ECMWF Copernicus Procurement

Invitation to Tender

Copernicus Climate Change Service

Operational Copernicus Climate Change Water Service

Volume II: Specification of Requirements

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1. Introduction

Copernicus is the European Union's flagship Earth-observation programme created to achieve operational monitoring of the atmosphere, oceans, and continental surfaces. It aims to provide reliable, validated information services for a range of environmental and security applications. The Copernicus Climate Change Service (C3S) responds to environmental and societal challenges associated with climate change. The service gives access to information for monitoring and predicting climate change and thus helps support adaptation and mitigation. C3S produces and brokers a wide range of data and products describing the past, present, and future of the climate system. This includes global and regional reanalysis, Essential Climate Variables (ECVs), near-term climate predictions, climate projections and a variety of sectoral climate information. The data are offered to users through the Climate Data Store (CDS) and the Atmosphere Data Store (ADS).

2. Context

During the initial phase of Copernicus (COP1), C3S focused on meeting the requirements of various sector-specific activities. Through the Sectoral Information System (SIS) initiatives, C3S catered to the needs of users across different sectors, including the water sector, serving not only Europe but also extending its support to a global user base. This involved providing tailored climate-related information and services that were valuable and relevant to users in diverse fields and regions, ensuring a broader reach and impact beyond Europe's borders. During the second phase of Copernicus (COP2), different operational SIS activities for the water sector have been established at the seasonal timescale.

The current operational hydrological services, one at the global and one at the European scale, produce timely, high quality, probabilistic pan-European and global multi-model hydrological seasonal forecast and retrospective forecast (also known as reforecasts or hindcasts) information, and make such information available through the Copernicus Climate Data Store (CDS), in synergy with the Copernicus Emergency Management Service (CEMS) hydrological seasonal forecasting component.

The current European service provides operational seasonal forecast and reforecast information of river discharge, runoff, snow depth water equivalent and soil moisture out to 6 months lead time at daily and monthly resolution from three hydrological models (at grid resolution of 5 km) and from a single model (an ensemble) at catchment level driven by two different dynamic meteorological seasonal forecast simulations (two models selected from the C3S multi-model system), after bias adjustment. The hydrological models include simulations from the JRC LISFLOOD model as used by the European Flood Awareness System Seasonal forecast (EFAS-Seasonal).

The current Global service, in synergy with the European service, provides operational seasonal forecast and reforecast information of river discharge, runoff, snow depth water equivalent and soil moisture out to 6 months lead time at daily and monthly resolution from five gridded hydrological models (at grid resolution of 10km) driven by dynamic meteorological seasonal forecast simulations, after bias adjustment. The hydrological models include simulations for the JRC LISFLOOD model as used by the Global Flood Awareness System Seasonal forecast (GloFAS-Seasonal) and the ECMWF land surface model (ECLand).

The information from the European and global C3S seasonal hydrological forecast service will be delivered and operationally published every month on the CDS, from Q2 2024.

During COP1, the C3S European Operational Sectoral Information System (SIS) for the Water Sector provided information also at the long-term climate projection timescale, by providing multi-model climate impact indicators at the pan-European scale, including all time horizons (historical, seasonal and multi decadal) within a single framework. This information is currently available in the CDS here[1].

[1] https://climate.copernicus.eu/operational-service-water-sector

2.1. The Climate Data Store

The backbone of the C3S is the cloud-based Copernicus Climate Data Store[2] (CDS) that provides users with a single point of access to quality assured climate and meteorology data. The datasets may be stored in different data centres worldwide or in remote servers, but this complexity will be transparent to CDS users. C3S data is offered with open access and is free to use under the Copernicus data licence. Data are properly documented and enriched by appropriate quality attributes provided by the EQC (Evaluation & Quality Control). All CDS data and tools are accessible from the C3S website as well as via open Application Programming Interfaces (APIs).

The CDS data catalogue provides access to climate datasets via a searchable catalogue. Categories of data include Climate Data Records (CDRs) and Interim Climate Data Records (ICDRs), quality-controlled archives of in-situ climate observations, reprocessed satellite data records, data from climate reanalysis, seasonal forecasts, climate model simulations, and a variety of derived climate impact indicators. Multiple datasets will be available in each category, e.g., for most of the Global Climate Observing System (GCOS) Essential Climate Variables (ECVs), on global or regional domains, with varying spatial resolutions and temporal coverage, from different data providers, based on different methodologies, etc. Several entry catalogues are relevant in the context of this tender, including: the ERA5 and ERA5 Land global reanalysis, CERRA European regional reanalysis, WFDE5 bias-corrected reanalysis, different river discharge information at the historical timescale and seasonal forecast timescale, and related indicators at the climate projection timescale.

2.2. Earthkit

EARTHKIT is a an open-source python project led by ECMWF which provides powerful and easy-to-use tools for working with earth system data. Earthkit users can access CDS and ADS datasets directly and use a range of processing, analysis and visualisation tools without having to worry about data formats. The development design of earthkit is modular and open source to encourage contributions from the wider community and contracted partners. The packages are fully documented and available for the whole world to use. Initial documentation is available here[3].

3. Objectives

This Invitation to Tender (ITT) aims to establish **a unique operational C3S water service** as a core provider of European and global scale climate and hydrological information to assist decision-making for a diverse range of users in the water sector at seasonal and climate timescales. Data will be delivered through the CDS and will offer a user-friendly web interface complete with links to data, applications, and demonstrations. This service encompasses historical data, a seasonal forecasting component, a collection of climate projection outlooks and a user service. Its design is flexible, ensuring the provision of consistent climate inputs for hydrological modeling (supporting both hydrological science and downstream operations), alongside a suite of pre-computed hydrological variables (from a multi-model composition, with possibility to include AI-based models) and indicators (supporting e.g. policy and decision-makers).

