-users, stakeholders and decision makers about the use of Copernicus Remote Sensing data for modelling inland water

Water-ForCE is a EU Horizon 2020 Coordination and Support Action (2021-2023) dedicated to developing a roadmap for the water component for the future Copernicus services. Our goal is to address the current disconnects between Remote Sensing and in situ observation research, deliver clarity in terms of the needs and expectations of the public and private sectors of the core Copernicus Program and the wider research and business innovation opportunities. Work Package 5 of the project aims to explore what are the needs for modelling water systems and aquatic environments when using satellite EO data and improving the interaction with the water modelling community even if they are not using Copernicus EO. We are kindly asking for your input with the present survey about the use of Copernicus Remote Sensing data for modelling inland water – water quantity. The survey has 3 parts (intro, current use, future needs). It will take max 15 minutes of your time, and will help us identifying the needs of Copernicus Services for modelling. Thank you for taking the time to answer the survey questions.

Intro Data

- **In which organisation are you working?**
    - academia
    - water management
    - research institute
    - consultancy
    - others (Please specify) ....
- **What is the name of your organisation?** (optional) ....

- **What is your position in the organisation you are working in?** (Please select up to three options)

    - researcher
    - decision maker
    - policy advisor
    - data specialist
    - modeller
    - others (Please specify) ....

Current Use of Copernicus Remote Sensing Data

INFO: Copernicus data = (Remote Sensing + Derived data from RS) services

Water-ForCE is a CSA that has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101004186.

- **Do you use any type of Remote Sensing Data? Yes/No**

(If the answer is Not)

  - **Could you please elaborate briefly why not?**

(If the answer is Yes, the following set of questions will appear)

• What Copernicus service(s) are you using in your work? (Please mention the 2 ones mostly used)

  - Atmosphere
  - Marine
  - Land
  - Security
  - Climate Change
  - Emergency

• How many years of experience do you have in using Copernicus EO for modelling?

  - < 2 years
  - 2 – 5 years
  - 5 – 10 years
  - > 10 years

For the following statements please select what is applicable for you.

• Copernicus data portals are easy to find

(1)	(2)	(3)	(4)	(5)	
Totally disagree				Totally agree	I do not know

• Copernicus data are accessible

(1)	(2)	(3)	(4)	(5)	
Totally disagree				Totally agree	I do not know

• Copernicus data are easy to use for modelling

(1)	(2)	(3)	(4)	(5)	
Totally disagree				Totally agree	I do not know

Remarks: Please provide any feedback you might have

Water-ForCE is a CSA that has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101004186.

- **What parameters are you using in your work? Please mention only the 3 most often used.**

	SPATIAL RESOLUTION	TEMPORAL RESOLUTION
Copernicus Marine (CMEMS)		
Precipitation	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others ……………………..	• Annual • Monthly • Daily • Hourly • Others ……………………………..
Soil moisture	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others ………………………..	• Annual • Monthly • Daily • Hourly • Others ……………………………..
Evapotranspiration	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others …………………………..	• Annual • Monthly • Daily • Hourly • Others ……………………………..
Surface runoff	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others …………………………..	• Annual • Monthly • Daily • Hourly • Others ……………………………..

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River discharge	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annual • Monthly • Daily • Hourly • Others ....
Flood extent	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Inland water temperature	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Land use/Land cover	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Land surface temperature	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....
Air temperature	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others	• Annually • Monthly • Daily • Hourly • Others ....

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Bathymetry	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others ………………………… …	• Annually • Monthly • Daily • Hourly • Others ………………………………
DEM	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others ………………………… …	• Annually • Monthly • Daily • Hourly • Others ………………………………
Water levels (lakes and rivers)	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others …………………………	• Annually • Monthly • Daily • Hourly • Others ………………………………
Other (please specify) …………………………………………………	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others …………………………	• Annually • Monthly • Daily • Hourly • Others ………………………………
Other (please specify) …………………………………………………	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others …………………………	• Annually • Monthly • Daily • Hourly • Others ………………………………
Other (please specify) …………………………………………………	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km	• Annually • Monthly • Daily • Hourly
	• Others …………………………	• Others ………………………………

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others (please specify) ………………………………………………………	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others ………………………	• Annually • Monthly • Daily • Hourly • Others ………………………
others (please specify) ………………………………………………………	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others ………………………	• Annually • Monthly • Daily • Hourly • Others ………………………
others (please specify) ………………………………………………………	• 200 × 200 m • 500 × 500 m • 2 × 2 km • 10 × 10 km • Others ………………………	• Annually • Monthly • Daily • Hourly • Others ………………………

• **How are the previous parameters used? (Please select as many as used)**
- ○ modelling inputs (hydrological, hydraulic models etc)
- ○ to compare to modelling outputs for calibration and/or validation
- ○ input to empirical predictions (monitoring/predicting extreme events – floods and droughts, etc) for decision making
- ○ others (please specify) ……………………………………………………

Current needs for Copernicus data services for modelling:

• **Which are the main limitations and gaps you can highlight? (Please select up to 4 most important ones)**
- ○ difficulties in processing/interpreting the data by the non-specialists (validation, data format, etc)
- ○ data quality (as compared with in-situ data)
- ○ reliability of the data (regular, consistent availability)
- ○ insufficient temporal resolution
- ○ insufficient spatial resolution
- ○ insufficient temporal coverage
- ○ insufficient spatial coverage
- ○ data latency (delayed availability)
- ○ others (please specify) ……………………

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- **Please state your interest for the following options of improved Copernicus Data Services.**

	Not important	Not very important	Important	Very important	Extremely important	Not applicable
1. Higher spatial coverage						
2. Processing, interpreting the data by the non-specialists						
3. Remote Sensing data reliability						
4. Remote Sensing data quality						
5. Higher update frequency						
6. Higher spatial resolution						
7. Higher temporal resolution						

- **What would be your preferred spatial and/or temporal resolution and update frequency for Copernicus Data Services?**

	SPATIAL RESOLUTION	**TEMPORAL RESOLUTION**	**UPDATE FREQUENCY**
precipitation	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………..
soil moisture	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………..

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evapotranspiration	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ……………………….	• Daily • Hourly • Others ……………………….	• Monthly • Daily • Others ………………………..
surface runoff	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ……………………….	• Daily • Hourly • Others ……………………….	• Monthly • Daily • Others ………………………..
river discharge	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ……………………….	• Daily • Hourly • Others ……………………….	• Monthly • Daily • Others ………………………..
flood extent	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ……………………….	• Daily • Hourly • Others ……………………….	• Monthly • Daily • Others ………………………..
inland water temperature	• 50 × 50 m	• Daily	• Monthly
	• 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ……………………….	• Hourly • Others ……………………….	• Daily • Others ………………………..
land use/ land cover	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ……………………….	• Daily • Hourly • Others ……………………….	• Monthly • Daily • Others ………………………..
Land surface temperature	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ……………………….	• Daily • Hourly • Others ……………………….	• Monthly • Daily • Others ………………………..

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air temperature	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
bathymetry	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
DEM	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
Water levels (lakes and rivers)	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
………………………………………………	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
	• Others ………………………		
………………………………………………	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………
………………………………………………	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………

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………………………………………………	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ……………………..	• Daily • Hourly • Others ……………………..	• Monthly • Daily • Others ………………………
………………………………………………	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ……………………..	• Daily • Hourly • Others ……………………..	• Monthly • Daily • Others ………………………
	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ……………………..	• Daily • Hourly • Others ……………………..	• Monthly • Daily • Others ………………………

- **New water quality products, as listed below, are developed by Copernicus. What would be your ideal spatial, temporal resolution and update frequency for them?**

	SPATIAL RESOLUTION	TEMPORAL RESOLUTION	UPDATE FREQUENCY
Water primary production	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ……………………..	• Daily • Hourly • Others ……………………..	• Monthly • Daily • Others ………………………
Total Nitrogen	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ……………………..	• Daily • Hourly • Others ……………………..	• Monthly • Daily • Others ………………………

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Total Phosphorus	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………..
Dissolved organic carbon .	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………..
Partial pressure of CO2 or CO2 concentration	• 50 × 50 m • 100 × 100 m • 200 × 200 m • 1 x 1 km • Others ………………………	• Daily • Hourly • Others ………………………	• Monthly • Daily • Others ………………………..

- **Please write any other comment or observation you think is important for this needs assessment**

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Annex 2

2.1. List of reviewed journals

- Advances in Space Research
- Advances in Water Resources
- Applied Geomatics
- Bulletin of the American Meteorological Society
- Cryosphere
- Earth-Science Reviews
- Egyptian Journal of Remote Sensing and Space Science
- Environmental Earth Sciences
- Environmental Remote Sensing and GIS in Iraq, Springer Water, Springer Nature Switzerland AG 2020
- EOMORES white paper
- Forests
- Geoderma
- Geosciences
- Global Journal of Environmental Science and Management
- Hydrological Processes
- Hydrological Sciences Journal
- Hydrology and Earth System Sciences
- Hydrology Research
- Hydrology SAF. Időjárás
- International Journal of Applied Earth Observation and Geoinformation
- International Journal of Disaster Risk Reduction
- International Journal of Information Management
- International Journal of Trend in Scientific Research and Development (IJTSRD)
- IOCCG Report Series
- IOP Conference Series: Earth and Environmental Science
- ISPRS Journal of Photogrammetry and Remote Sensing,
- Journal of Advances in Modeling Earth Systems
- Journal of African Earth Sciences
- Journal of Environmental Management
- Journal of Flood Risk Management
- Journal of Geographic Information System

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- Journal of Geosciences
- Journal of Hydroinformatics
- Journal of Hydrology
- Journal of Hydrology: Regional Studies
- Journal of Hydrometeorology
- Journal of the Indian Society of Remote Sensing
- Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering,
- Natural Hazards
- Proceedings of the 3rd International Conference on Green Environmental Engineering and Technology, Lecture Notes in Civil Engineering 214
- Remote Sensing
- Remote Sensing Applications: Society and Environment
- Remote Sensing of Environment
- Science of the Total Environment
- Sensors
- Surveys in Geophysics
- Water (Switzerland)
- Water Resources Management
- Water Resources Research
- Water SA

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2.2. Remote Sensing data products mentioned in reviewed papers

2.2.1 Rainfall data

Precipitation data product used in reviewed articles

Product	Spatial extent	Spatial resolution	Temporal extent	Temporal resolution	Articles
TRMM Tropical Rainfall Measuring Mission TMAP 3B42	50° N – 50° S, 180° W – 180° E	0.25°	1998-NP	daily	Islam et al., 2018; Khairul et al., 2018; Singh & Saravanan, 2020; Lakew et al., 2020; Dembele et al., 2020; Mao et al., 2019; Zhang et al., 2020; Munizimi et al., 2019; Luo et al., 2017; Liu et al., 2016; Qi et al., 2016; Ha et al., 2018; Sun et al., 2018
MSWEP Multi-Source Weighted-Ensemble Precipitation	Global	0.1°	1979-NP	3-hourly	Dembele et al., 2020a; Khairul et al., 2018; Lakew et al., 2020; Strohmeier et al., 2020; Beck et al., 2020; Lakew, 2020; Lazin et al., 2020; Siqueira et al., 2018
TRMM Tropical Rainfall Measuring Mission Near real time data products 3B42RT or 3B41RT	50° N – 50° S, 180° W – 180° E	0.25°	1998-NRT	daily	Dembele et al., 2020; Leroux et al., 2016; Shi et al., 2020; koppa et al., 2019; Qi et al., 2016; Sun et al., 2018
CMORPH Climate Prediction Center (CPC) MORPHing technique (CMORPH)	60° N – 60° S, 180° W – 180° E	8 km, 0.25°	199 8-NRT	3-hourly, daily	Dembele et al., 2020a; Lakew et al., 2020; Leroux et al., 2016; Shi et al., 2020; Sun et al., 2018
CHIRPS Climate Hazards Group InfraRed Precipitation with Stations	50° N – 50° S, 180° W – 180° E	0.05°	1981 - NRT	daily	Dembele et al., 2020a; Dembele et al., 2020b; Pang et al., 2020; Khairul et al., 2018; Ha et al., 2018

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GSMaP Global Satellite Mapping of Precipitation (GSMaP) Versions 1: Moving Vector with Kalman (MVK) Standard V6 2: Guage adjusted	60° N – 60° S, 180° W – 180° E	0.1°	1: 2001-2013 2:2000 - NRT	daily	Dembele et al., 2020a; Khairul et al., 2018; Sugiura et al., 2016; Qi et al., 2016
IMERG Integrated Multi-satellitE Retrievals for GPM	60° N – 60° S, 180° W – 180° E	0.10°	2015 - NRT	3 hourly	Al-Areeq et al., 2021; Sharif et al., 2017; Zhang et al., 2020; Lazin et al., 2020
APRHODITE Asian Precipitation – Highly- Resolved Observational Data Integration Towards Evaluation	55° N – 15° S, 60° E – 150° E	25 km / 0.25°	1951- NRT	daily	Islam et al., 2018; Singh & Saravanan, 2020; Qi et al., 2016
NCEP CFSR (the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) Swat Database)	Global	0.3125°	1979 - 2014	daily, monthly	Alemayehu et al., 2018; Singh & Saravanan, 2020; Sahoo et al., 2021
MEERA-2 Modern-Era Retrospective Analysis for Research and Applications-2 (rainfall: M2T1NXFLX_V5.12.4; temperature: M2SDNXSLV_V5.12.)	Global	0.625° x 0.5°	1980 - NP	hourly	Dembele et al., 2020a; Mao et al., 2019; Gupta & Tarboton et al., 2016
PERSIANN Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks	60° N – 60° S, 180° W – 180° E	0.25°	2000 - to NRT	3-hourly	Leroux et al., 2016; Qi et al., 2016

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GPCP Global Precipitation Climatology Project	Global	2.5°, 1.0°	1979- NRT, 1996- 2015	Monthly, daily	Islam et al., 2018; Singh & Saravanan, 2020
ERA Interim	Global	0.25°	1979-2019	3-hourly, Daily	Lakew et al., 2020; Hostache et al., 2020;
ERA 5 European Centre for Medium-range Weather Forecasts Reanalysis 5	Global	0.25°	1979-NP	hourly	Dembele et al., 2020a; Dahri et al., 2021;
GLDAS (Global Land Data Assimilation System)	90° N – 60° S, 180° W – 180° E	0.25°	2000 - 2015	3-hourly	Mao et al., 2019; Qi et al., 2016
RFE V2 NOAA's Rainfall Estimation Climate Prediction Center Africa	Africa 40° N – 40° S, 20° W – 55° E	0.1°	2001-NP	daily	Dembele et al., 2020; Gupta & Tarboton, 2016
GPCC (Global Precipitation Climatology Centre)	Global	2.5°, 1.0°,0.5° & 0.25°	1891-2016	daily	Lakew et al., 2020
E-OBS 2.0	25° N – 71.5° N, 25° W – 45° E	0.25°	1950 - 2019	daily	Busari et al., 2021
PERSIANN-CCS Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks- Cloud Classification System	60° N – 60° S, 180° W – 180° E	0.04°	2003 to near time	Hourly	Li et al., 2019

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PERSIANN-CDR Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks-Climate Data Record	60º N – 60º S, 180º W – 180º E	0.25º	1983 - to 2016	6-hourly	Dembele et al., 2020
TAMSAT v3.0 Tropical Application of Meteorology using SATelite (TAMSAT) Africa	Africa 38º N – 36º S, 19º W – 52º E	0.0375º	1983-NP	daily	Dembele et al., 2020
ARC v2 African Rainfall Estimate Climatology	Africa 40º N – 40º S, 20º W – 55º E	0.1º	1983-NP	daily	Dembele et al., 2020
WFDEI-CRU Watch forcing data ERA-Interim – Corrected using Climatic Research Unit CRU data.	Global	0.5º	1979-2018	3-hourly	Dembele et al., 2020
WFDEI-GPCC WATCH Forcing Data ERA-Interim (WFDEI) corrected using Global Precipitation Climatology Centre (GPCC) dataset	Global	0.5º	1979-2016	3-hourly	Dembele et al., 2020
PGF v3 (Princeton University Global meteorological Forcing)	Global	0.25º	1948-2012	3-hourly	Dembele et al., 2020; Aloysius & Saiers, 2017
EWEMBI v1.1 Earth20bserve, WFDEI and ERA-Interim merged and bias-corrected (ISIMIP- EWEMBI)	Global	0.5º	1976-2013	Daily	Dembele et al., 2020
JRA-55 Japanese 55-year Reanalysis	Global	1.25º	1959 - NP	3-houly	Dembele et al., 2020

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2.2.2. DEM data

Digital Elevation Models (DEM) products used in reviewed articles

Product	Resolution	Extent	Year of release	Articles
SRTM: Spatial Information Shuttle Radar Topographic Mission	90 m	60º N – 60º S	2003	Islam et al., 2018; Sahoo et al., 2021; Meng et al., 2018; Pang et al., 2020; Busari et al., 2021; Mao et al., 2019; Soulis et al., 2020; Watson et al., 2020; Abdollahi et al., 2017; Maza el al., 2020; Yang et al., 2020; Arthur et al., 2020; Koo et al., 2020; Becket et al., 2019; Pan et al., 2019; Imhoff et al., 2020; Siqueira et al., 2018; Tao & Barros, 2019; Ayala et al., 2020; Abeysingha et al., 2016; Hiep et al., 2018; Li et al., 2019; Munzimi et al., 2019; Ha et al., 2018; Alemayehu et al., 2018; Zhu et al., 2017.
ASTER GDEM: Advanced Space Borne Thermal Emission and Reflection Radiometer-Global Digital Elevation Model	30 m	83º N – 83º S	2009	Alataway et al., 2019; Atif et al., 2019; Cazares-Rodriguez et al., 2017; Jin & Jin, 2020; Shi et al., 2020; Singh & Saravanan, 2020; Zhang et al., 2021; Zhang et al., 2020.
GMTED 2010: Global Multi-resolution Terrain Elevation Data 2010	225 m	60º N – 60º S	2010	Pakaksung & Takagi, 2021; Dembele et al., 2020a; Dembele et al., 2020b.
HydroSHEDS: Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales	500 m	60º N – 60º S	2009	Jiang et al., 2020; Khairul et al., 2018; Lazin et al; 2020; Pakaksung & Takagi, 2021; Siqueira et al., 2018.
GTOPO 30: Global Multi-resolution Terrain Elevation Data 2010	1000 m	90º N – 90º S	1993	Corbari et al., 2019; Koppa et al., 2019; Lakew,2020
MERIT: Multi-Error-Removed Improved-Terrain DEM	90 m	90º N – 60º S	2017	Pakoksung & Takagi, 2021
TanDEM-X: TerraSAR-X add-on for Digital Elevation Measurement	12 m, 30 m, 90 m	90º N – 90º S	2016	Pakoksung & Takagi, 2021

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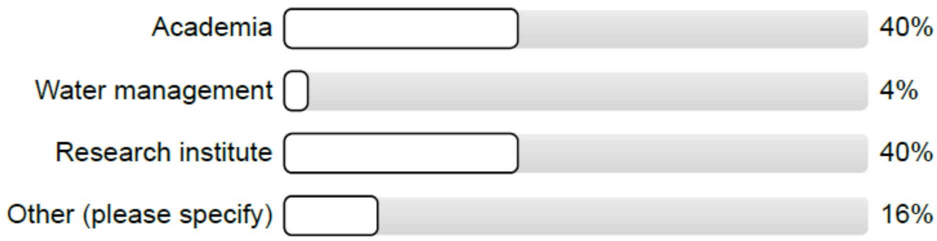
Annex 3

3.1. Water quality survey – response result per questions

Intro Data

- In which type of organisation are you working? (n=25)



Other types of organisations not mentioned in the questionnaires but specified by the survey were non-profit organisations and private companies.

- What is the name of your organisation?
  - CNR
  - CNR-IREA
  - Griffith University
  - IGRAC
  - IHE Delft
  - Leibniz Institute of Freshwater Ecology and Inland Fisheries
  - Plymouth Marine Laboratory
  - TU Vienna
  - Terrasigna
  - UFZ Magdeburg
  - University of Bari
  - University of Coimbra (Portugal)
  - Vrij Universiteit Brussel
  - Wageningen University (2 Counts)
  - Waterbouwkundig Laboratorium
  - Eawag

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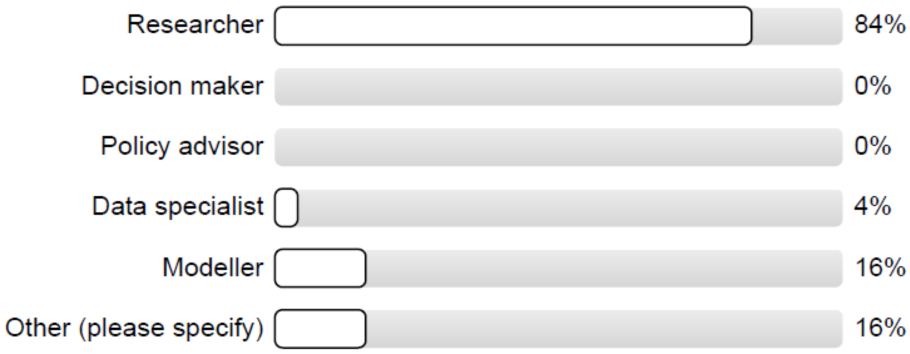
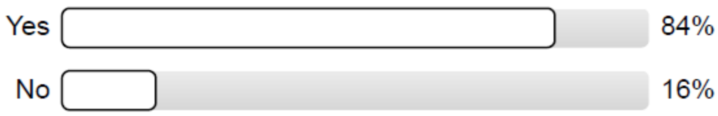
- What is your position in the organisation you are working in? (n=25)



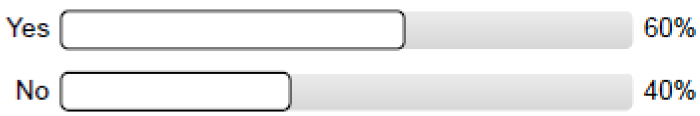
Other types of positions not mentioned in the questionnaires but specified by the survey were Assistant professor, PhD student and Project manager.

Current Use of Copernicus Remote Sensing Data

- Do you use any type of Remote Sensing Data? **Yes/No** (n=25)



  - Could you please elaborate briefly why not?
    - I do not have knowledge how to collect/access, process and use remote sensing data. I also do not know what remote sensing data is available for water quality modelling.
    - I do not know much about it.
    - I do not know what data is available and how can be relevant for water quality.
    - not familiar enough with remote sensing products, or ways to access them.
- Do you use Copernicus Data Services? **Yes/No** (n=25)



  - Could you please elaborate briefly Why not?
    - I did not hear about it before.
    - I do not use Copernicus directly but I have students and collaborators who do.

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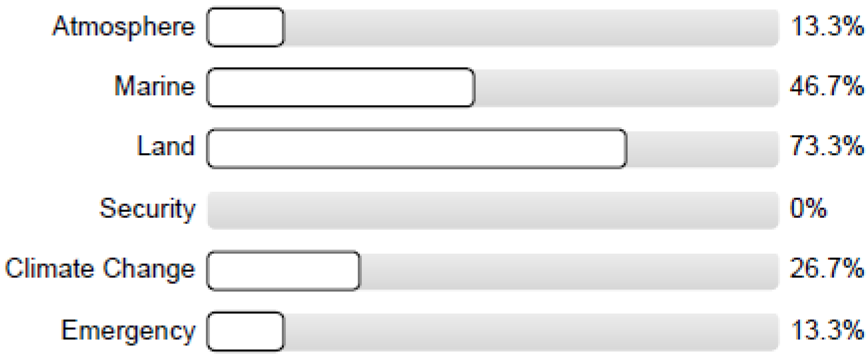
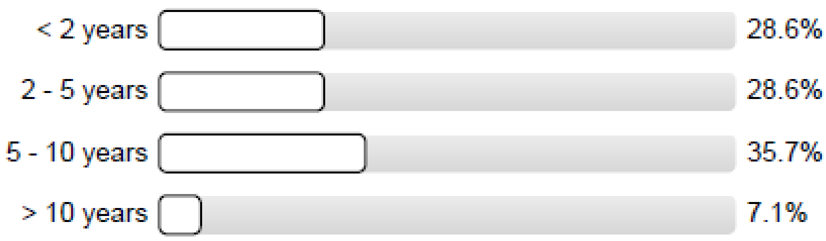
- I have not had time yet to learn how to access the data- when briefly skimming the web site I could not find an option. At the moment I have to finish other tasks first.
- I need to explore options how to use services in water quality modelling. I am not sure how this data is relevant and whether useful.
- The Copernicus Global Land Service water quality products are not at full spatial resolution and do not cover all inland waters.
- Two reasons: (1) Used other sources of data in the past such as NASA-NOAA products and ESA CCI products (2) Tried recently to access CLMS and CMEMS products and the latter contained so many different datasets that I became overwhelmed (and also did not find exactly what I was looking for). I found CLMS easier to navigate around.
- We don't use Copernicus data products directly, but we participate in projects where our partners use Copernicus data.
- We use other data sources. I am not familiar with Copernicus and do not know much what is available there.
- Not familiar with.

- What Copernicus service(s) are you using in your work? (n=15)



- How many years of experience do you have in using Copernicus EO for modelling? (n=14)



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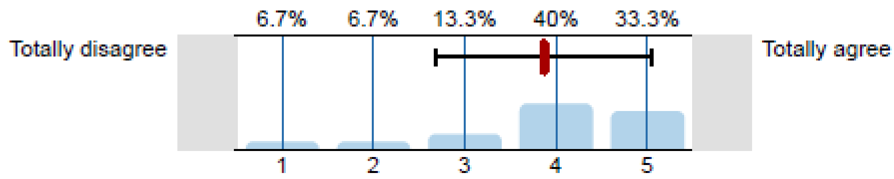
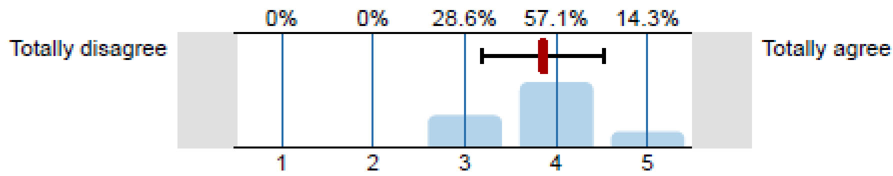
For the following statements please select what is applicable for you

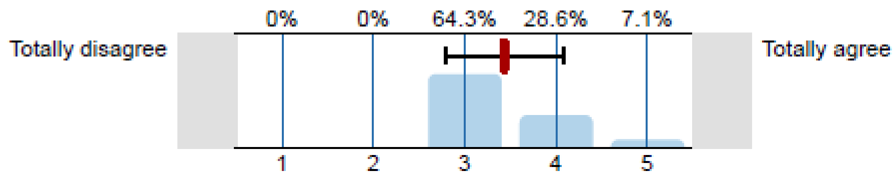
- Copernicus data portals are easy to find



- Copernicus data are accessible



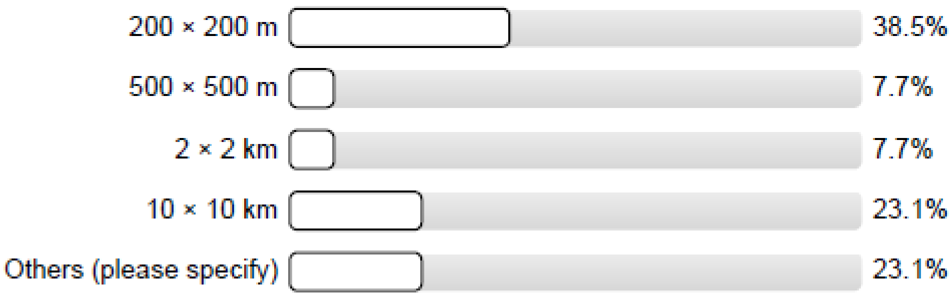
- Copernicus data are easy to use in a model



Remarks: Please provide any feedback you might have.

  - The Services do not offer uniform data access. The C3S API is great.
  - There is a problem on data format from different services, it would be easier to have a harmonization of the products.
  - Not all datasets have DOIs.

- What parameters are you using in your work?
  - Chlorophyll-a (Chla) - Spatial resolution (n=13)



Others: 1 x 1 km

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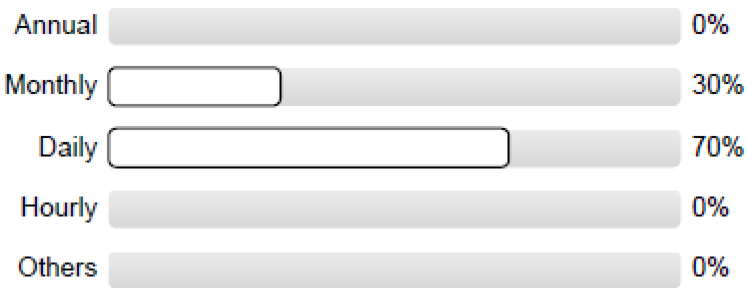
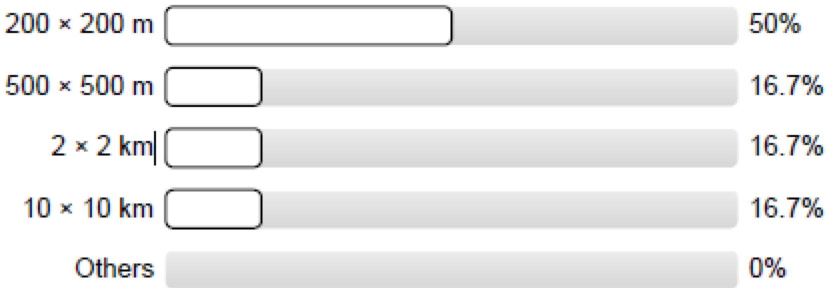
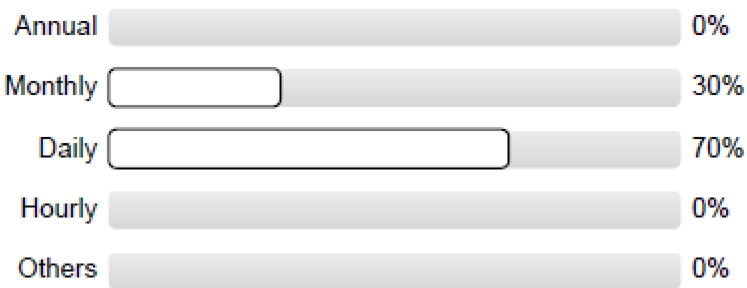
- Chlorophyll-a (Chla) - Temporal resolution (n=10)



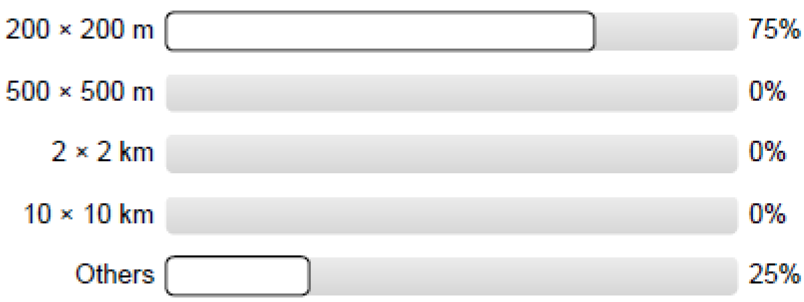
- Phytoplankton Absorption Coefficient (a_{phy}) - Spatial resolution (n=6)



- Phytoplankton Absorption Coefficient (a_{phy}) - Temporal resolution (n=5)



- Total Absorption Coefficient (a_{tot}) - Spatial resolution (n=4)



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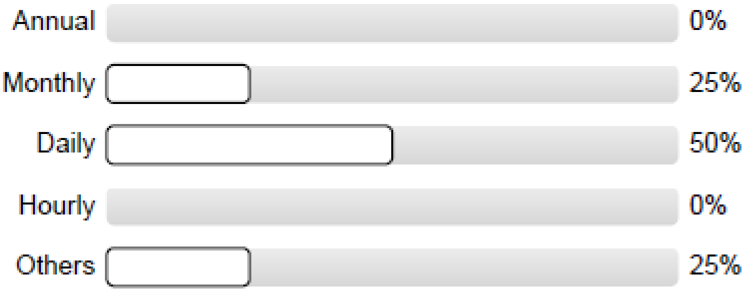
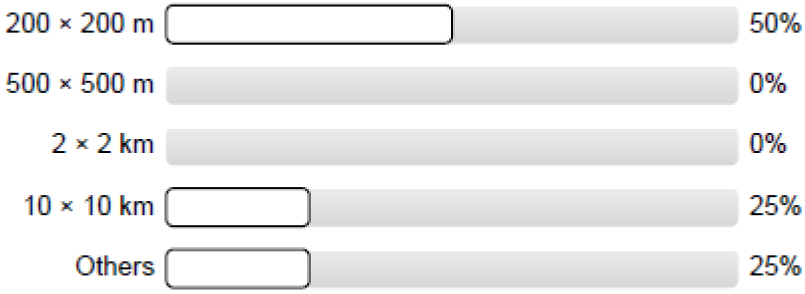
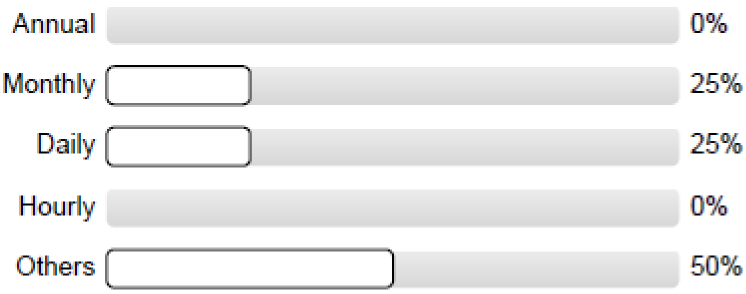
- Total Absorption Coefficient (a_{tot}) - Temporal resolution (n=4)



- Coloured Dissolved Matter (CDM) - Spatial resolution (n=4)

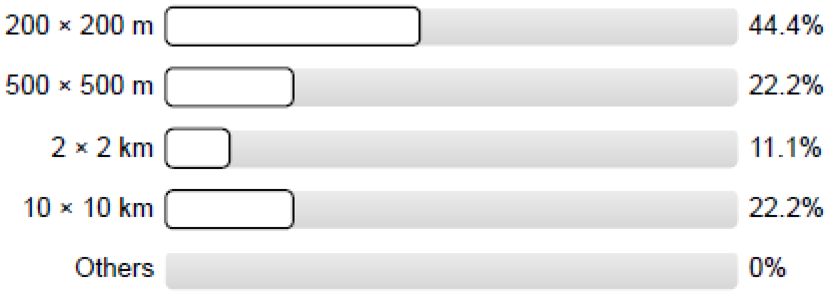


- Coloured Dissolved Matter (CDM) - Temporal resolution (n=4)



Others: weekly

- Suspended Particulate Matter (SPM) - Spatial resolution (n=9)



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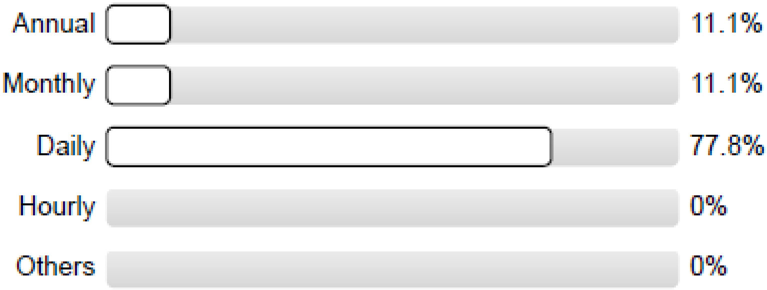
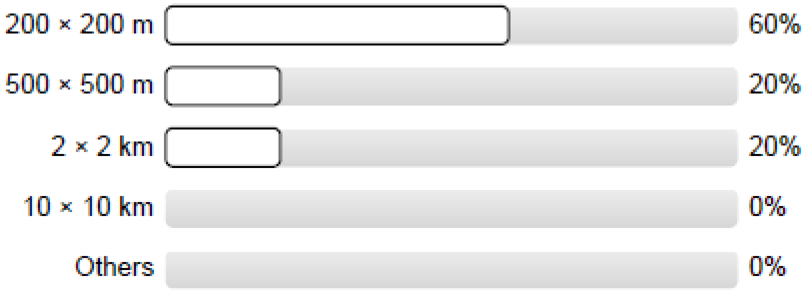
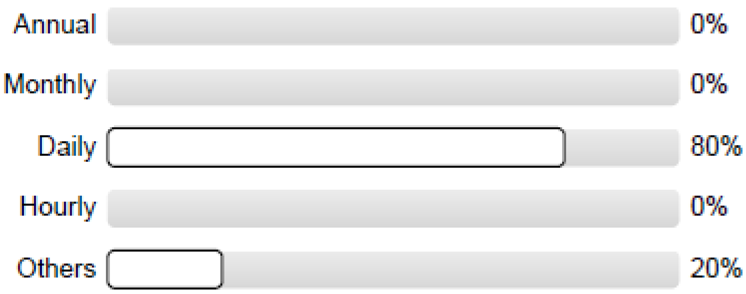
- Suspended Particulate Matter (SPM) - Temporal resolution (n=9)



- Diffuse Attenuation Coefficient (K_d) - Spatial resolution (n=5)

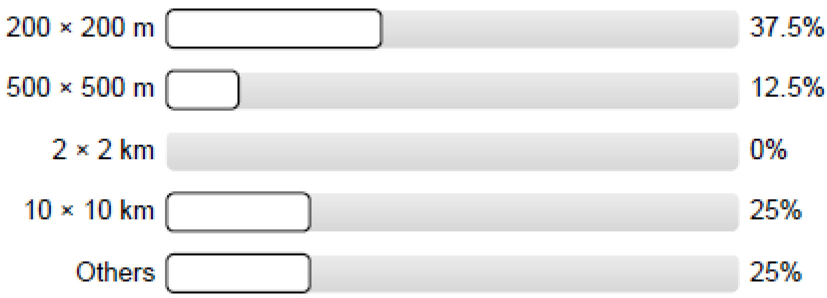


- Diffuse Attenuation Coefficient (K_d) - Temporal resolution (n=5)



Others: weekly

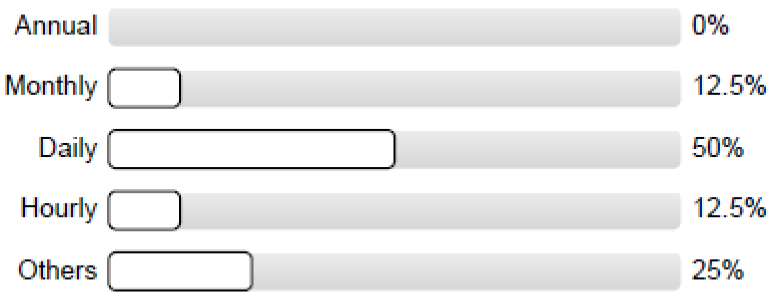
- Sea Surface Temperature (SST) - Spatial resolution (n=8)



Others: 1 x 1 km

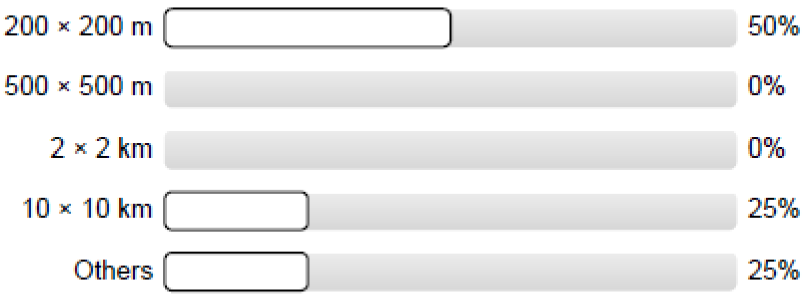
- Sea Surface Temperature (SST) - Temporal resolution (n=8)

Water-ForCE is a CSA that has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101004186.