The primary objectives of the new service are as follows: Firstly, to generate a fully operational water service across timescales (historical, seasonal, multi-decadal), expanding on the current C3S offer to reach a wider audience within the water sector. Secondly, to strengthen collaboration with CEMS and propose the thorough integration of hydrological models, such as JRC LISFLOOD and ECMWF ECLand, into the C3S Climate Offer. Simultaneously, any user interested in contributing to the hydrological multi-model information with their own hydrological model, utilizing the same post-processed climate forcing data, will have access to all

[2] https://cds.climate.copernicus.eu
[3] https://earthkit.readthedocs.io/en/latest/index.html

necessary tools to do so downstream of the service. The service evolution will be designed so that any downstream models (including AI-based models) adhering to a defined framework can be added to the multi-model service in the CDS.

4. Contract summary for Lot 1, Lot 2 & Lot 3

This ITT invites Tenders for three distinct Lots, as follows: to produce timely, high-quality information for the water sector at the seasonal and historical timescales (Lot 1), to produce timely, high-quality information for the water sector at the multidecadal to centennial timescales (Lot 2), as well as to provide a user-oriented service and interface (Lot 3).

For each Lot, ECMWF intends to award a single Framework Agreement for a period of **36 months**, which shall be implemented via Service Contracts expected to commence in Q4 2024.

Tenderers are invited to submit their Tenders for any one of the Lots, a combination of two, or for all three Lots. In cases where a Tenderer opts to submit Tenders for more than one Lot, it is mandatory that each Tender is presented as a separate submission, with its own set of documents, including but not limited to, technical proposals, pricing tables and any required supporting documents. Tenderers must ensure that the submissions for each Lot are independently viable and stand on their own merits. At the same time, Tenderers should indicate what synergies, including cost savings, can be achieved should more than one Lot be awarded to them.

Tenderers shall include in their Tender any necessary computing and storage needs and associated estimated costs (pricing tables excel file). The modernized CDS may offer some cloud resources, subject to evaluation at the negotiation phase.

4.1. Summary of Lot 1 objectives

The successful Tenderer for Lot 1 – the historical to seasonal forecast multi-model component of the C3S operational water service – will:

- Establish an operational multi-model European and global-scale hydrological prediction service at equivalent service levels to that currently operational. The service will produce hydrological reanalysis, seasonal forecast, and seasonal reforecast datasets and push them to the CDS.
- Undertake a major upgrade to both the European and global service to add additional and common seasonal climate model forcings, produce a new Ensemble Streamflow Prediction (ESP) forecast for benchmarking skill gained from seasonal climate models, include additional hydrological models if demonstrated added benefit to multi-model forecast skill, and investigate the value of increased hydrological spatial resolution for seasonal hydrological prediction.
- Align the European and global service further, including common data formats and archival, variables, bias adjustment and downscaling techniques, and evaluation protocols.
- Ensure the new operational framework is flexible to allow other model groups to contribute their hydrological models (including AI hydrological models) consistent with the defined technical specifications.
- Produce each month a multi-model seasonal hydrological status and outlook product. This product should summarise the status of current hydrological conditions (e.g. has river discharge in the past month been anonymously high or low) and a forecast outlook of the expected evolution of those conditions (e.g. is river discharge expected to be anonymously high or low in the following month(s)). The refinement of this product will be guided by feedback from Lot 3, particularly how such a product should be designed with multiple climate and hydrological models.
- Collaborate with ECMWF on integration of ECLand and CEMS EFAS- and GloFAS-Seasonal, especially at the beginning of the contract and during major upgrades.

- Collaborate with Lot 3 and Lot 2 to ensure consistency in the selection of hydrological information and in seasonal hydrological forecast use cases.
- Provide operational user support throughout the contract to fix bugs and facilitate user understanding, and utilization of the service and data through comprehensive user guides.

4.2. Summary of Lot 2 objectives

The successful Tenderer under Lot 2 – the multi-decadal to centennial multi-model component of the C3S operational water service – will:

- Generate and make available climate forcing fields to drive multi-model hydrological simulations, based on a large multi-model CMIP and CORDEX climate simulations selection.
- Establish and implement a robust methodology for any of the following steps: bias adjustment, downscaling, re-gridding and evaluation metrics for selecting and processing climate forcing variables needed for hydrological simulations.
- Generate and publish in the CDS impact climate & water time-space aggregated indicators and their quality metrics, based on multi-model hydrological simulations relevant to water management in different sectors, including energy and agriculture (e.g., indicators for water resources management, flood management, water scarcity, water quality...)
- Develop protocols for integrating downstream hydrological simulations, including AI hydrological models, into the CDS and contribute to the multi-model offer.
- Collaborate with Lots 1 & 3 to ensure consistency in the selection of climate and hydrological models, the definition of indicators, and use cases.
- Provide regular updates and maintenance to accommodate new datasets, service elements, and user requirements.
- Facilitate user understanding and utilization of the service and data through comprehensive user guides.

4.3. Summary of Lot 3 objectives

The successful Tenderer under Lot 3 – user oriented elements of the C3S operational water service – will:

- Present the C3S water service and all its components to the broad water-service audience.
- Utilise links with user communities and key stakeholders to ensure the water activities products and services are aligned with user priorities, needs and requirements.
- Exploit the data from Lots 1 & 2 to create user-oriented applications and further processed information, taking advantage of the CDS infrastructure.
- Ensure all software developed within Lot 3 is consistent with ECMWF software strategy, including, where appropriate Earthkit.
- Engage with key stakeholders to develop ‘use cases’, showcasing how C3S activities can support and add value to users requiring timely and high-quality climate information in the water management sector.
- Co-define and implement a ‘user engagement strategy’ with C3S user engagement team and develop bespoke training and outreach materials to showcase the developments in the C3S water service.
- Ensure all user requirements are recorded and managed according to the activities performed in the user intelligence / Evaluation and Quality Control (EQC) activities.
- Develop and maintain service and data user guides, with Lots 1 & 2 contribution, to maximize usability of the products from the C3S water service.
- Inform Lots 1 & 2 of gaps in data provision.
- Assess user needs and requirements to inform C3S and Lots 1 & 2 of perceived gaps in the service offering, leading to evolution of the water services. This will require close co-ordination with Lots 1 & 2.

5. Background Information on the current C3S water service

During COP1, through the SIS, C3S addressed the needs of water users at the climate change and seasonal scales with the development of two web applications[4]: 1) the European hydrology and climate data explorer and 2) Hydrological seasonal forecast explorer.

5.1. Description of the existing service

Under COP2, the service for water was extended with a strong operational focus. The current operational phase of the C3S water service was provided by the two contracts awarded as a result of the C3S2_410 ITT (Multi-model Operational Hydrological Prediction Service; Lot 1 – Global and Lot 2 – Europe). The service is running operationally at ECMWF on the Atos supercomputing facility in Bologna[5]. The production suites run the seasonal hydrological forecast chain each month and push data to the CDS (catalogues expected to be published in Q2 2024). The suites (one for European domain and one for global) are written using the Python ecFlow packages, pyflow[6] and Wellies[7]. The suites were developed by the current contract working closely with ECMWF technical staff and are currently being maintained by ECMWF production staff in an operational production environment.

An overview of the current multi-model operational hydrological prediction service is provided in Figure 1. Key to both the European and global service is the integration and synergy with the seasonal hydrological component of the Copernicus Emergency Management Service (CEMS)[8] European and global Flood Awareness Systems (EFAS & GloFAS; see documentation here[9]), which is run by ECMWF as its role as CEMS computational centre.

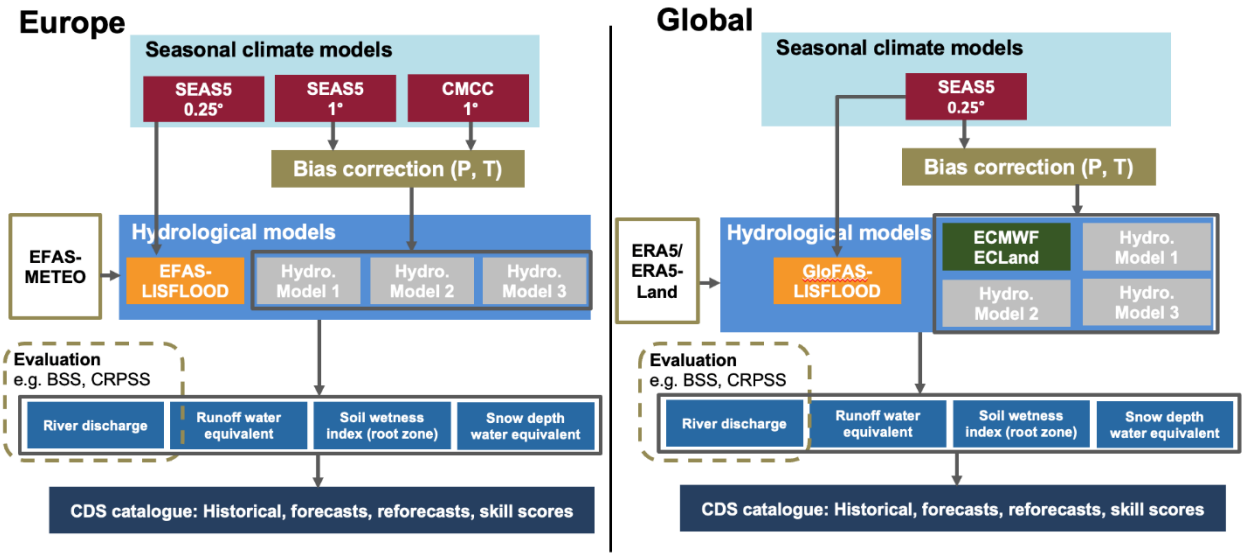

Figure 1: Current structure of the C3S multi-model hydrological prediction service for contract C3S2_410_Lot1 (global) and C3S2_410_Lot2 (Europe)

At the start of each month, the C3S operational hydrological prediction service generates **ensemble seasonal hydrological forecasts** at a **daily time step** out to **6 months lead time**. The JRC LISFLOOD hydrological modelling used in EFAS and GloFAS is contributed to the C3S service by ECMWF/CEMS so strong synergy

[4] https://climate.copernicus.eu/operational-service-water-sector
[5] https://www.ecmwf.int/en/computing/our-facilities/supercomputer-facility
[6] https://pyflow-workflow-generator.readthedocs.io/en/latest/
[7] https://github.com/ecmwf/pyflow-wellies
[8] https://emergency.copernicus.eu/
[9] https://confluence.ecmwf.int/display/CEMS/CEMS-Flood

between CEMS and C3S seasonal hydrological services is essential. In the current contract three hydrological models at the European-scale are included in addition to EFAS-LISFLOOD. At the global scale three hydrological models are included in addition to GloFAS-LISFLOOD and ECMWF ECLand (formally known as HTESSEL).

At the European scale, hydrological forecasts are initialised using the operational meteorological forcing data from EFAS, EFAS-METEO[10], currently gridded across Europe at ~1.5km. Data are available from 1990 at 6h time step and are available in near-real-time. C3S provides a real-time multi-system seasonal climate forecast service with forecast and reforecast (hindcast) data available through the C3S Climate Data Store (CDS) at daily time steps[11]. The ECMWF Seasonal Forecast (SEAS5) is currently used as forcing for all hydrological models, with the seasonal forecast from Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) to force three additional hydrological models. For the three additional hydrological models (excluding EFAS-LISFLOOD), the seasonal climate forecasts are bias adjusted to EFAS-METEO using a quantile-mapping method.