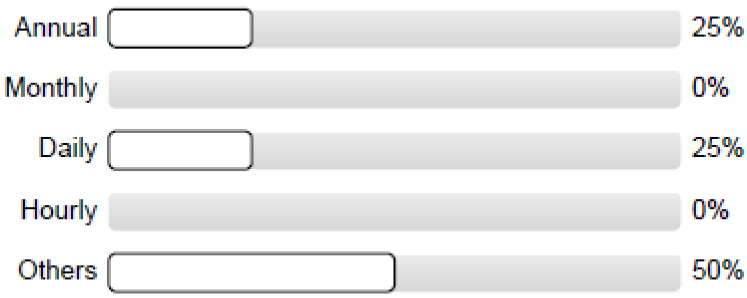


Others: Weekly

- Particulate Backscattering Coefficient (B_{bp}) - Spatial resolution (n=4)

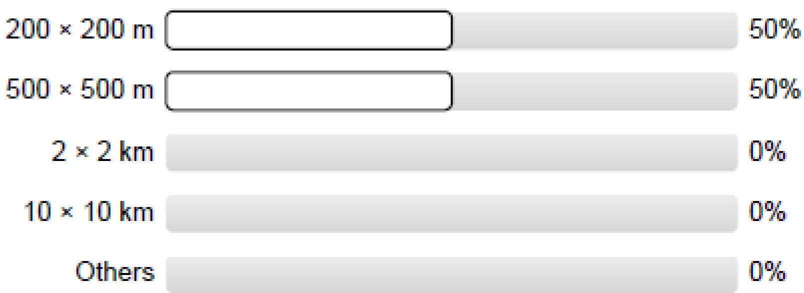


- Particulate Backscattering Coefficient (B_{bp}) - Temporal resolution (n=5)



Others: Weekly

- Secchi Disk Depth (ZSD) - Spatial resolution (n=4)



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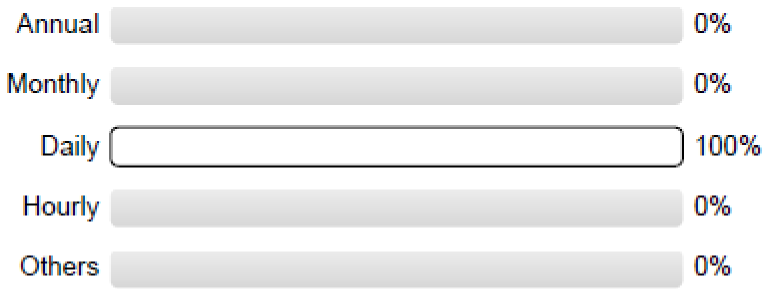
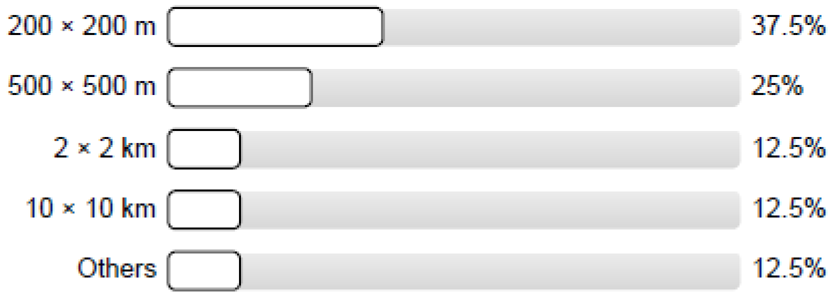
- Secchi Disk Depth (ZSD) - Temporal resolution (n=5)

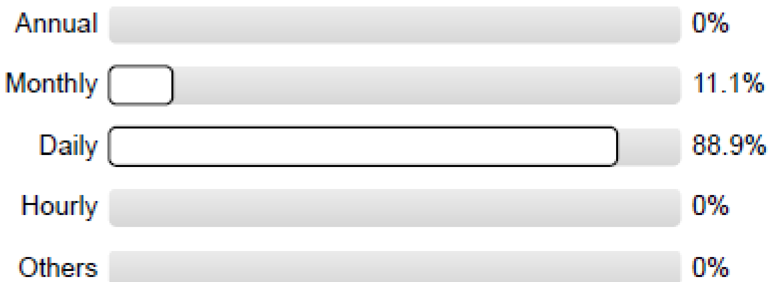


- Remote Sensing Reflectances (R_{rs}) - Spatial resolution (n=8)

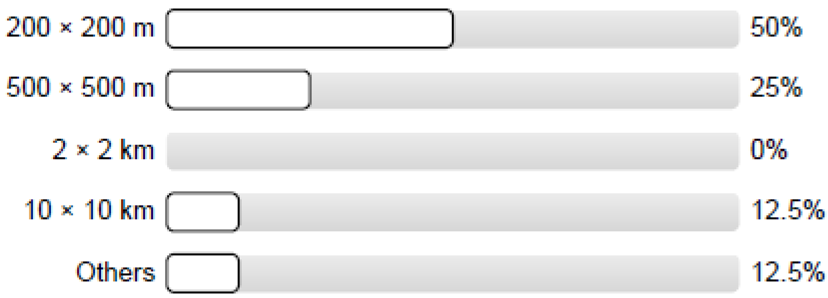


Others: 1 x 1 km

- Remote Sensing Reflectances (R_{rs}) - Temporal resolution (n=9)



- Lake Surface Water Temperature (LSWT) - Spatial resolution (n=8)



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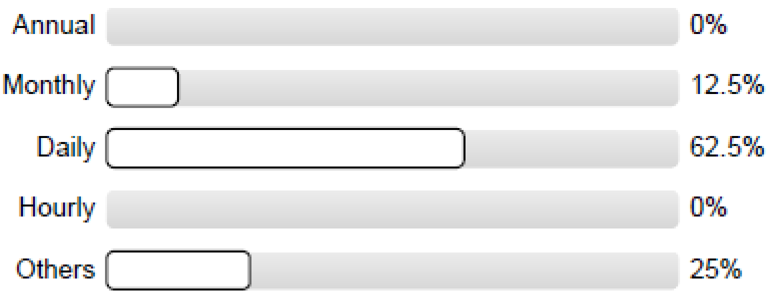
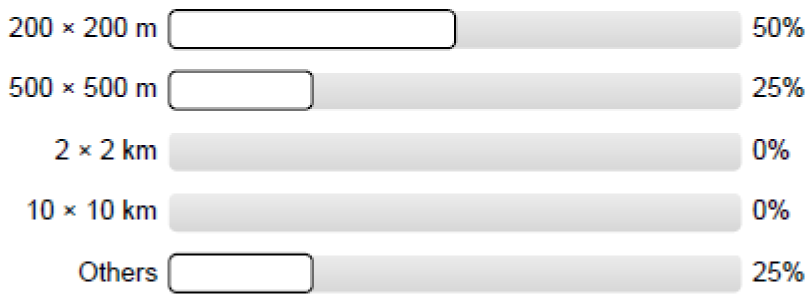
- Lake Surface Water Temperature (LSWT) - Temporal resolution (n=8)

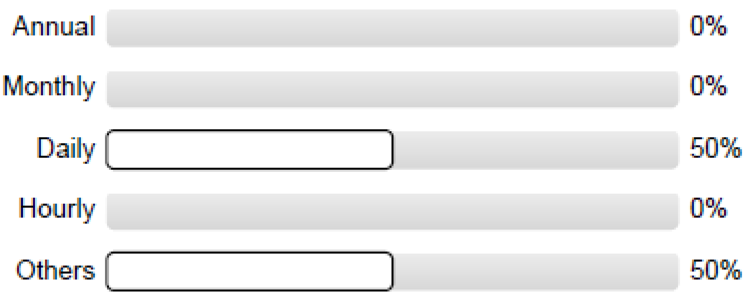


Others: Weekly

- Trophic State Index - Spatial resolution (n=4)

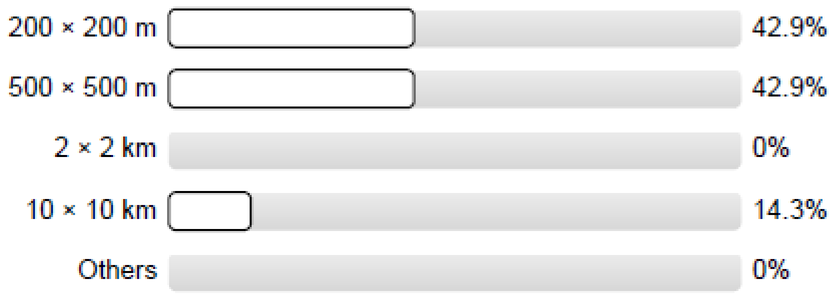


- Trophic State Index - Temporal resolution (n=4)



Others: Weekly

- Water leaving reflectance - Spatial resolution (n=7)



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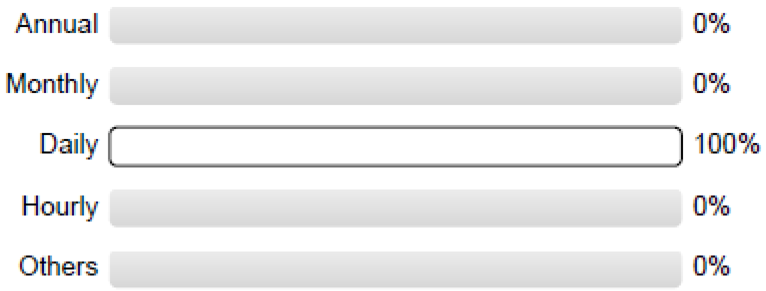
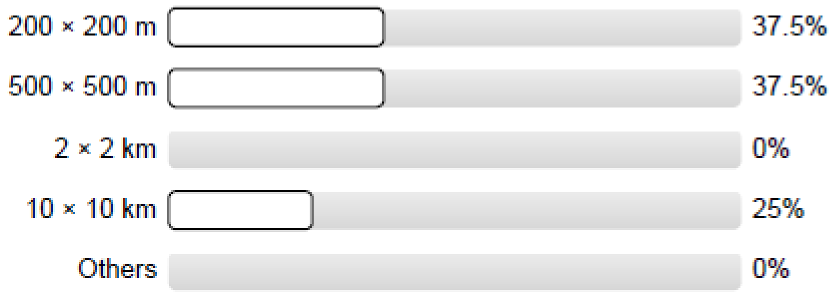
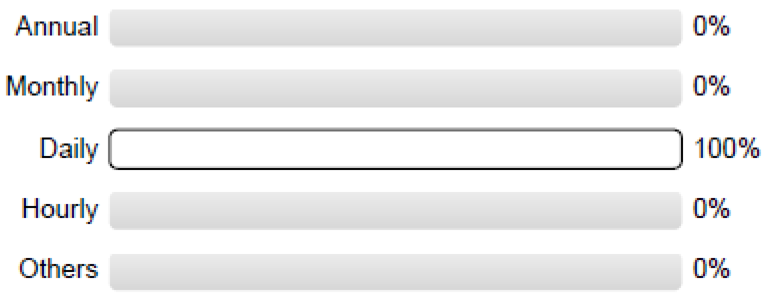
- Water leaving reflectance - Temporal resolution (n=7)



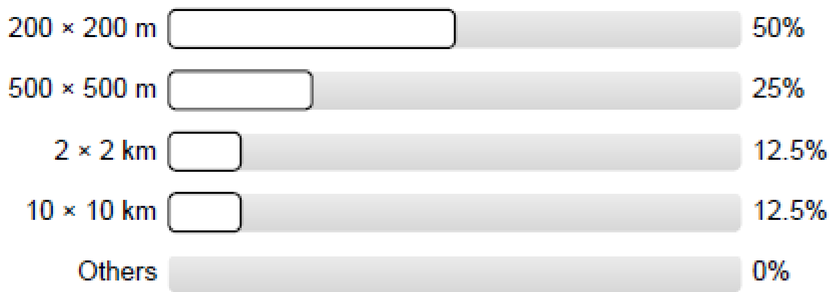
- Mass concentration of chlorophyll-a - Spatial resolution (n=8)



- Mass concentration of chlorophyll-a - Temporal resolution (n=8)



- Remote Sensing reflectance - Spatial resolution (n=8)



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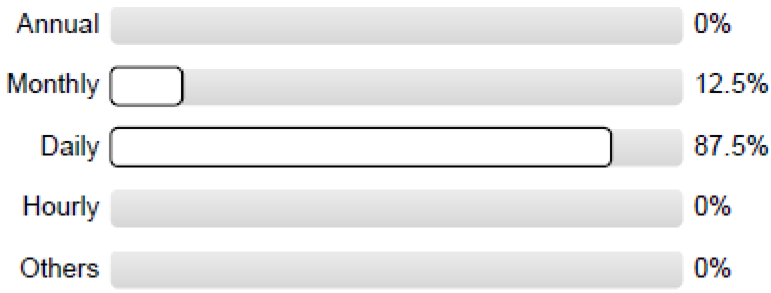
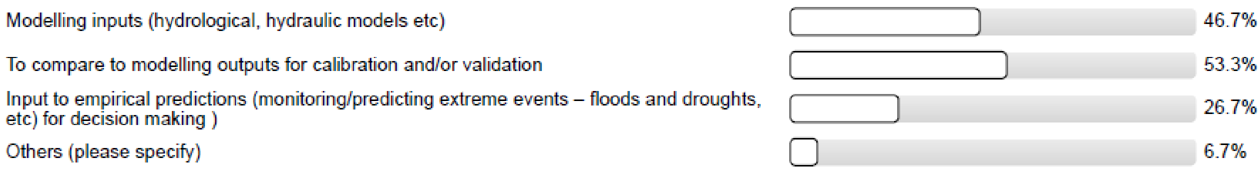
- Remote Sensing reflectance - Temporal resolution (n=8)



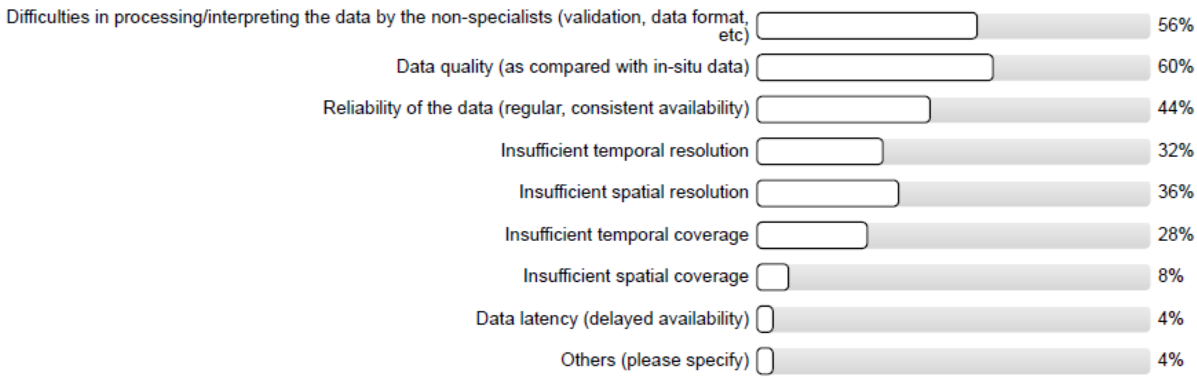
- How are the previous parameters used? (n=15)



Others: Identifying climate trends; identifying ecosystem monitoring solutions

Current needs for Remote Sensing Copernicus data services for modelling:

- Which are the main limitations and gaps you can highlight? (n=25)



Others: Type of data needed is not available through Copernicus services

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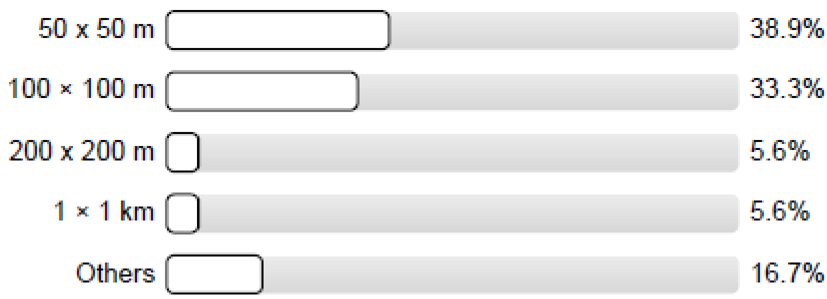
- Please state your interest for the following options of improved Copernicus Data Services.