At the global scale, hydrological forecasts are initialised using near-real-time meteorological forcing data from ECMWF climate reanalysis, ERA5[12] or ERA5-Land[13]. All hydrological models are currently forced with SEAS5. For ECMWF ECLand and three additional hydrological models (excluding GLoFAS-LISFLOOD), the seasonal climate forecasts are bias adjusted to using a quantile-mapping method.

The service provides **four core hydrological variables**, from each hydrological model, with hyperlinks to corresponding GRIB2 parameter: River discharge[14], Runoff water equivalent (surface plus subsurface)[15], Soil wetness index (root zone)[16], and Snow depth water equivalent[17]. Variables are provided to users in daily time steps across three datasets: **1) the historical period** and updated in near-real time, **2) operational ensemble seasonal hydrological forecasts** at the start of each month, and **3) a corresponding set of ensemble seasonal hydrological reforecasts** covering the period 1993 to present. A set of **hydrological performance metrics** (example, Kling Gupta Efficiency (KGE)) and **ensemble forecast skill scores** (example, Brier Skill Score; Continuous Ranked Probability Skill Score) are generated. The three datasets and skill scores are pushed to dedicated catalogue entries on the CDS (expected to be published Q2 2024) and available to users along with dedicated user documentation and a user support service.

5.2. Limitations of the current water service and a way forward

While web apps at the climate change and seasonal scale were developed for the water sector during COP1, the focus in the first part of COP2 (2022-2024) was on the operationalization of the multi-model seasonal hydrological forecast service. In the next part of COP2 (2024-2027) this new ITT aims to understand in-more depth the needs of users in the water sector (Lot 3) and adapt and evolve the existing seasonal multi-model hydrological forecast service (Lot 1) and the multi-decadal to centennial multi-model component (Lot 2) to user needs.

Key limitations of the current service:

- While there exists many possible combinations of seasonal climate and hydrological models at various spatial scales across Europe and globally, it is not yet demonstrated what the added value of a multi-

[10] https://data.jrc.ec.europa.eu/dataset/0bd84be4-cec8-4180-97a6-8b3adaac4d26
[11] https://cds.climate.copernicus.eu/cdsapp#!/dataset/seasonal-original-single-levels?tab=overview
[12] https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview
[13] https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-land?tab=overview
[14] https://codes.ecmwf.int/grib/param-db/240024
[15] https://codes.ecmwf.int/grib/param-db/231002
[16] https://codes.ecmwf.int/grib/param-db/231026
[17] https://codes.ecmwf.int/grib/param-db/228141

model product is over a single model product, and how many models/differing types of models are needed to provide a scientifically robust multi-model product.

- While there exist several possible combinations of high and lower resolution climate model forcing, and high and lower resolution hydrological models, it is not yet demonstrated if the additional computation and data size costs are worth going to higher resolution at seasonal and climate timescales for core hydrological variables.
- The operational seasonal hydrological forecast service is currently provided across two separate services to cover both European and global scales. This has resulted in separate production suites, seasonal climate forecast preparation and bias adjustment, data production and documentation, and technical and project administration. Increased efficiencies and synergies would be possible if seasonal forecast activities were provided by a single service covering both European and global domains.
- The current multi-decadal to centennial component has not been updated to cover the global scale and there is currently no consistency between the hydrological models and products ran over the historical period and updated in near-real time (as in the seasonal service) with those used for climate change projections. There is a growing need to track the evolving climate change signals in hydrological variables in near-real time (e.g. updated every month) as well as provide long-range projections.
- The current C3S water service is not flexible to changing user needs or contribution of other hydrological model providers to the service. The new phase of the service should take a more flexible approach to service provision and strive to provide the hydrological modelling community the core meteorological, seasonal climate and climate change forcings to be used to drive their own hydrological models (including AI based ones), with the possibility for them then to directly contribute their own hydrological data to the CDS catalogues.

The next sections provide the technical specifications for Lot 1, Lot 2 and Lot 3.

6. Lot 1: The historical to seasonal forecast multi-model component of the C3S operational water service

The vision of Lot 1 is to provide a state-of-the-art operational multi-model seasonal hydrological forecasting service at the European and global scale to a wide range of users in the water sector. Lot 1 will develop a flexible framework to bring diverse types of hydrological models together in a consistent way so that outputs can be compared to understand past, current, and future changes in hydrological variables.

Lot 1 consists of two main parts: **Part A) Deliver operational seasonal hydrological predictions at current service levels** and **Part B) Evolution of the C3S multi-model seasonal hydrological prediction service**. The successful Tenderer will first deliver an equivalent service to that currently operational (Figure 1 with technical specifications in Table 1) as outlined in section 5.1 above. This service must be maintained at current service levels until the service evolution (Part B) is ready to be implemented operationally (version 2) and would then supersede the current operational service (version 1).

Part A: Deliver operational seasonal hydrological predictions at current service levels

Part A of Lot 1 will deliver an equivalent operational seasonal prediction service at similar service levels as outlined above with technical specifications summarised in Table 1. The successful Tenderer should write their ecFlow suite(s) using the ECMWF pyflow library and run hydrological models directly on the ECMWF Atos supercomputing facility. The successful Tenderer will have guidance from ECMWF technical staff regarding the design and implementation of software using the pyflow library and ecFlow suites. Access to ECMWF MARS and a project space will also be provided. Any developed suite will be reviewed and must be approved by ECMWF development and production staff before it can be deployed in operations.