- What would be your preferred spatial and/or temporal resolution and update frequency for Copernicus Data Services?
  - Chlorophyll-a (Chla) - Spatial resolution (n=18)



Others: 50 x 50 km or 5 x 5 m

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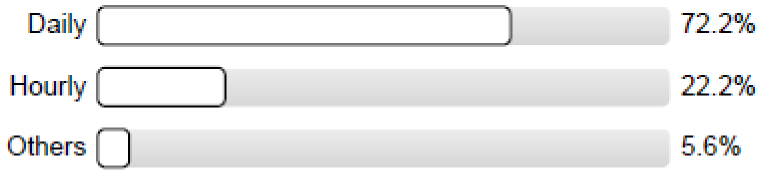
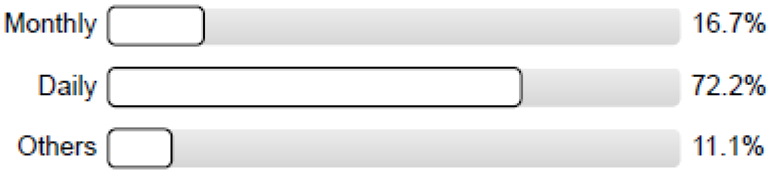
- Chlorophyll-a (Chla) - Temporal resolution (n=18)



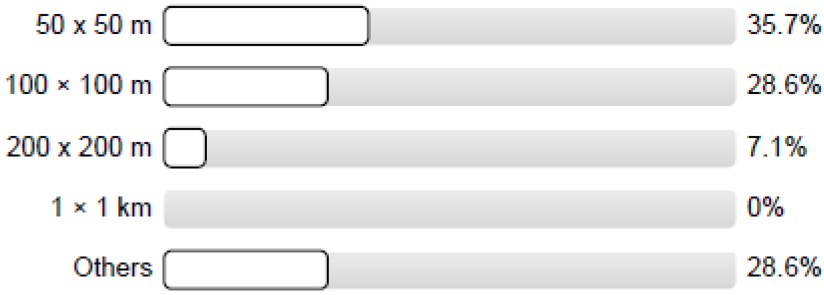
Others: Seasonal

- Chlorophyll-a (Chla) – Update frequency (n=18)



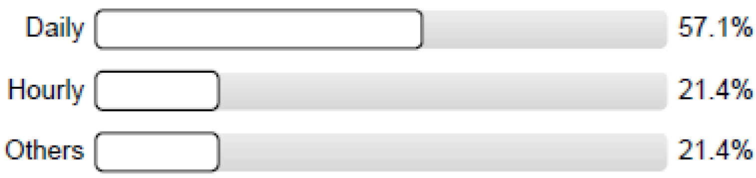
Others: Seasonal

- Phytoplankton Absorption Coefficient (a_{phy}) - Spatial resolution (n=14)



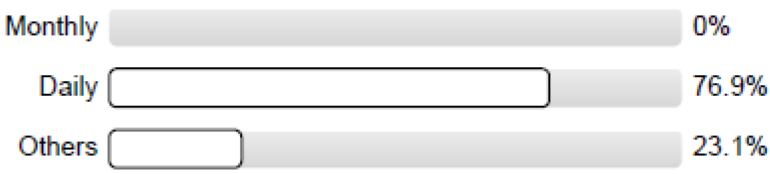
Others: 50 x 50 km or 5 x 5 m

- Phytoplankton Absorption Coefficient (a_{phy}) - Temporal resolution (n=14)



Others: Seasonal

- Phytoplankton Absorption Coefficient (a_{phy}) – Update frequency (n=13)



Others: Seasonal

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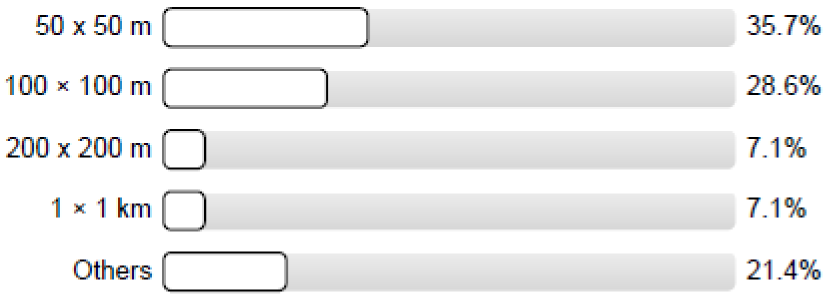
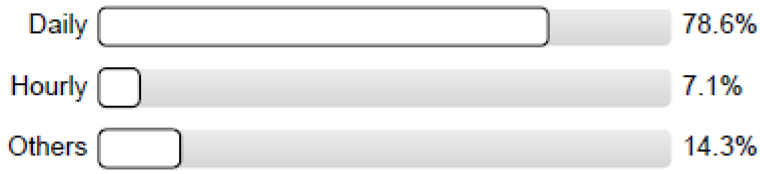
- Total Absorption Coefficient (a_{tot}) - Spatial resolution (n=14)

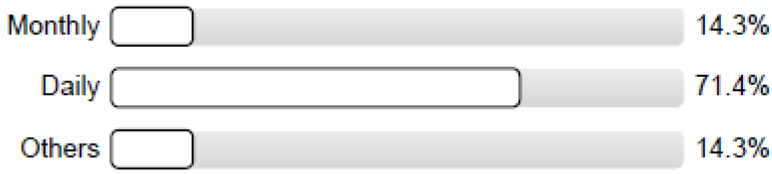


Others: 5 x 5 m

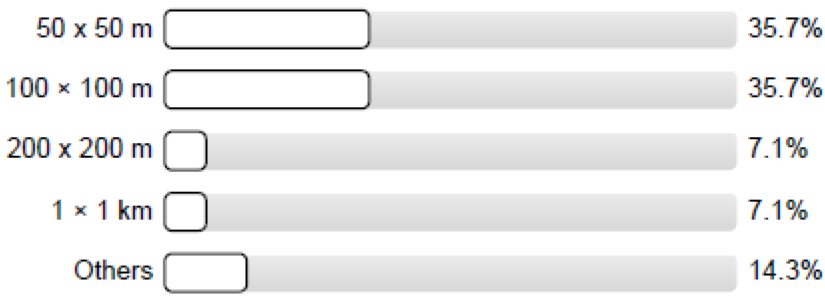
- Total Absorption Coefficient (a_{tot}) - Temporal resolution (n=14)



- Total Absorption Coefficient (a_{tot}) – Update frequency (n=14)

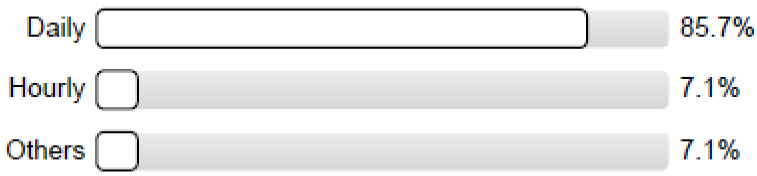


- Coloured Dissolved Matter (CDM) - Spatial resolution (n=14)



Others: 5 x 5 m

- Coloured Dissolved Matter (CDM) - Temporal resolution (n=14)



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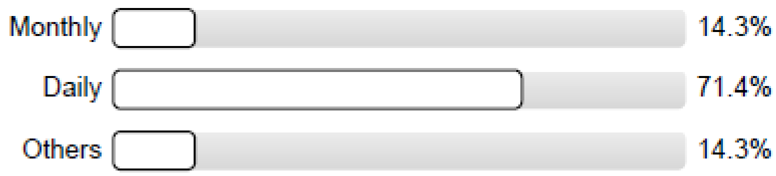
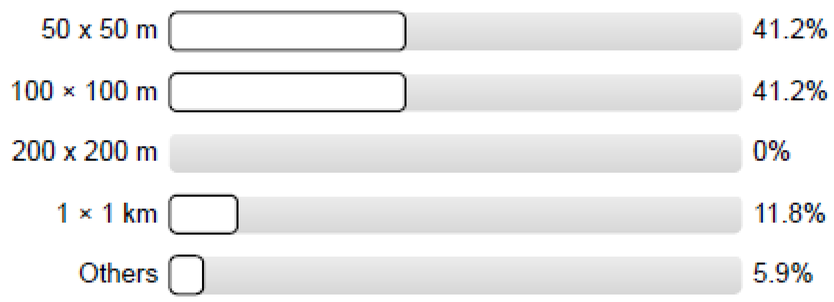
- Coloured Dissolved Matter (CDM) – Update frequency (n=14)



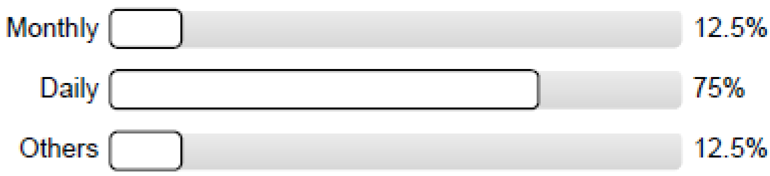
- Suspended Particulate Matter (SPM) - Spatial resolution (n=17)



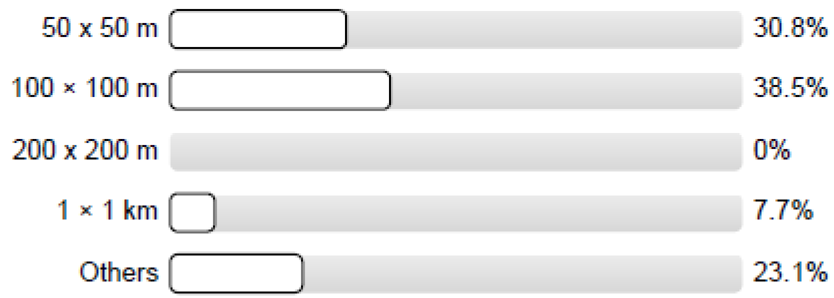
Others: 5 x 5 m

- Suspended Particulate Matter (SPM) - Temporal resolution (n=17)

- Suspended Particulate Matter (SPM) – Update frequency (n=16)



- Diffuse Attenuation Coefficient (K_d) - Spatial resolution (n=13)



Others: 5 x 5 m

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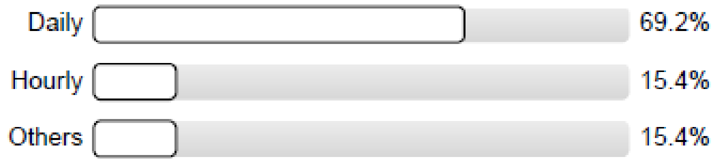
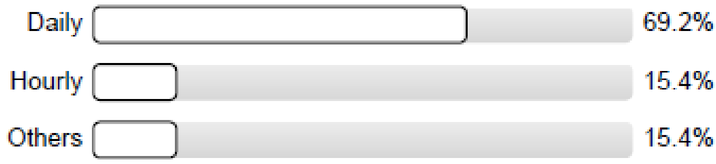
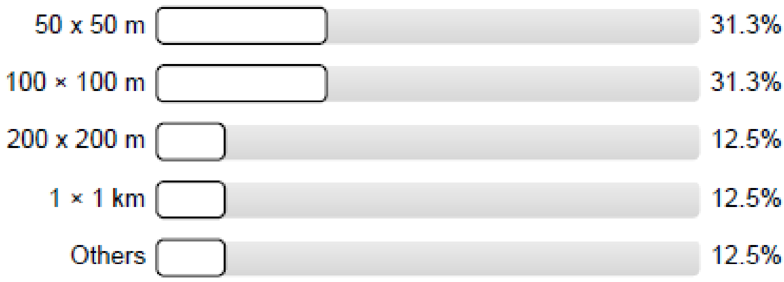
- Diffuse Attenuation Coefficient (K_d) - Temporal resolution (n=13)



- Diffuse Attenuation Coefficient (K_d) – Update frequency (n=12)

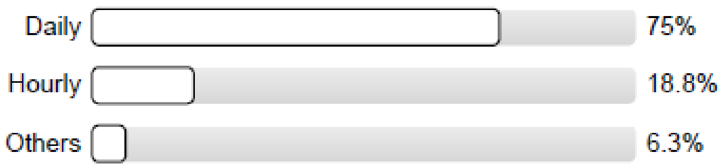


- Sea Surface Temperature (SST) - Spatial resolution (n=16)

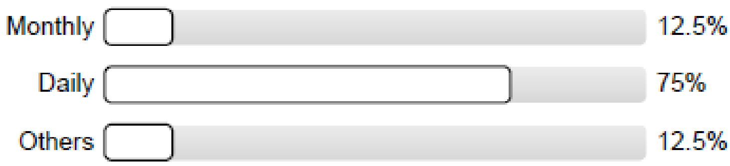


Others: 5 x 5 m

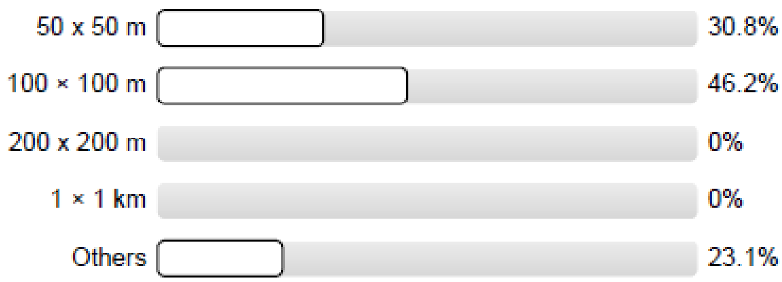
- Sea Surface Temperature (SST) - Temporal resolution (n=16)



- Sea Surface Temperature (SST) – Update frequency (n=16)



- Particulate Backscattering Coefficient (B_{bp}) - Spatial resolution (n=13)



Others: 5 x 5 m

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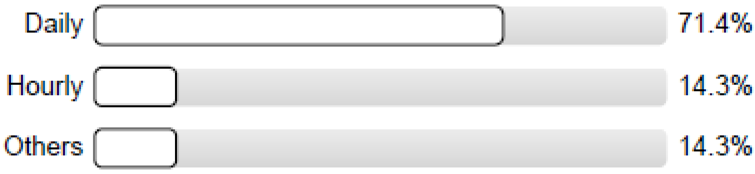
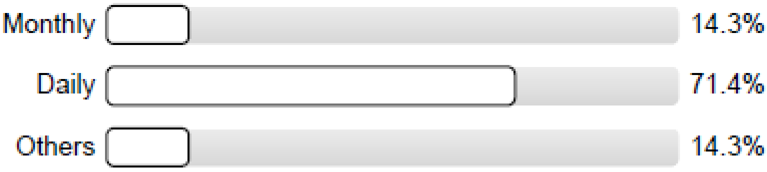
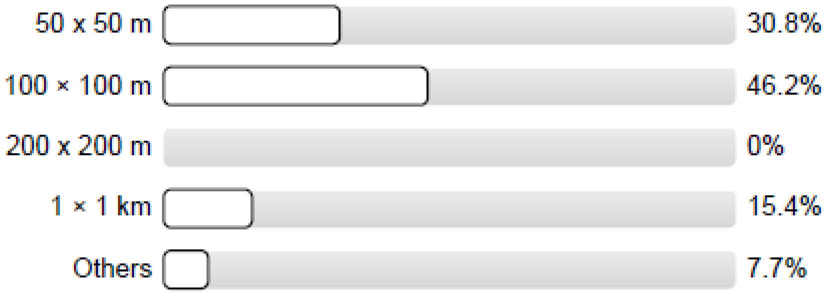
- Particulate Backscattering Coefficient (B_{bp}) - Temporal resolution (n=14)



- Particulate Backscattering Coefficient (B_{bp}) – Update frequency (n=14)



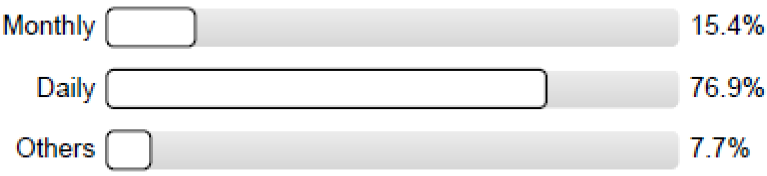
- Secchi Disk Depth (ZSD) - Spatial resolution (n=13)



Others: 5 x 5 m

- Secchi Disk Depth (ZSD) - Temporal resolution (n=13)

- Secchi Disk Depth (ZSD) – Update frequency (n=13)



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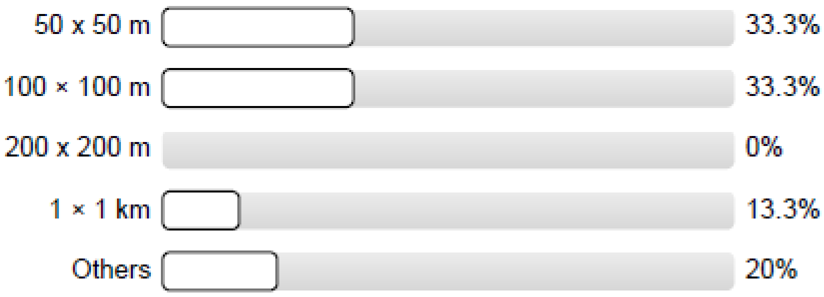
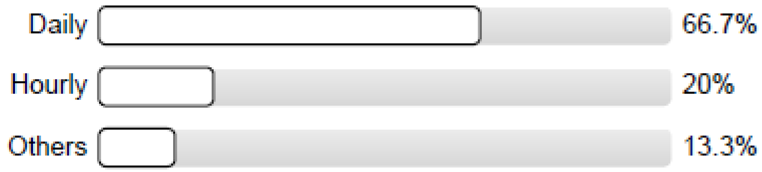
- Remote Sensing Reflectances (R_{rs}) - Spatial resolution (n=15)

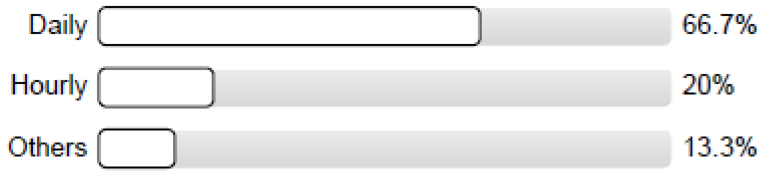


Others: 5 x 5 m

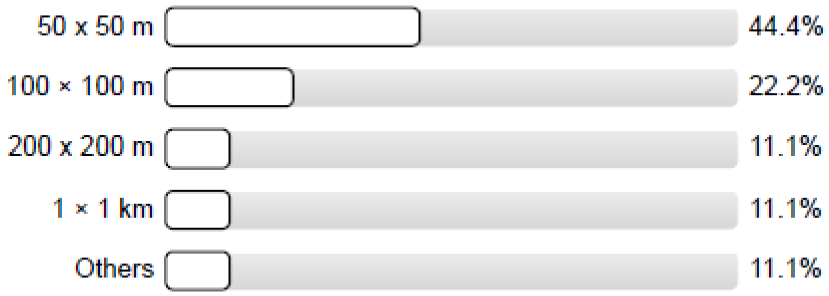
- Remote Sensing Reflectances (R_{rs}) - Temporal resolution (n=15)



- Remote Sensing Reflectances (R_{rs}) – Update frequency (n=15)

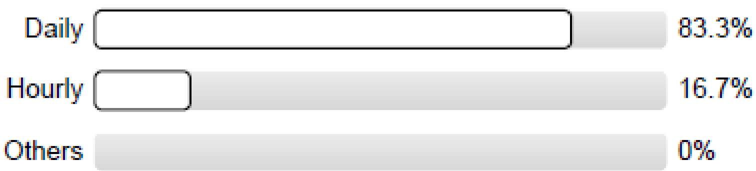


- Lake Surface Water Temperature (LSWT) - Spatial resolution (n=18)



Others: 5 x 5 m; or it depends on the size of the lake. I am happy with 50 m for large lakes, but would like 10 m for smaller ones.