The successful Tenderer will work closely with the CEMS computational team at ECMWF who run EFAS- and GloFAS-Seasonal to ensure integration of CEMS into the C3S multi-model hydrological seasonal forecasting

service. For the global scale, the ECMWF ECLand model code and required climate fields will be provided by ECMWF and the successful Tenderer will be required to implement seasonal hydrological forecasts based on ECLand within their developed ecFlow suite.

Computation and data requirements for Lot 1: Given the seasonal hydrological service will be running on the ECMWF Atos supercomputing facility and data stored in ECMWF MARS, an estimate of both the computing and data storage requirements should be provided in the response. Atos resources can be estimated by System Billing Units (SBU) found here[18].

	Service component	Europe	Global
a	Meteorological forcing data	CEMS EFAS-METEO	ERA5/ERA5-Land
b	Seasonal ensemble climate models	At least SEAS5 and one extra seasonal climate model	At least SEAS5
c	Hydrological models	At least EFAS-LISFLOOD[a] and one additional hydrological model	At least GloFAS-LISFLOOD[a], ECMWF ECLand to be run by successful Tenderer and one additional hydrological model
d	Target horizontal resolution	At least ~5km for gridded hydrological models; models run for comprehensive set of catchments across Europe also possible	At least ~10km for gridded hydrological models; models run for comprehensive set of catchments across globe also possible
e	Temporal resolution	Daily	Daily
f	Historical simulation / reanalysis	At least from 1991 and updated in near-real time	At least from 1981 and updated in near-real time
g	Operational ensemble seasonal hydrological forecasts	Updated at the start of each month for at least 6 months lead time	Updated at the start of each month for at least 6 months lead time
h	Seasonal reforecasts	At least covering 1993 to present	At least covering 1993 to present
i	Hydrological variables	At least include the following variables at daily time steps and averaged monthly: • River discharge • Runoff water equivalent (surface plus subsurface) • Soil wetness index (root zone) • Snow depth water equivalent	At least include the following variables at daily time steps and averaged monthly: • River discharge • Runoff water equivalent (surface plus subsurface) • Soil wetness index (root zone) • Snow depth water equivalent
j	Suite, data and user support	Fix minor and major bugs in suite; answer any user queries regarding the methods and use of data published on the CDS; maintain live documentation on C3S Confluence space	Fix minor and major bugs in suite; answer any user queries regarding the methods and use of data published on the CDS; maintain live documentation on C3S Confluence space

Table 1: Technical specifications of the current (version 1) C3S multi-model seasonal hydrological prediction service

[a] will be run by ECMWF as part of CEMS computational contract.

[18] https://confluence.ecmwf.int/display/UDOC/HPC2020%3A+Accounting

Part B: Evolution of the C3S multi-model seasonal hydrological prediction service

A central aim of the existing service was to create synergy across both the European and global service, and with the CEMS EFAS- and GloFAS-Seasonal service. This contract will enhance this synergy further. Both the European and global seasonal hydrological seasonal service will be provided under a single Lot (Lot 1) to allow for increased collaboration and efficiency between the successful Tenderer and ECMWF, who are the current computational centre for CEMS EFAS and GloFAS.

There remain several differences between the European, global and CEMS components that should be addressed in this contract:

- The number of seasonal climate models is not consistent, and the methods used for bias-adjustment and downscaling (while similar) are different.
- Currently, CEMS EFAS- and GloFAS-Seasonal do not force JRC LISFLOOD with bias adjusted and downscaled seasonal climate forcings. This contract will provide a common set of bias adjusted and downscaled multi-model seasonal climate forecast forcings for any hydrological model, including those used in CEMS, to be operational and publicly available each month.

There are several limitations with the current service that should be addressed in the evolution of the service Part B:

- Demonstrate if there is substantial added value from a multi-model seasonal hydrological forecast product over a single model product, and how many seasonal climate and hydrological models/differing types of models are needed to provide a scientifically robust multi-model product/service.
- Demonstrate if there is substantial scientific benefit running seasonal climate and hydrological models at higher resolutions for seasonal forecasting, given the significant increase in computational and data storage costs.
- Run an operational Ensemble Streamflow Prediction (ESP) for each hydrological model to understand the added skill gained from seasonal climate forecasts compared to the skill from initial hydrological conditions (e.g. Arnal et al., 2018[19]; Wanders et al., 2019[20]).
- The service will evolve based on user feedback and needs with close collaboration with Lot 3 and ensuring consistency in the selection of hydrological information with Lot 2.
- Establish a common evaluation protocol and tools to be applied across all hydrological models. In addition to forecast skill scores calculated using reforecasts, an operational forecast evaluation procedure shall be implemented, and scores updated for recent past forecast performance each month.

The contract will be implemented in work packages (WPs). Preliminary list of WPs and timetable of major deliverables are proposed below. These work packages and deliverables are indicative at this stage and Tenderers are free to propose a more refined work package list and timetable.

6.1. WP0: Management and Coordination

WP0 specifications are the same for the three Lots and are described in section 9.1 below.

6.2. WP1: Deliver seasonal hydrological forecasts at current service levels

WP1 contributes to Part A and aims to deliver operational seasonal hydrological predictions at current service levels (this is referred to as version 1 here) as outlined in the technical specification in Table 1. The successful Tenderer will be required to fulfil the following tasks:

[19] https://hess.copernicus.org/articles/22/2057/2018/
[20] https://journals.ametsoc.org/view/journals/hydr/20/1/jhm-d-18-0040_1.xml

Task 1: Develop an equivalent operational multi-model hydrological prediction service at the European and global scale adhering to the technical specifications outlined in Table 1. The successful Tenderer will work with staff at ECMWF to integrate EFAS- and GloFAS-Seasonal into the service. The successful Tenderer will be responsible to operationalise seasonal hydrological forecasts from the ECMWF ECLand model at the global scale (model code and forcing climate fields to be provided to the successful Tenderer by ECMWF). **The successful Tenderer must include at least one additional hydrological** model beyond **JRC LISFLOOD** and **ECMWF ECLand** at both European and global scales. Note: while there are three additional hydrological models running in the current service (i.e. Figure 1), the technical specifications require at least one additional hydrological at both European and global domains in order to meet the minimum service level defined in Table 1.

The operational workflows will be implemented as ecFlow suite(s) using the ECMWF pyflow library with guidance and support from ECWMF technical staff. The suite(s) will run operationally on the ECMWF supercomputing facility in close collaboration with ECMWF production staff. This task includes any minor updates and bug fixes to operational suites once they are deployed. Ensure any changes in e.g. forcing data throughout the contract period (such as, upgrades to EFAS-METEO; upgrade from ERA5 to ERA6; upgrade from SEAS5 to SEAS6) are incorporated into the suite in a timely manner to avoid interruptions in the service. This also includes ensuring CDS catalogue entries and documentation are maintained.

Task 2: Provide level-2 support for any queries from users regarding the service. This can include, for example, user queries about data access, skill of the seasonal forecasts and details on models and methods.

Expected Deliverables:

D1.1: By month 2, the successful Tenderer will deliver the workplan and selection criteria of seasonal climate models, hydrological models (and justification of adding new hydrological models based on model diversity and quality), space-time resolutions, etc. to meet the definition of current service levels set out in Table 1. This list may be revised and updated if new models become available (e.g. SEAS6, ERA6, GloFAS-LISFLOODv5) or at ECMWF's request. This deliverable will include the description of the relevant bias adjustment and downscaling techniques, (including proposed reference datasets), their limitations and context of use, based on current scientific literature and guidance to their use.

D1.2: Codebase using the pyflow library to define ecFlow suite(s) following ECMWF production requirements submitted to a repository at ECMWF with comprehensive documentation to allow ECMWF production staff to run in a continuous operational environment.

D1.3: Manifest files and documentation to allow data to be pushed to the relevant CDS catalogue entries. This task includes archival of the data on ECMWF MARS[21] for both European and global datasets.

Milestones:

M1.1: By month 12, CDS catalogue entries are populated and serving data to users at equivalent service levels to current service.

6.3. WP2: Service evolution: New consistent seasonal climate forcing dataset

WP2 builds on WP1 and Part A and forms part of the evolution of the seasonal hydrology service (Part B) as outlined in the technical specifications for the upgraded service (this is referred to as version 2 here) in Table 2. The successful Tenderer will be required to fulfill the following tasks:

Task 1: Prepare a new set of consistent seasonal climate forecast forcings (e.g. precipitation, temperature, etc.) to be used to drive hydrological models. The number of seasonal climate models should be expanded beyond SEAS5 in **Part A** to **at least one additional model at both European and global domains** from those

[21] https://confluence.ecmwf.int/display/UDOC/MARS+user+documentation

currently available from the operational C3S seasonal climate forecast service[22] with comprehensive documentation found here[23]. An Ensemble Streamflow Prediction (ESP) forcing dataset based on historical climate data should be created. Propose, implement, and thoroughly test one or more methods for bias adjusting, and downscaling seasonal climate forecasts. Methods proposed should be grounded in established scientific literature and justified for hydrological applications. Given that various methods yield different outcomes and may be suitable for distinct downstream applications, guidance should be provided to users on limitations and recommendations of such methods. The delivered documentation will provide support and direction for downstream users wishing to implement their own or an alternative approach to bias adjustment within their hydrological modeling chain.

Task 2: Deliver bias adjusted and downscaled seasonal climate forecast forcings, and ESP historical climate forecast forcing, to the C3S Climate Data Store (CDS) in a timely manner at the beginning of each month. These forcings will be used by existing or new hydrological models and serve as a consistent forcing dataset for the seasonal hydrological model community.

Expected Deliverables:

D2.1: By month 4, the successful Tenderer will deliver the initial workplan and selection criteria of additional seasonal climate models, climate variables to be extracted, Ensemble Streamflow Prediction (ESP) meteorological forcing, and choice of spatial resolution(s). Models and methods considered may be revised and updated if new seasonal climate models and/or versions become available (e.g. SEAS6) or at ECMWF's request. This deliverable will include the description of the relevant bias adjusting and downscaling techniques, (including proposed reference datasets), their limitations and context of use, based on current scientific literature and driven by the user requirements gathered in Lot 3 (delivered M2). Note if the same bias adjustment method is well justified in Part A, then it can extend to Part B. The workplan and selection criteria should be updated by month 15 based on scientific and user-based findings (Lot 3).

D2.2: Deliver the software code for bias adjustment and downscaling of the seasonal climate forcing variables. The code will be delivered as a standalone python package(s) and be openly available through the ECMWF GitHub repository and follow established code documentation standards.

D2.3: Update ecFlow suite(s) from WP1 for the new set of seasonal climate forcings. The suite(s) will archive processed climate forcings on ECMWF MARS (i) each month for operational seasonal climate forecasts, and (ii) each time there are additional/major upgrades to seasonal climate models for reforecasts (hindcasts). Suites must follow ECMWF production guidelines and will be designed and tested in collaboration with ECMWF development and production staff.

D2.4: Seasonal climate forcing data delivered to the CDS (JIRA ticket for ingestion, manifest file(s), and documentation).

Milestones:

M2.1: By month 18, new CDS catalogue entries are populated and serving operationally new seasonal climate datasets to users.