- Lake Surface Water Temperature (LSWT) - Temporal resolution (n=18)



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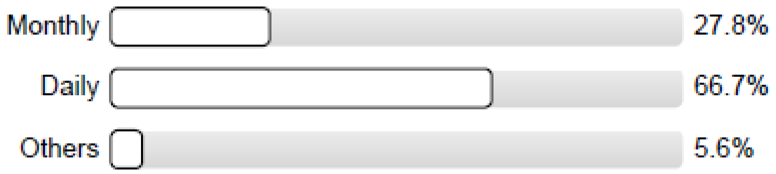
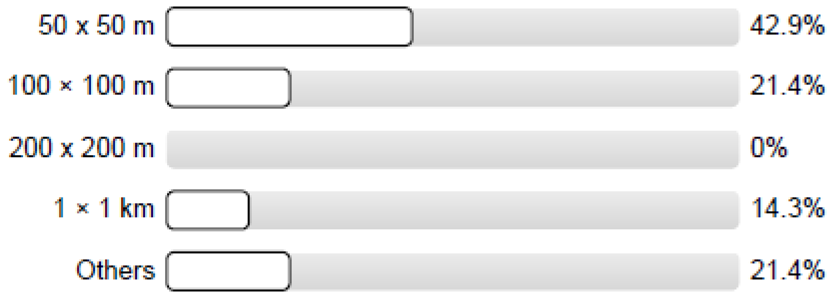
- Lake Surface Water Temperature (LSWT) – Update frequency (n=18)



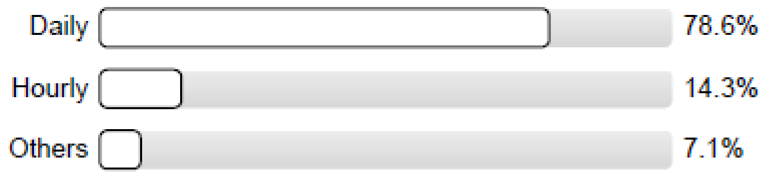
- Trophic State Index - Spatial resolution (n=14)



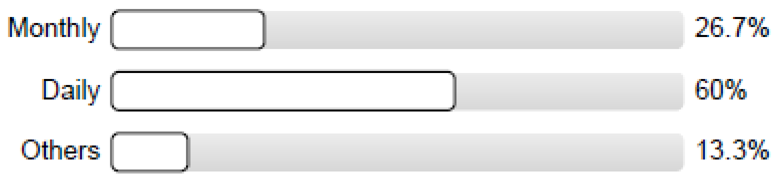
Others:

- 5 x 5 m
- it depends on the size of the lake. I am happy with 50 m for large lakes, but would like 10 m for smaller ones.

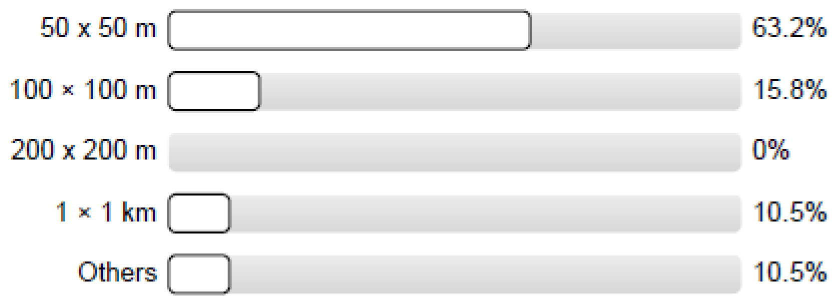
- Trophic State Index - Temporal resolution (n=14)



- Trophic State Index – Update frequency (n=15)



- Turbidity - Spatial resolution (n=19)



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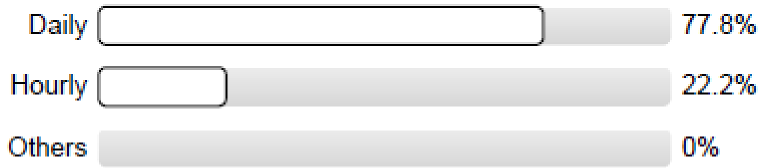
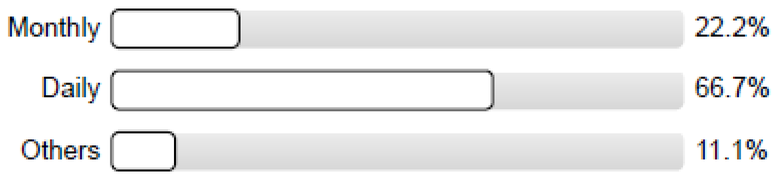
Others:

- 5 x 5 m
- it depends on the size of the lake. I am happy with 50 m for large lakes, but would like 10 m for smaller ones.

  - Turbidity - Temporal resolution (n=18)

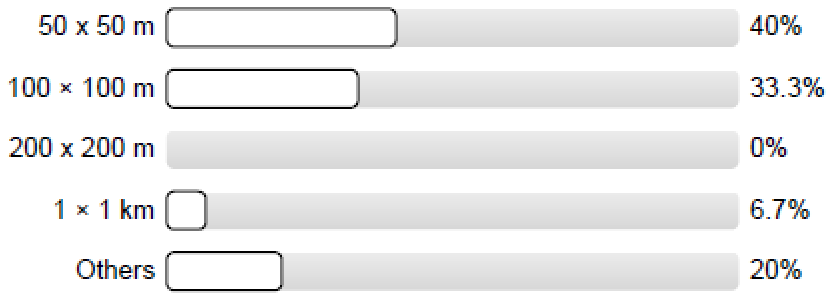


  - Turbidity – Update frequency (n=18)



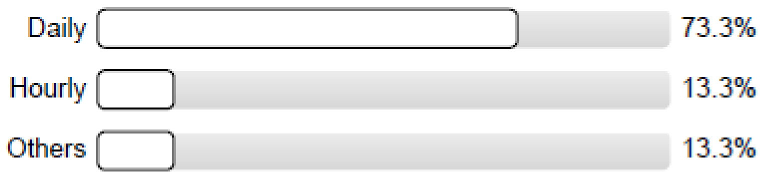
Others: cfr SSC, ideally timeseries with sufficient temporal resolution to resolve intratidal variation

  - Water leaving reflectance - Spatial resolution (n=15)

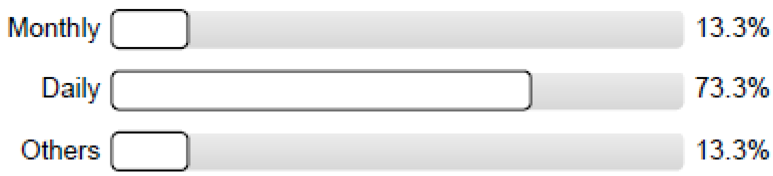


Others: 5 x 5 m

  - Water leaving reflectance - Temporal resolution (n=15)



  - Water leaving reflectance – Update frequency (n=15)



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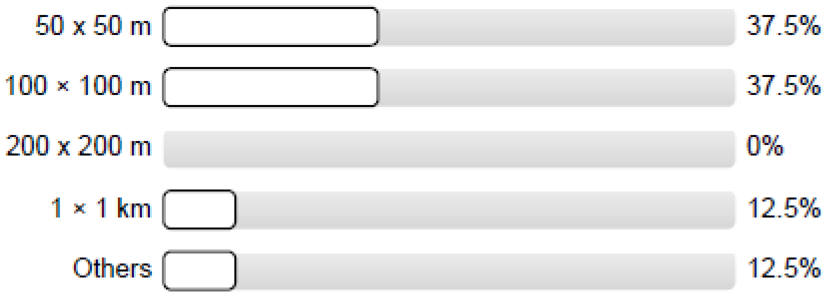
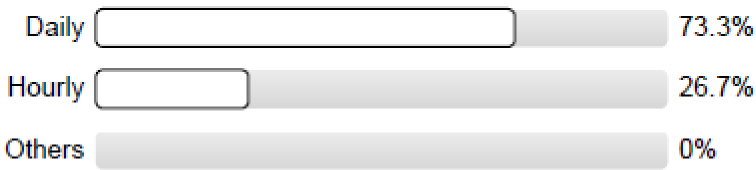
- Mass concentration of chlorophyll-a - Spatial resolution (n=16)



Others

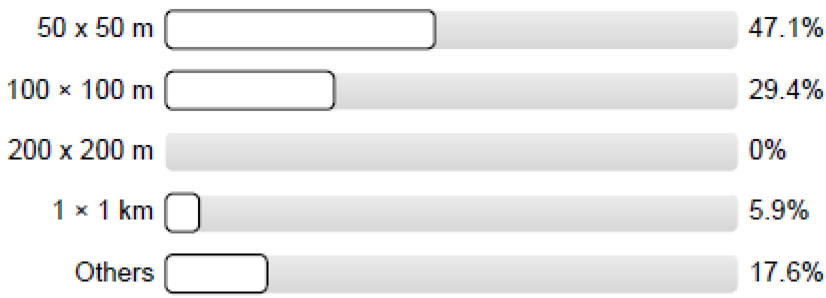
- 50 m for larger lakes, 10 m for smaller lakes
- 5 x 5 m

- Mass concentration of chlorophyll-a - Temporal resolution (n=15)



- Mass concentration of chlorophyll-a – Update frequency (n=16)

- Remote Sensing reflectance - Spatial resolution (n=17)



Others: 5 x 5 m

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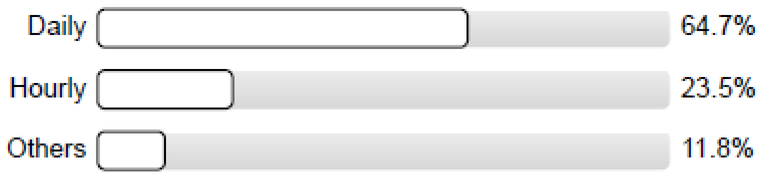
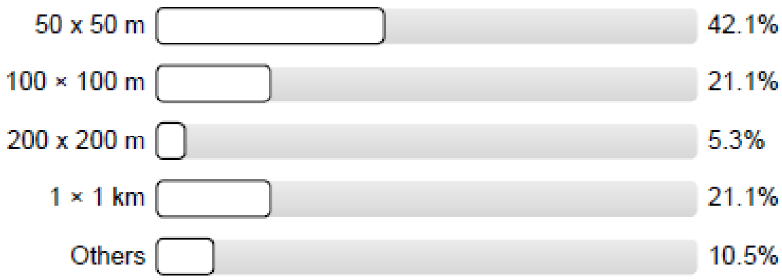
- Remote Sensing reflectance - Temporal resolution (n=17)

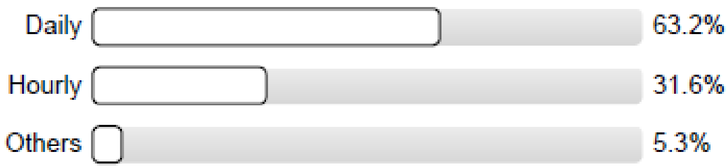


- New water quality products, as listed below, are developed by Copernicus. What would be your ideal spatial, temporal resolution and update frequency for them?
  - Water primary production - Spatial resolution (n=19)

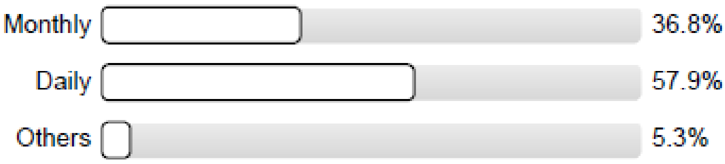


Others: 5 x 5 m

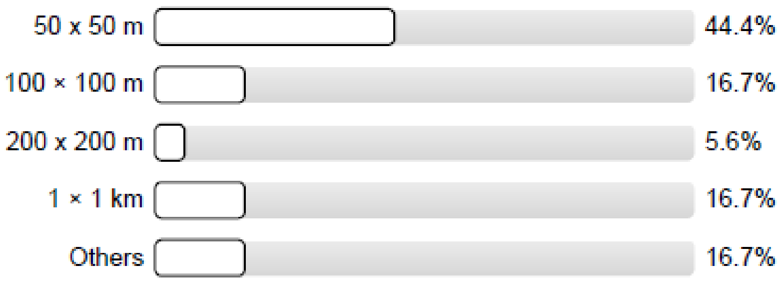
- Water primary production - Temporal resolution (n=19)



- Water primary production – Update frequency (n=19)



- Total Nitrogen - Spatial resolution (n=18)



Others: 0.5 by 0.5 degree; or 5 x 5 m

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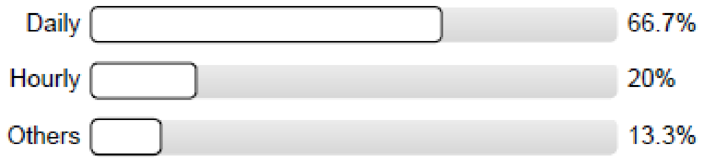
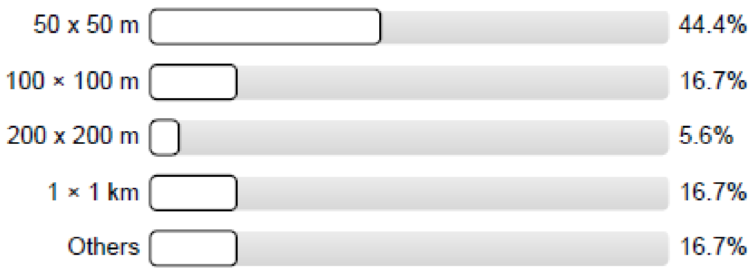
- Total Nitrogen - Temporal resolution (n=18)

- Total Nitrogen – Update frequency (n=18)

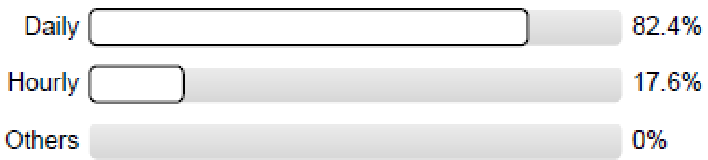


- Total Phosphorus - Spatial resolution (n=18)

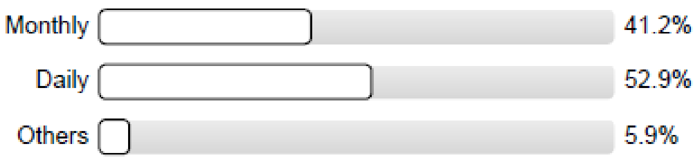


Others: 0.5 by 0.5 degree; or 5 x 5 m

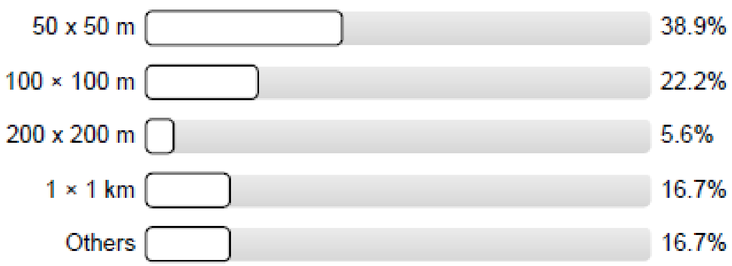
- Total Phosphorus - Temporal resolution (n=17)



- Total Phosphorus – Update frequency (n=17)



- Dissolved organic carbon - Spatial resolution (n=18)



Others: 0.5 by 0.5 degree; 5 x 5 m

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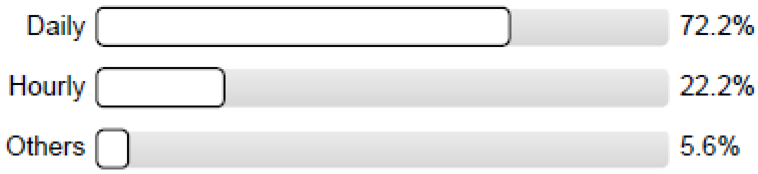
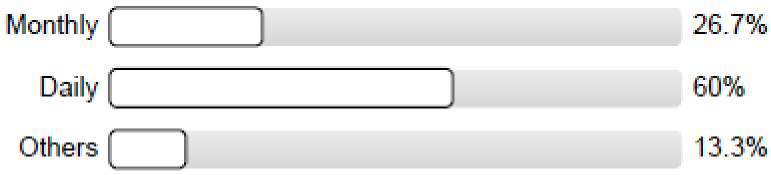
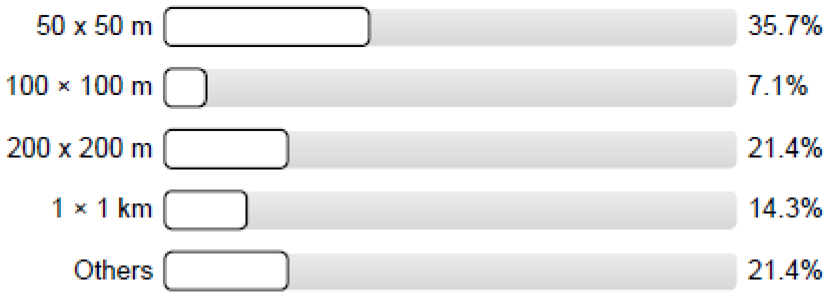
- Dissolved organic carbon - Temporal resolution (n=18)



- Dissolved organic carbon– Update frequency (n=18)

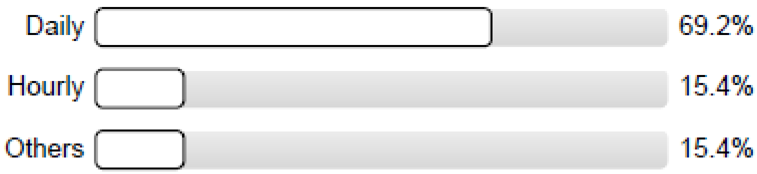


- Partial pressure of CO_2 or CO_2 concentration - Spatial resolution (n=14)

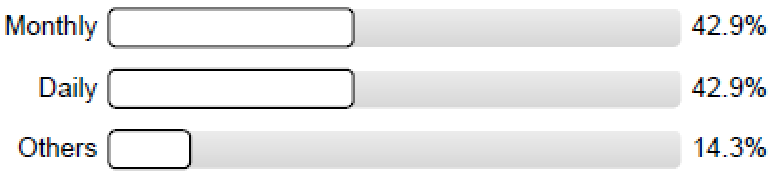


Others: 5 x 5 m

- Partial pressure of CO_2 or CO_2 concentration - Temporal resolution (n=13)



- Partial pressure of CO_2 or CO_2 concentration – Update frequency (n=14)



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- Please write any other comment or observation you think is important for this needs assessment:
  - Simpler search interface when lots of variables are on offer by any Copernicus Service. (2) Guidance on novice users on how to choose the best parameter for their needs (e.g. tutorials, or onboarding). (3) The recent CMEMS training webinars for the Baltic/ Arctic/(and soon the Mediterranean) were brilliant - more like those please!
  - DOIs and clear citation guidelines for every dataset. Reduced update latency. Improved spatio-temporal resolutions.
  - For my case study, I need time series of the RS data. Extracting time series data was very time-consuming. If this data can be provided, the use of RS data will be easier.
  - I think it would be nice for me to learn how to bridge the gap between modellers and remote sensing and vice versa. For me it is not clear what is out there and how to use it.
  - I wonder if the products suggested are also suitable to be used in groundwater assessments, or if this is only focused on surface water. More products dedicated to groundwater are needed.
  - Validated EO data.
  - please also provide uncertainty bands around the values, and technical reports on how the processing was done that we can refer to.