6.4. WP3: Service evolution: Upgraded seasonal hydrological forecast service

WP3 builds on WP1 and Part A and forms part of the evolution of the seasonal hydrology service (Part B) as outlined in the technical specifications for the upgraded service (this is referred to as version 2 here) in Table 2. The successful Tenderer will be required to fulfill the following tasks:

Task 1: The C3S seasonal water service is multi-model service so this task shall include **at least one hydrological model** at both Europe and global domains, in addition to **JRC LISFLOOD** as used in CEMS EFAS-

[22] https://cds.climate.copernicus.eu/cdsapp#!/dataset/seasonal-original-single-levels?tab=overview
[23] https://confluence.ecmwf.int/display/CKB/C3S+Seasonal+Forecasts

(for European domain) and GloFAS-Seasonal (global domain) service and **ECMWF's ECLand** for the global domain. The selection of hydrological models would cover a range hydrological model types and spatial resolutions to capture uncertainties, such as (i) physically based catchment/(semi-)distributed hydrological models, (ii) land surface models, and (iii) data-driven (AI-based) hydrological models.

The successful Tenderer should investigate the benefit, if any, of multi-model hydrological forecasts and whether adding models at higher spatial resolutions adds substantial benefits, given the additional data and computational costs. The successful Tenderer should benchmark hydrological forecasts forced with seasonal climate models against those forced with ESP historical climate forcing to established when and where gains in forecast skill are possible from dynamical models. These analyses will provide scientific guidance to users and will be used to develop any multi-model-based products if required from Lot 3.

One of the core challenges of the service is how to combine different types of hydrological models in a consistent way, especially gridded models with different native river networks and varying resolutions. Solutions could include all gridded hydrological models using a common river network; a common river routing scheme implemented across all gridded models to ensure river discharge can be combined across models with different spatial resolutions; or at least each model reports data from a common set of catchments with comprehensive coverage across the European and global domain. Proposals for other solutions or a combination of methods are encouraged. To allow a multi-model composition, the successful Tenderer will be responsible to ensure hydrological model output variables are standardized between all models used in Lot 1 and Lot 2, including collaboration with ECMWF on ECLand and CEMS outputs.

Task 2: Produce long-term historical hydrological simulations for each hydrological model (also known as a hydrological "reanalysis"). Specifications are summarised in Table 2. The historic simulations should be run at a daily time-step to produce exploitable time series (e.g. after spin-up impact) from at least 1991 (Europe) and 1981 (Global) and updated in near-real time for at least the core set of hydrological variables (Table 2). The hydrological simulations should be updated each month and archived to ECMWF MARS and be publicly available through the CDS. Details and evaluation results of hydrological calibrations should be documented and be made available to users following established scientific standards in hydrological modelling.

Task 3: Produce multi-model ensemble seasonal hydrological forecasts operationally each month according to the specifications in Table 2. Ensemble forecasts should be produced for at least 6 months lead time for at least the core set of hydrological variables (Table 2). The hydrological forecasts should be archived on ECMWF MARS and publicly available on the CDS.

Task 4: Establish a common evaluation protocol and tools to be applied across all hydrological models. In addition to forecast skill scores calculated using reforecasts, an operational forecast evaluation procedure shall be implemented and scores updated for recent past forecast performance each month. The software evaluation code will be delivered as a standalone python package(s) and be openly available through the ECMWF GitHub repository and follow established code documentation standards.

Task 5: Produce each month a multi-model seasonal hydrological status and outlook product, designed in close collaboration with Lot 3 and ECMWF. The product would show at European and global domains the hydrological status for the past month (e.g. river discharge above/below normal) and the forecast outlook (e.g. river discharge is expected to be extremely high/low). Examples of some products available for C3S seasonal climate forecast service here: https://climate.copernicus.eu/seasonal-forecasts and https://climate.copernicus.eu/charts/packages/c3s_seasonal/.

Expected Deliverables:

D3.1: By month 4, the successful Tenderer will deliver the initial workplan and selection criteria of additional hydrological models, choice of spatial resolution(s), and a proposal for combining and serving hydrological models in a consistent way as part of a single service. Models and methods considered may be revised and updated if new hydrological models and/or versions become available (e.g. JRC LISFLOOD-GloFASv5) or at

ECMWF's request. The workplan and selection criteria should be updated by month 15 based on scientific and user-based findings (Lot 3).

D3.2: Deliver a hydrological model protocol that can be used by any new hydrological model/modelling group to include their model into the service. The protocol shall outline the minimum specifications for inclusion of new models, how historical and forecast meteorological forcing data can be used and accessed, for example. The protocol should outline the format of output variables to comply with ingestion into MARS/CDS catalogues and endeavor to supply tools/software to help with data archival formatting.

D3.3: A report on the scientific assessment of benefits, if any, in running multiple seasonal and hydrological models, and at higher resolutions, for the purpose of improving seasonal hydrological forecasting. The report should provide guidance on the scientific skill of multi-model forecasts and outcomes used in collaboration with Lot 3 to develop multi-model seasonal hydrological status and outlook products.

D3.4: Establish a common evaluation protocol and tools to be applied across all hydrological models. In addition to forecast skill scores calculated using reforecasts, an operational forecast evaluation procedure shall be implemented, and scores updated to track recent past forecast performance each month. The software evaluation code will be delivered as a standalone python package(s) and be openly available through the ECMWF GitHub repository and follow established code documentation standards.

D3.5: Update ecFlow suite(s) from WP1 for the new set of hydrological model(s). The suite(s) will archive hydrological outputs on ECMWF MARS (as defined in Table 2), (i) each month for hydrological reanalysis data, (ii) each month for operational seasonal hydrological forecasts, and (iii) each time there are additional/major upgrades to seasonal climate and/or hydrological models for reforecasts (hindcasts). Software for creating the ecFlow suite(s) must use the pyflow library and follow ECMWF software design and production guidelines and will be designed and tested in collaboration with ECMWF development and production staff.