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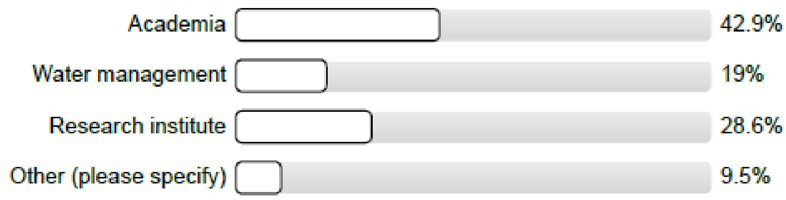
3.2 Water quantity survey – results per question

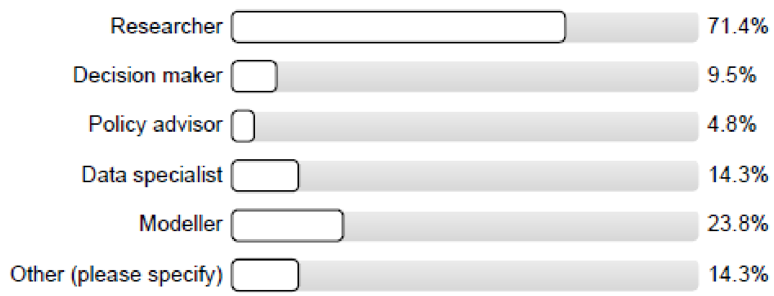
Intro Data

- In which type of organisation are you working? (n=21)



  Other types of organisations not mentioned in the questionnaires but specified by the surveyed were non-profit organisations and private companies.

- What is the name of your organisation?
  - Confederación Hidrográfica del Ebro
  - Federal Waterways Engineering and Research Institute
  - German Research Centre for Geosciences (GFZ Potsdam)
  - Griffith University
  - IGRAC
  - IHE Delft (2 Counts)
  - IHE Delft Institute for Water Education
  - National Institute for Marine Geology and Geoecology GeoEcoMar Romania
  - Russian State Hydrological institute
  - SMHI
  - Sorbonne University
  - TU Vienna
  - University of Bari
  - University of Coimbra (Portugal)
  - Water Resources Management Authority
- What is your position in the organisation you are working in? (n=21)

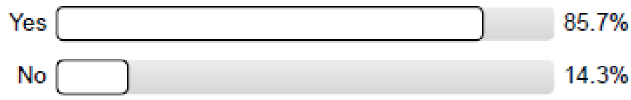


Water-ForCE is a CSA that has received funding form the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101004186.

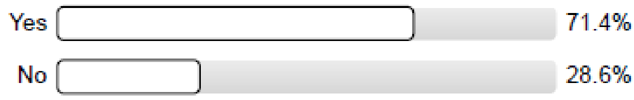
Others types of positions not mentioned in the questionnaires but specified by the surveyed were Lecturer, PhD student and Team lead.

Current Use of Copernicus Remote Sensing Data

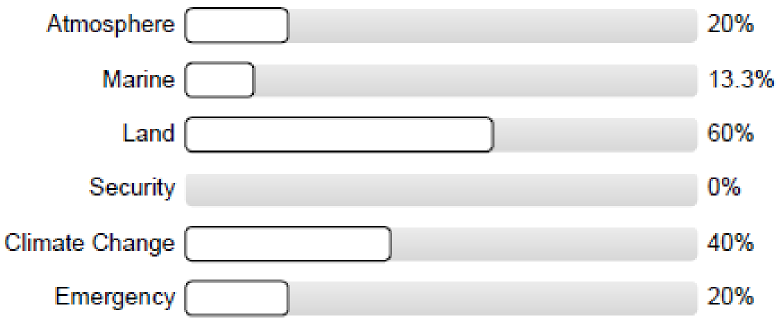
- Do you use any type of Remote Sensing Data? **Yes/No** (n=21)



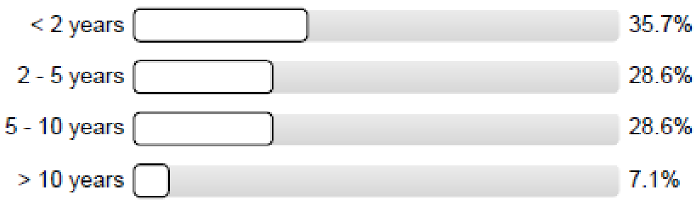
  - Could you please elaborate briefly why not?
    - My students and colleagues use remote sensing data
    - Not yet, but I think they could be useful for my work
- Do you use Copernicus Data Services? **Yes/No** (n=21)



  - Could you please elaborate briefly why not?
    - Limited data analysis resources
    - My students and colleagues use the Data Services
    - Not currently needed to answer my research questions
    - I haven't used them so far, but I intend to.
    - We don't directly use Copernicus data but we participate in projects where these data are used.
- What Copernicus service(s) are you using in your work? (n=15)



- How many years of experience do you have in using Copernicus EO for modelling? (n=14)



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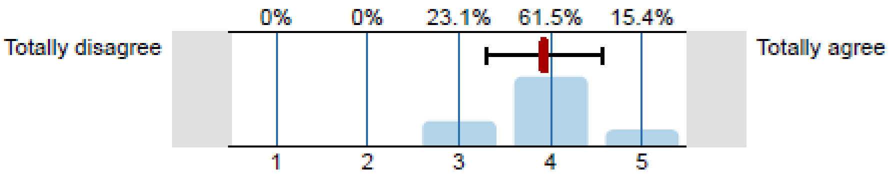
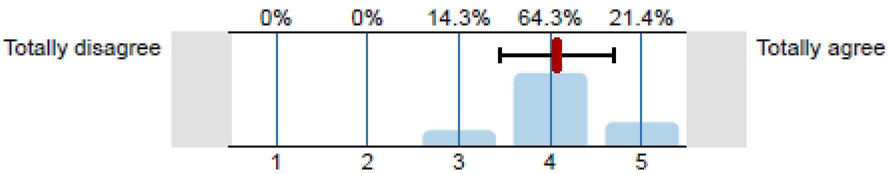
For the following statements please select what is applicable for you.

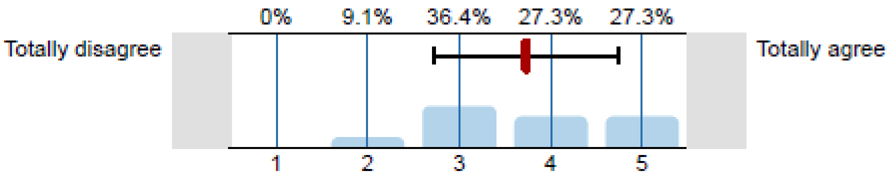
- Copernicus data portals are easy to find



- Copernicus data are accessible



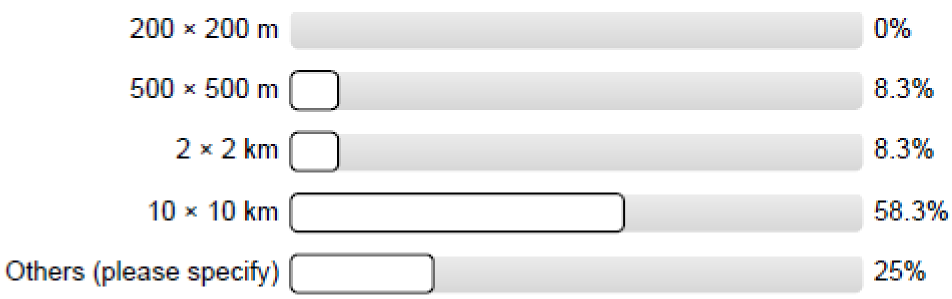
- Copernicus data are easy to use in a model



Remarks: Please provide any feedback you might have.

  - We have been using DIAS to collect data and to my awareness access was not for free.
  - When using the river altimetry portal, it is hard to see the location of the virtual stations for detailed selection (points on map too small).
  - My colleagues do the data collection and processing.

- What parameters are you using in your work?
  - Precipitation - Spatial resolution (n=12)



Others: CHIRPS (5km)

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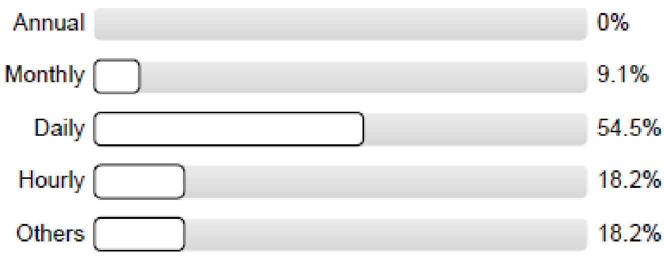
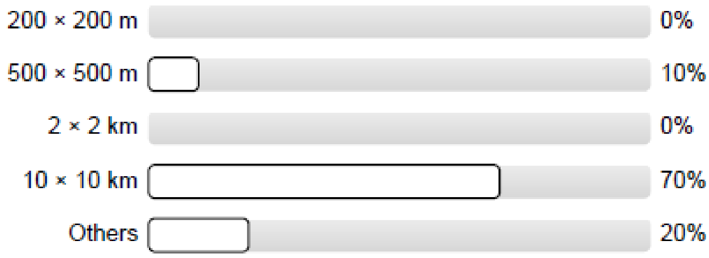
- Depending on the application, but mainly it is projections or seasonal forecasts at 12 or 18 km resolution
    - Precipitation - Temporal resolution (n=11)

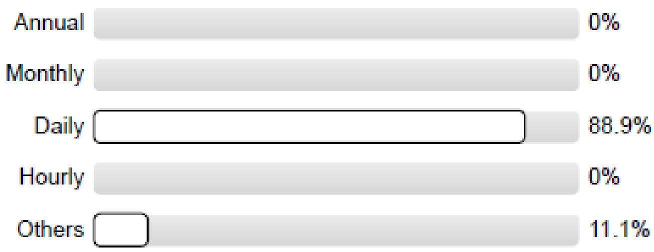


    - Soil moisture - Spatial resolution (n=10)



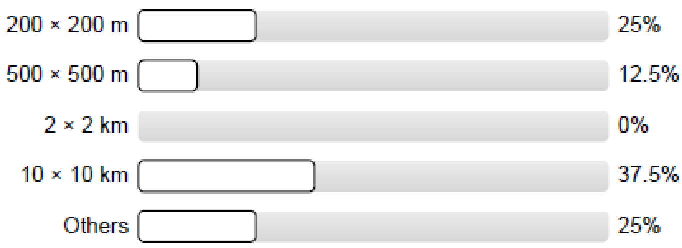
Others:

- 0.25 degree
- Not used due to limitations, calculated using soil moisture balance
    - Soil moisture - Temporal resolution (n=9)



Others: Not used due to limitations

    - Evapotranspiration - Spatial resolution (n=8)



Others:

- 10 x 10 km up to 3 x 3 km
- 250 x 250 m or 100 x 100 m or 30 x 30 m (WaPOR)

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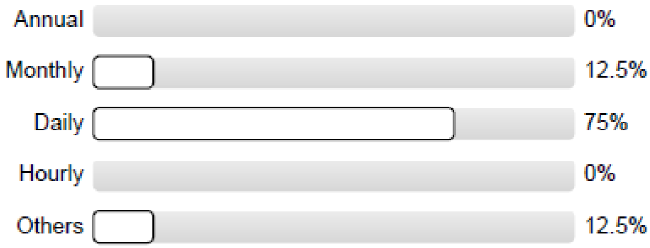
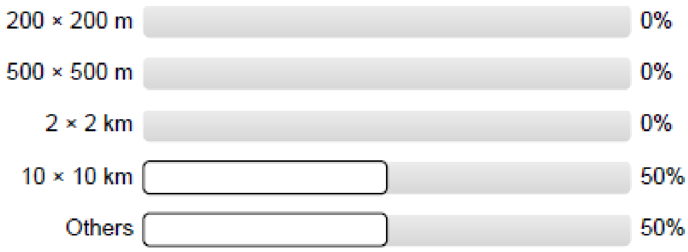
- Evapotranspiration - Temporal resolution (n=8)



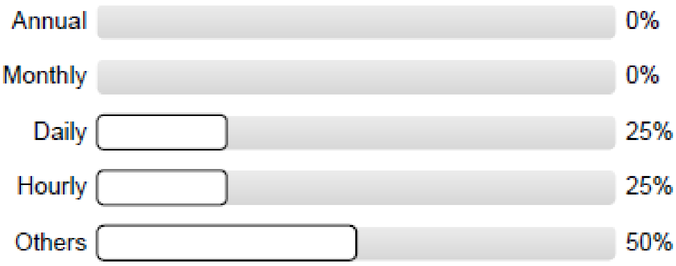
Others: Decadal (WaPOR)

- Surface runoff - Spatial resolution (n=4)



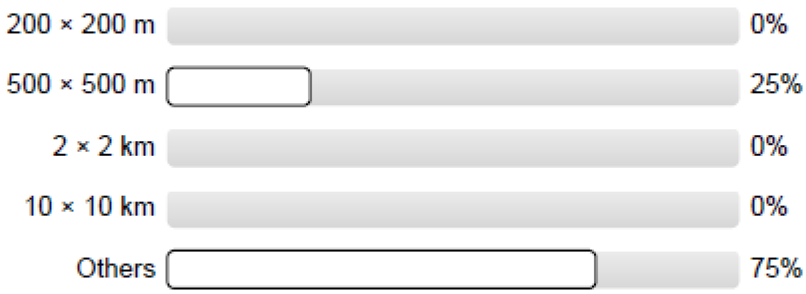
Others: It depends on subbasin shape; or Not used, calculated from model

- Surface runoff- Temporal resolution (n=4)



Others: 5 x 5 km; or Not used, calculated from model

- River discharge - Spatial resolution (n=4)



Others:

- 5 x 5 km
- Not used, calculated from model
- It depends on the river reach every time there is a new tributary

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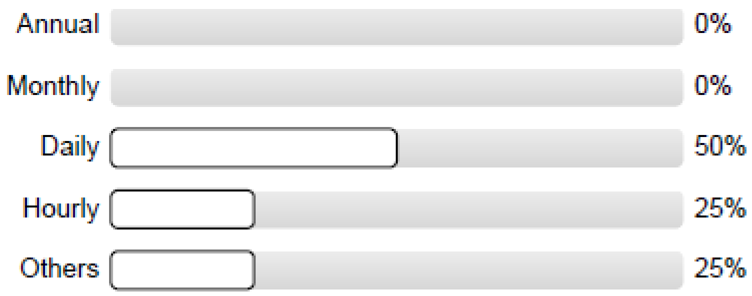
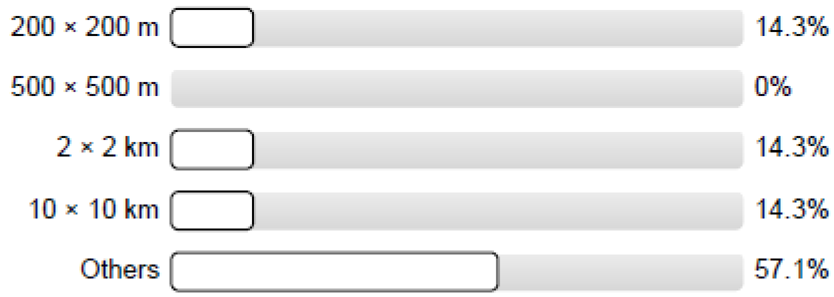
- River discharge - Temporal resolution (n=4)



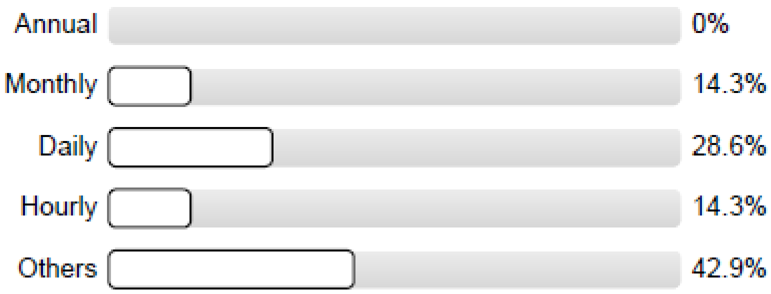
Others: Not used, calculated from model

- Flood extent - Spatial resolution (n=7)



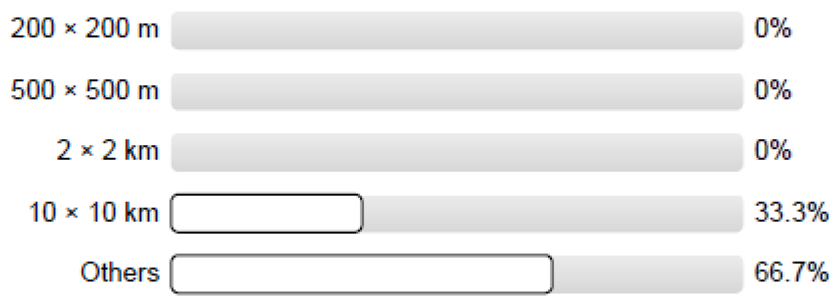
Others: 10 x 10 m; or 5 x 5 km

- Flood extent - Temporal resolution (n=7)



Others: 6 hours

- Inland water temperature - Spatial resolution (n=3)



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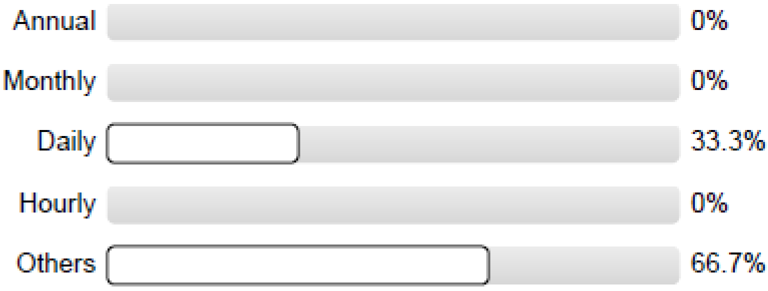
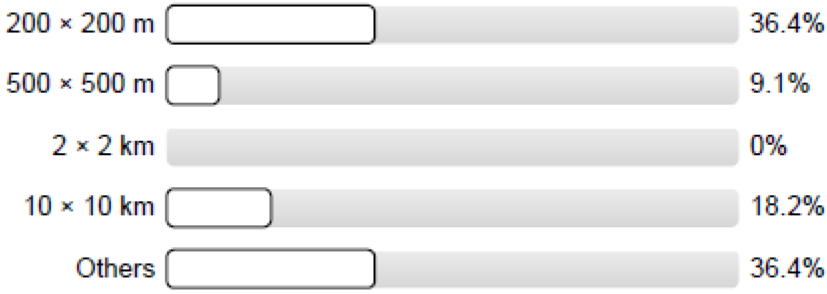
- Inland water temperature - Temporal resolution (n=3)



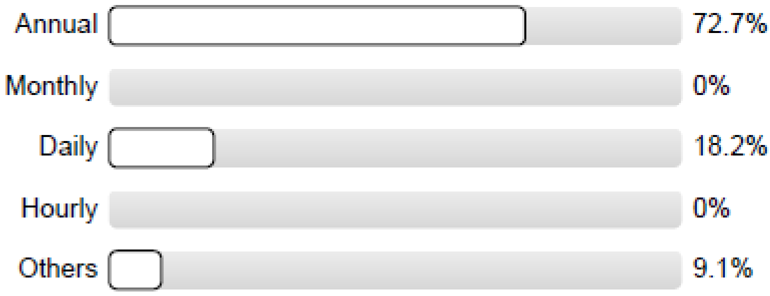
- Land use / land cover - Spatial resolution (n=11)



Others:

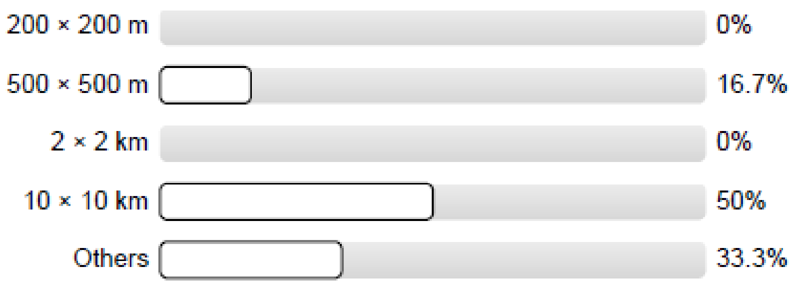
- 100 x 100 m
- 10 x 10 m
- WorldCover 10 m

- Land use / land cover - Temporal resolution (n=11)



Others: Static in time

- Land surface temperature - Spatial resolution (n=6)



Others: 60 x 60 m

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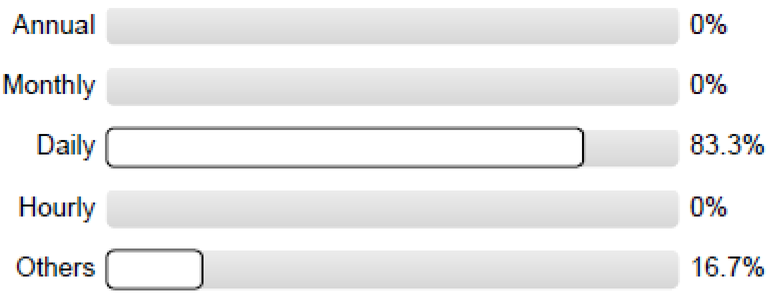
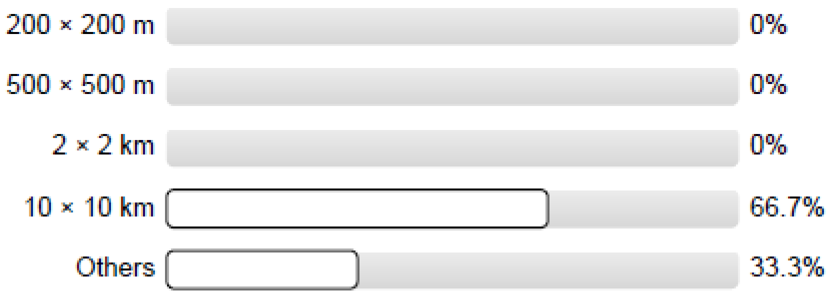
- Land surface temperature - Temporal resolution (n=6)

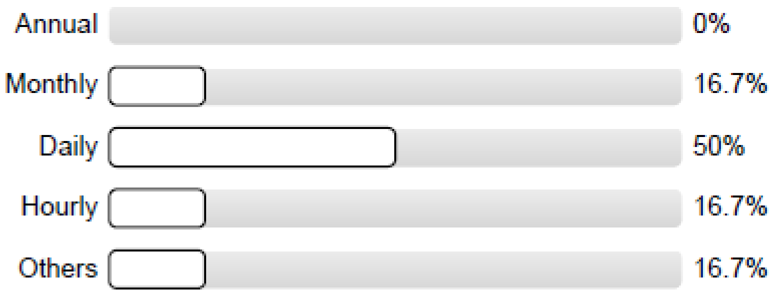


- Air temperature - Spatial resolution (n=6)

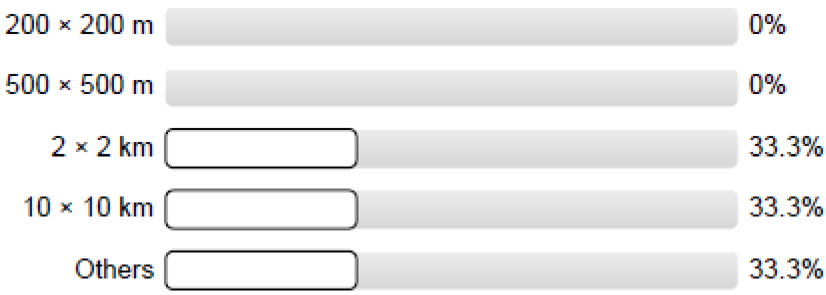


Others: Similarly, for precipitation. It comes in 12.5 km (i.e. Euro-CORDEX projections) or 18 km (i.e. ECMWF SEAS5 seasonal forecasts)

- Air temperature - Temporal resolution (n=6)



- Bathymetry - Spatial resolution (n=3)



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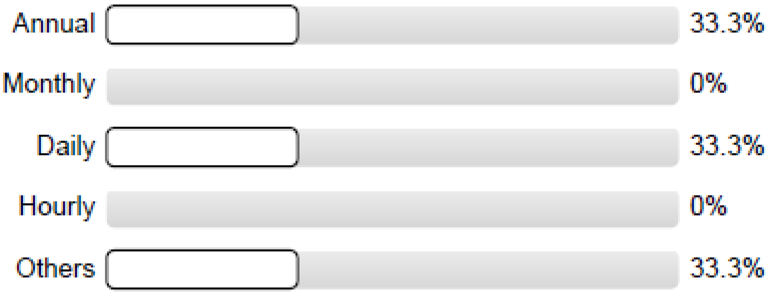
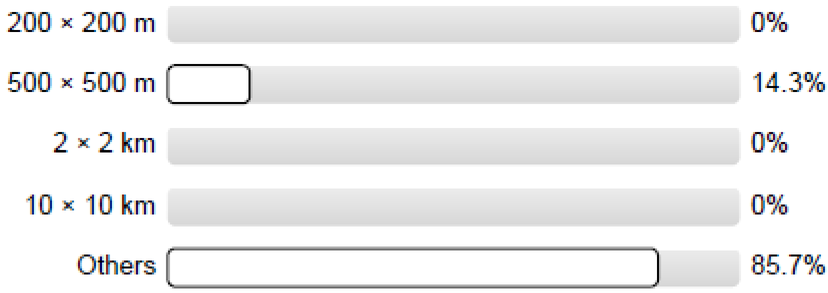
- Bathymetry - Temporal resolution (n=3)

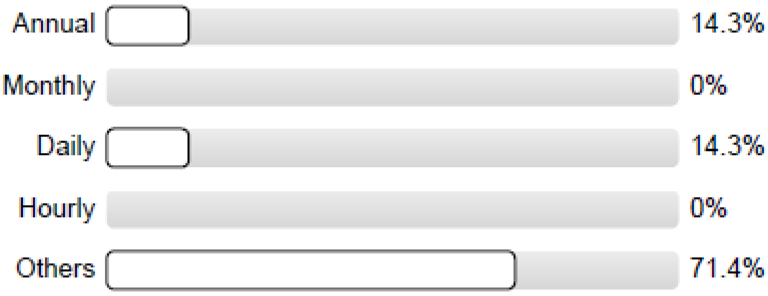


- DEM - Spatial resolution (n=7)



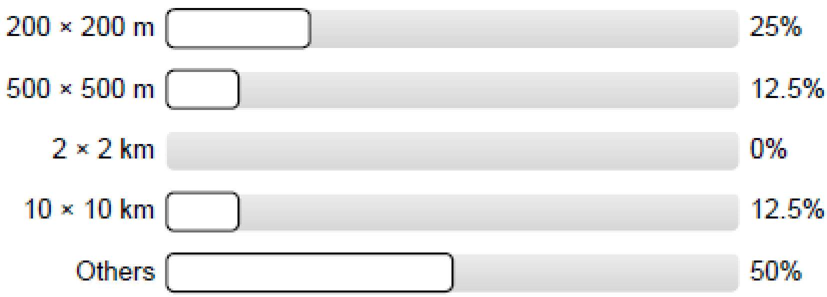
Others: 10 x 10 m; 30 x 30 m; 90 x 90 m; Copernicus DEM 30 m

- DEM - Temporal resolution (n=7)



Others: Temporal resolution is not so important for me; or Static in time

- Water levels (lakes and rivers) - Spatial resolution (n=8)



Others: 10 x 10 cm; or Depending on the water body

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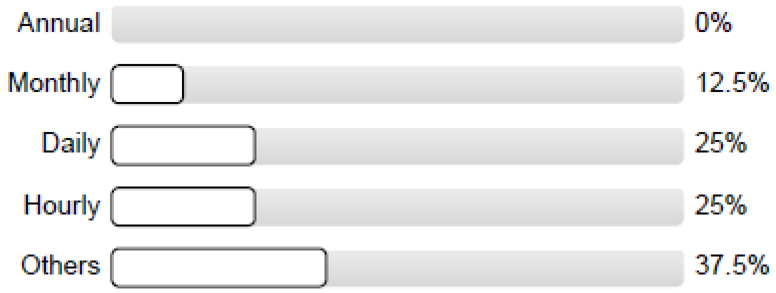
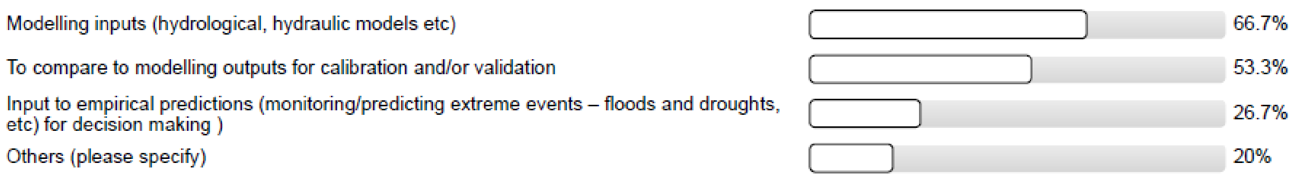
- Water levels (lakes and rivers) - Temporal resolution (n=8)



Others: Depending on Earth Observation availability; Depending on availability

- How are the previous parameters used? (n=15)

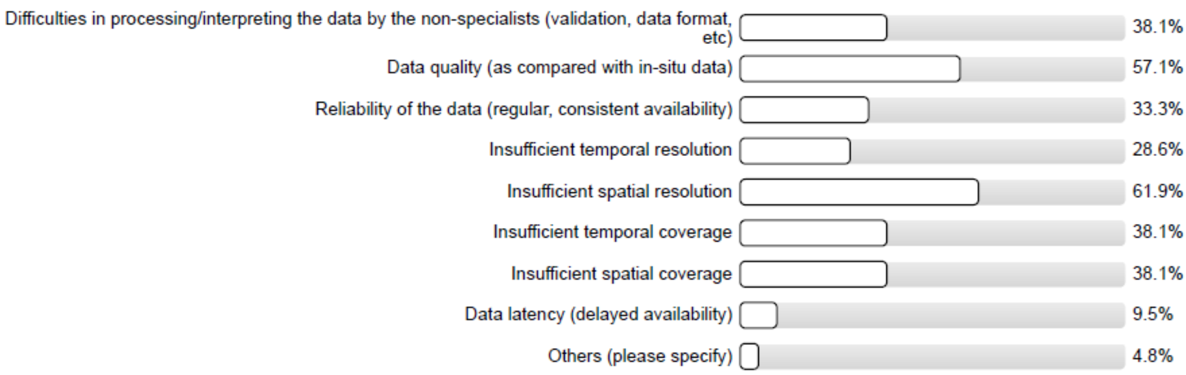


Others:

- For comparison of satellite and in-situ lake water level data in order to improve a methodology for correcting satellite data.
- Signal separation of terrestrial water storage variations.
- Water productivity assessments.

Current needs for Remote Sensing Copernicus data services for modelling:

- Which are the main limitations and gaps you can highlight? (n=21)



Others: In some products cropping of data is not easy.

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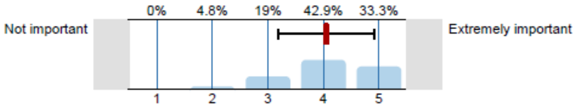
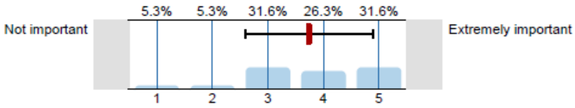
- Please state your interest for the following options of improved Copernicus Data Services.

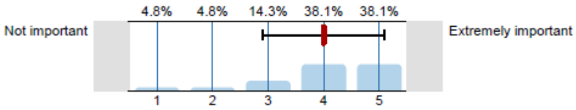
Higher spatial coverage



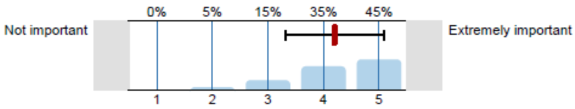
Processing, interpreting the data by the non-specialists



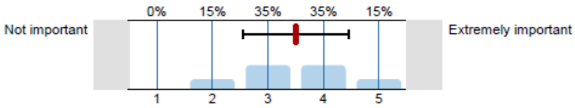
Remote sensing data reliability



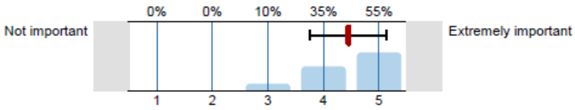
Remote sensing data quality



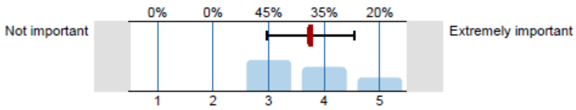
Higher update frequency



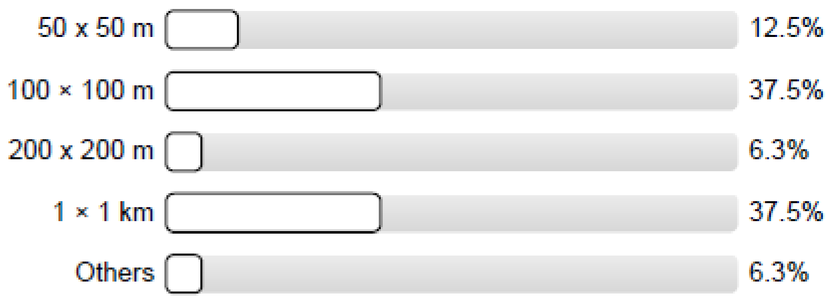
Higher spatial resolution



Higher temporal resolution



- What would be your preferred spatial and/or temporal resolution and update frequency for Copernicus Data Services?
-
  - Precipitation - Spatial resolution (n=16)



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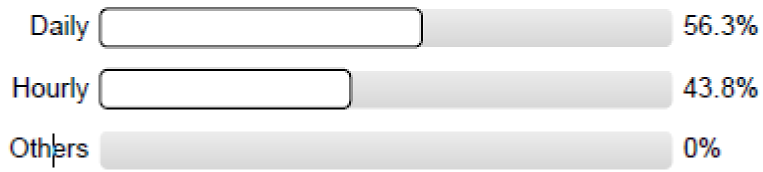
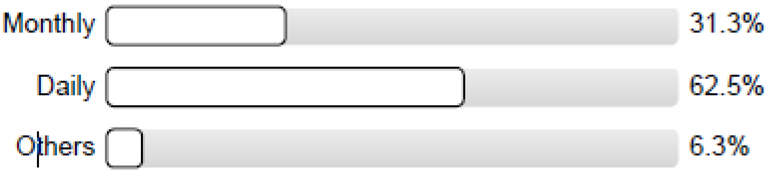
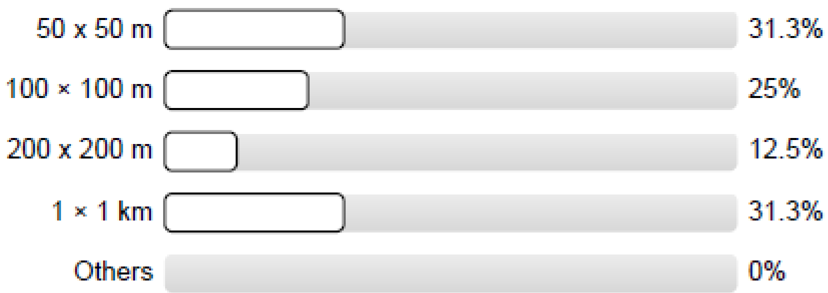
- Precipitation - Temporal resolution (n=16)



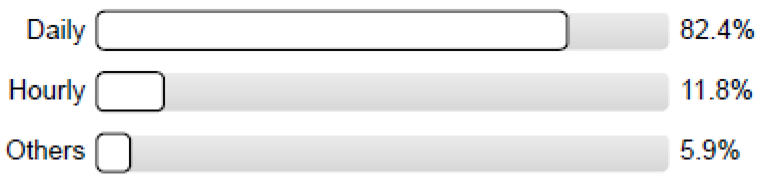
- Precipitation – Update frequency (n=16)



- Soil moisture - Spatial resolution (n=16)

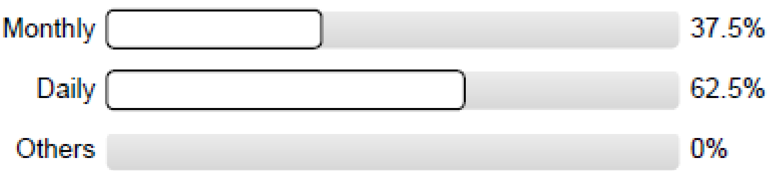


- Soil moisture - Temporal resolution (n=17)



Others: 6-12 hrs

- Soil moisture – Update frequency (n=16)



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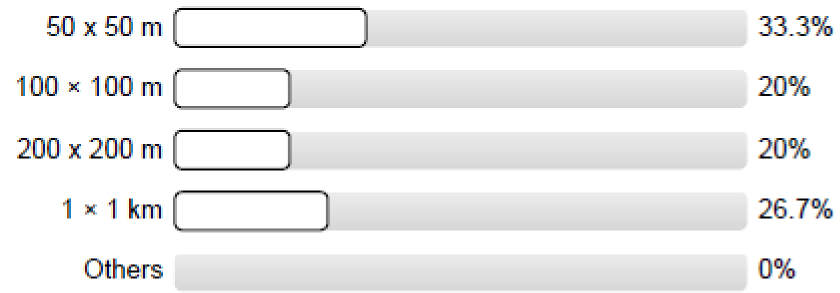
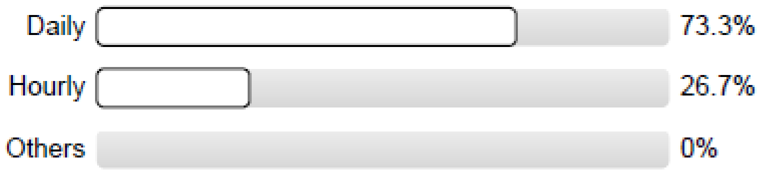
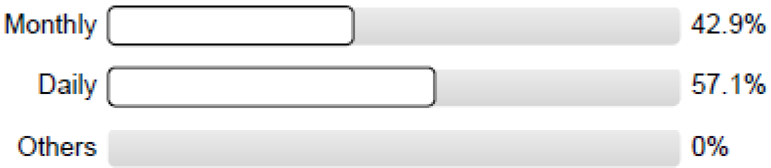
- Evapotranspiration - Spatial resolution (n=15)



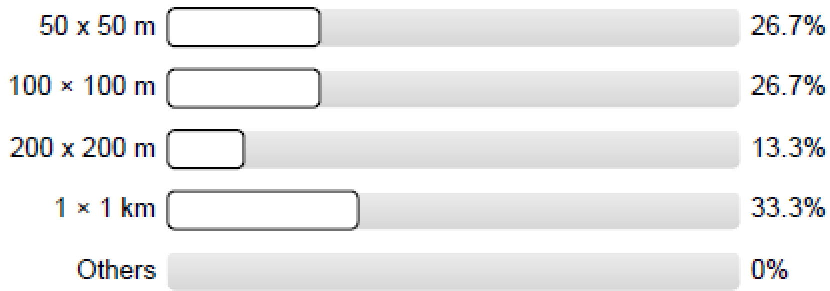
- Evapotranspiration - Temporal resolution (n=15)



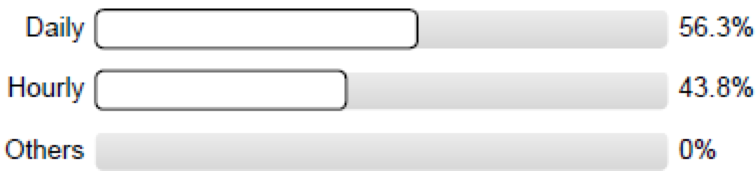
- Evapotranspiration – Update frequency (n=14)



- Surface runoff - Spatial resolution (n=15)



- Surface runoff - Temporal resolution (n=16)



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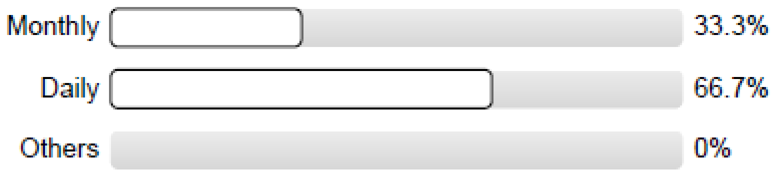
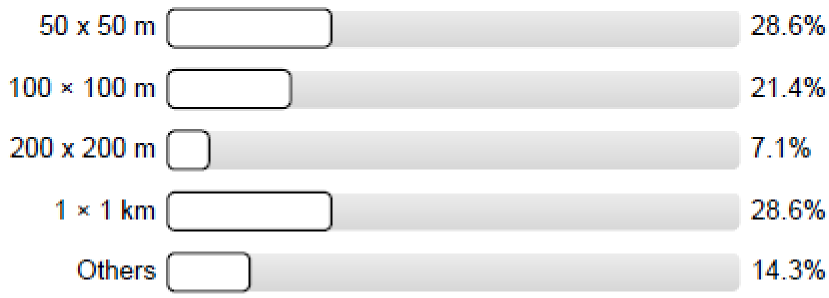
- Surface runoff – Update frequency (n=15)

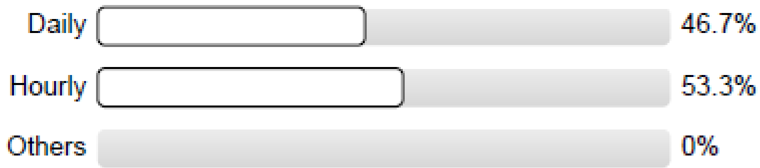


- River discharge - Spatial resolution (n=14)

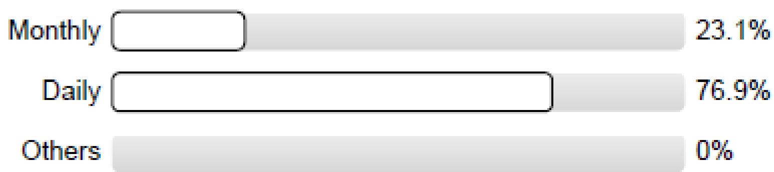


Others: 1 x 1 m

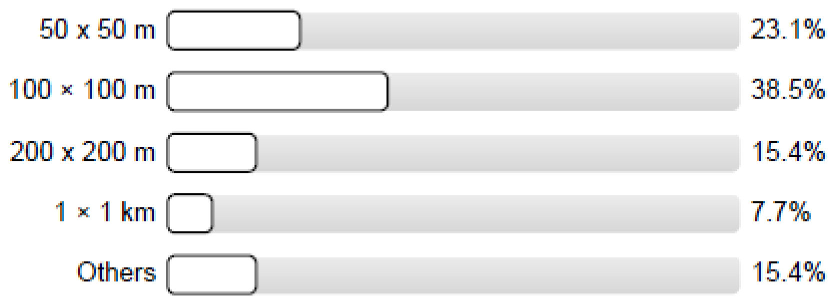
- River discharge - Temporal resolution (n=15)



- River discharge – Update frequency (n=13)



- Flood extent - Spatial resolution (n=13)



Others: 10 x 10 m

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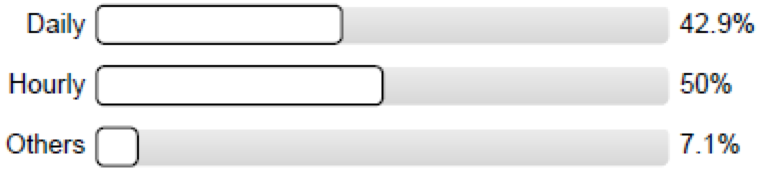
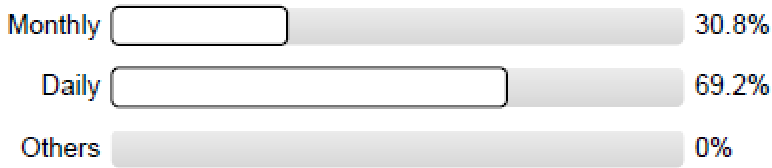
- Flood extent - Temporal resolution (n=14)

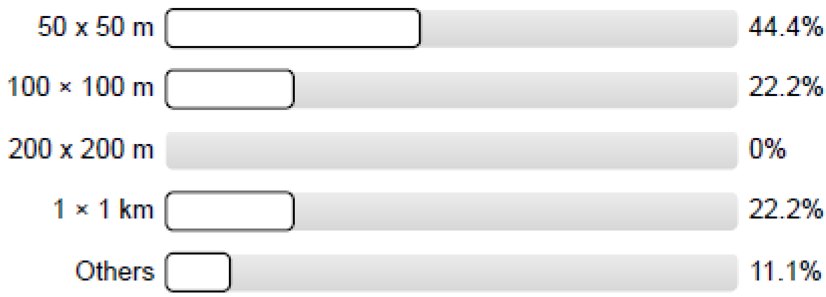


Others: 6-hourly

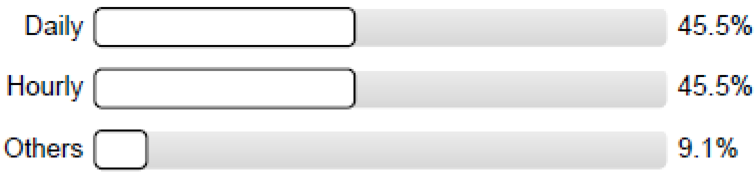
- Flood extent – Update frequency (n=13)



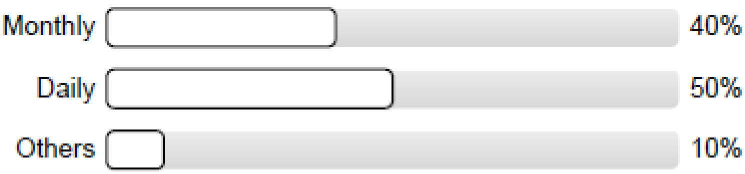
- Inland water temperature - Spatial resolution (n=9)



- Inland water temperature - Temporal resolution (n=11)



- Inland water temperature – Update frequency (n=10)



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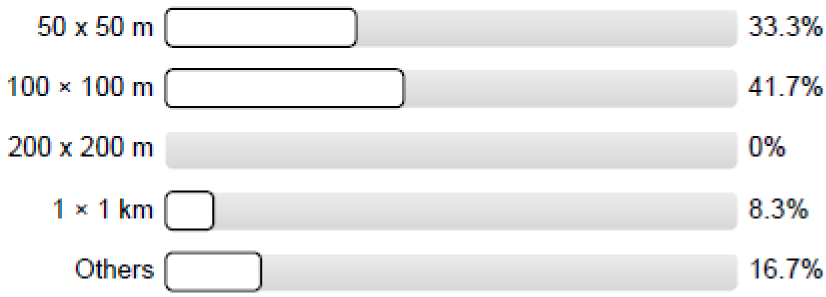
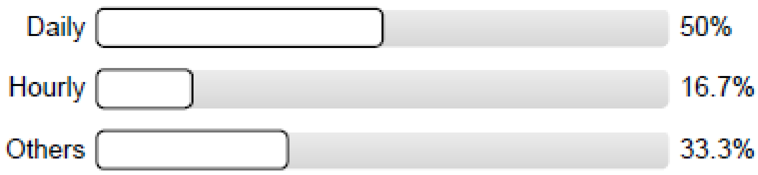
- Land use / Land cover - Spatial resolution (n=12)



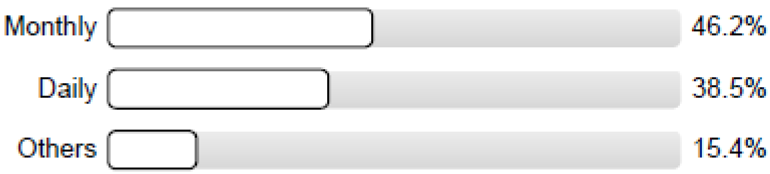
Others: 5 x 5 m

- Land use / Land cover - Temporal resolution (n=12)



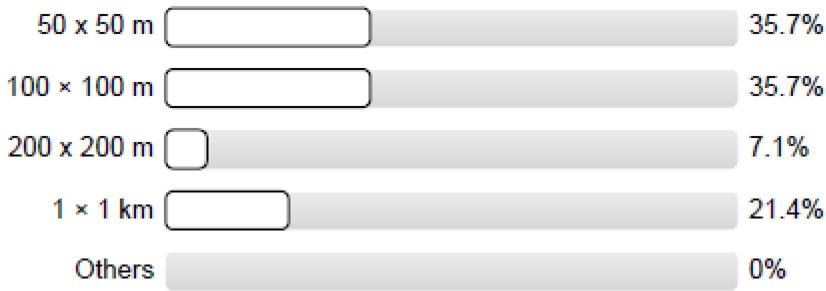
Others: Monthly or Seasonal

- Land use / Land cover – Update frequency (n=13)

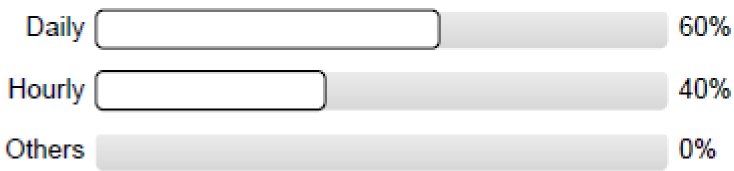


Others: Yearly; or Yearly or seasonal

- Land surface temperature - Spatial resolution (n=14)



- Land surface temperature - Temporal resolution (n=15)



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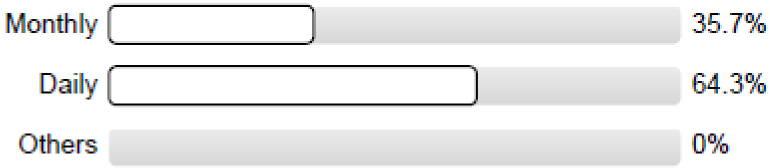
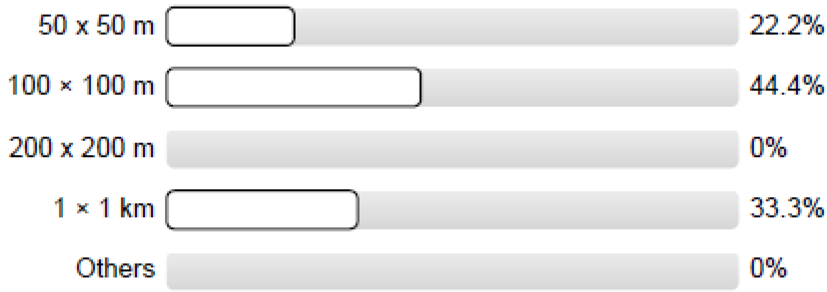
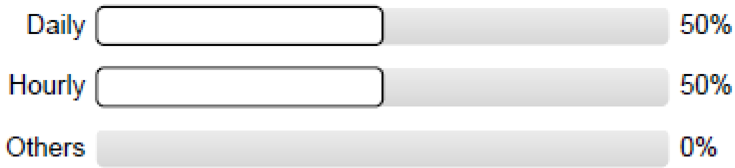
- Land surface temperature – Update frequency (n=14)



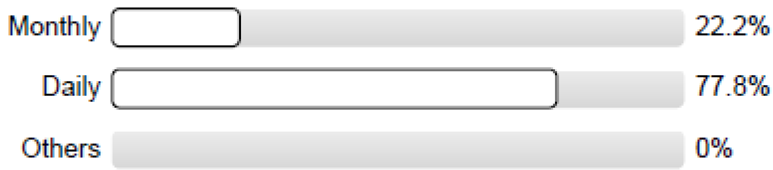
- Air temperature - Spatial resolution (n=9)



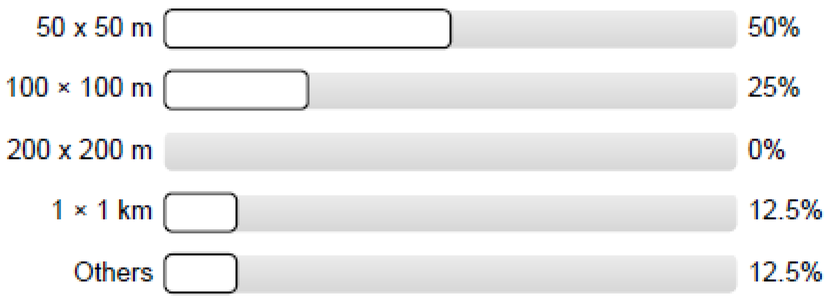
- Air temperature - Temporal resolution (n=10)



- Air temperature – Update frequency (n=9)



- Bathymetry - Spatial resolution (n=8)



Others: 5 x 5m

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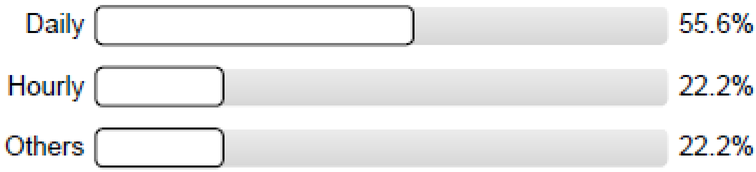
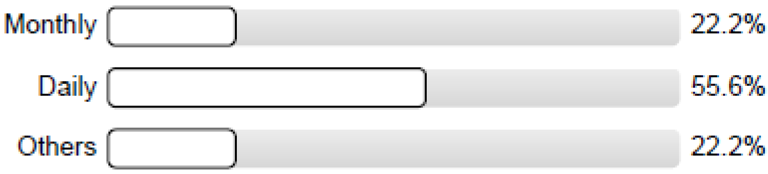
- Bathymetry - Temporal resolution (n=9)



Others: Monthly or Annual; or Annual

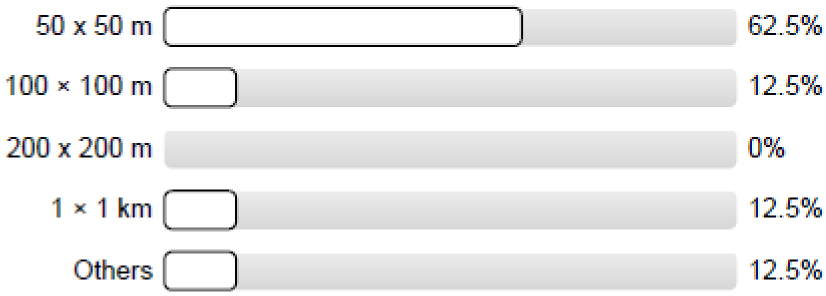
- Bathymetry – Update frequency (n=9)



Others:

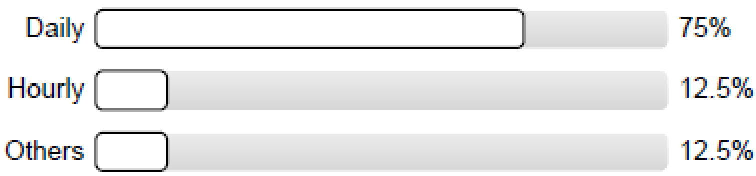
- Monthly or Annual
- Yearly

- DEM - Spatial resolution (n=8)



Others: 10 x 10 m

- DEM - Temporal resolution (n=8)



Others: Monthly or annual

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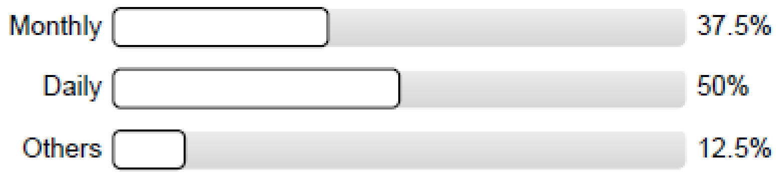
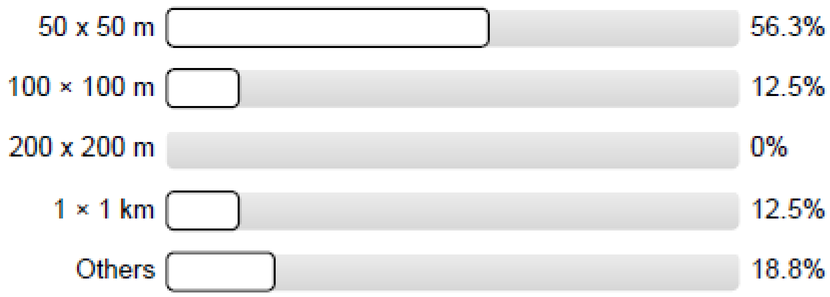
- DEM – Update frequency (n=8)



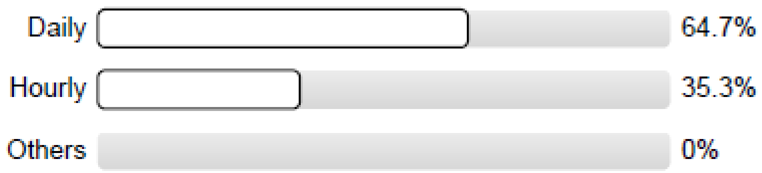
Others: Monthly or annual

- Water levels (lakes and rivers) - Spatial resolution (n=16)

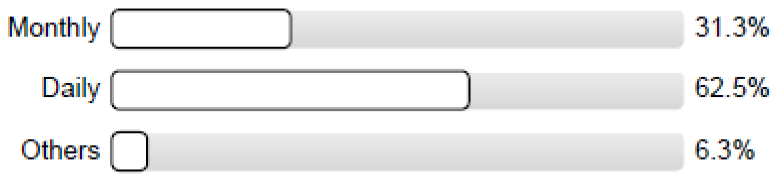


Others: 1 x 1 m; or 10 x 10 cm

- Water levels (lakes and rivers) - Temporal resolution (n=17)



- Water levels (lakes and rivers) – Update frequency (n=16)



Others: Yearly

- Please write any other comment or observation you think is important for this needs assessment
  - Copernicus data service for the ECV (Essential Climate Variable) groundwater storage.
    Copernicus data service for the ECV (Essential Climate Variable) terrestrial water storage (TWS).
  - DOI and clear dataset citation
  - I think that more products related to groundwater are needed (e.g. groundwater storage change, or even total water storage change).

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