D3.6: Seasonal hydrological data delivered to the CDS (JIRA ticket for ingestion, manifest file(s), and documentation) with accompanying comprehensive user guide.

Milestones:

M3.1: By month 24, updated data ingested into ECMWF MARS and CDS catalogue entries are updated and serving operationally new seasonal hydrological datasets to users.

	Service component	**Europe**	**Global**
a	Meteorological forcing data	Same as Table 1 **OR** alternative if well justified and agreed with ECMWF	Same as Table 1 **OR** alternative if well justified and agreed with ECMWF
b	Seasonal ensemble climate models	Same as Table 1 **AND** run an ESP based on historical meteorological forcing	Same as Table 1 **AND** one extra seasonal climate model **AND** run an ESP based on historical meteorological forcing
c	Hydrological models	Same as Table 1 **AND** adjust number and diversity of hydrological models based on a scientific assessment and in response to user needs in Lot 3	Same as Table 1 **WITH** a newer version of ECMWF ECLand (model code and climate forcing fields to be provided to the successful Tenderer by ECMWF) **AND** adjust number and diversity of hydrological models based on a scientific assessment and in response to user needs in Lot 3
d	Target horizontal resolution	Same as Table 1 **AND** adjust spatial horizontal resolution of hydrological model(s) based on a	Same as Table 1 **AND** adjust spatial horizontal resolution of hydrological model(s) based on a scientific

		scientific assessment and in response to user needs in Lot 3	assessment and in response to user needs in Lot 3
e	Temporal resolution	Same as Table 1 **WITH** possibility to adjust in response to user needs in Lot 3	Same as Table 1 **WITH** possibility to adjust in response to user needs in Lot 3
f	Historical simulation / reanalysis	Same as Table 1 **WITH** possibility to adjust in response to user needs in Lot 3	Same as Table 1 **WITH** possibility to adjust in response to user needs in Lot 3
g	Operational ensemble seasonal hydrological forecasts	Same as Table 1 **WITH** possibility to adjust in response to user needs in Lot 3	Same as Table 1 **WITH** possibility to adjust in response to user needs in Lot 3
h	Seasonal reforecasts	Same as Table 1 **WITH** possibility to adjust in response to user needs in Lot 3	Same as Table 1 **WITH** possibility to adjust in response to user needs in Lot 3
i	Hydrological variables	Same as Table 1 **WITH** new variables added based on user requirements in Lot 3	Same as Table 1 **WITH** new variables added based on user requirements in Lot 3
j	Suite, data and user support	Fix minor and major bugs in suite; answer any user queries regarding the methods and use of data published on the CDS; maintain live documentation on C3S Confluence space	Fix minor and major bugs in suite; answer any user queries regarding the methods and use of data published on the CDS; maintain live documentation on C3S Confluence space

Table 2: Technical specifications of the upgraded (version 2) C3S multi-model seasonal hydrological prediction service

6.5. WP4: Cross Lot Coordination Activities

Lot 1, Lot 2 and Lot 3 form an interconnected framework and coordination between the Lots is critical to the success of the C3S water service. The objective of this work package is to establish effective communication between the Lots to coordinate activities, decisions and ultimately define and implement the C3S water service. Please, also refer to Table 3 provided in section 9.2.

WP4 enables effective communication between the contracts to define an implementation strategy to respond to the user requirements collected and analysed by Lot 3. The work package will develop a cross-lot workplan, that will be kept 'live' over the duration of the 36-months contracts.

This work package is common to all three Lots; however, Lot 3 will be tasked with coordinating the delivery of WP4 deliverables, though these deliverables will include contributions from all Lots.

The activities that require seamless co-ordination between the Lots, include, but are not limited to:

- Technical feasibility and priority of addressing user requirements based on available resources and time frames of the contract.
- Selection of climate & hydrological models, variables and their space-time resolution.
- Definition of indicators, multi-model statistics and quality metrics.
- Definition of use cases to demonstrate the utilization of indicators and hydrological information in user workflows and applications.
- Common revision of applications and their correct use.
- Potential use of common river routing scheme (e.g., use the C3S defined river networks) and/or a common set of catchments to allow multiple hydrological models at differing spatial resolutions to be compared across the service.

- Consistency in the products being implemented across the Lots, including standardization of model output variables.
- Management of critical dependencies between Lots.
- Data and metadata management.
- Consistent guidance for users to assess fitness for purpose of information produced and used within the C3S water service, including guidance documents to use and select climate and hydrological products in the user domain.
- Software standards and management and implementation strategy.
- Emerging requirements, user feedback and updates to the service.
- Limitations & fitness for purpose of data for users and Lot 3 applications.
- Material to support C3S water service microsite.

Lot 3 is tasked with developing a cross Lot workplan, which is kept 'live' over the duration of the contract. The deliverable ensuring the service's adaptability to address requirements, thus maintaining a user-oriented approach. This workplan should include the critical dependencies, timelines for interactions with the Lots, specifying how user requirements will be addressed within the contract's timeframe. It should also clearly identify those requirements that can be met during the contract period, including those dependent on new variables from projections or models evolution, as well as those that might be addressed in potential future (post-contract) developments. To accomplish this, the successful Tenderer must work with all Lots to assess the practicalities (including scientific), impact, cost, effort, and time required to address these requirements.

Bi-annual updates, (every six months), are anticipated to reflect the integration of new high-priority datasets or service elements to support the objectives of the other Lots.

Lot 1 needs to ensure there is sufficient effort allocated to WP4 to provide relevant inputs to support Lot 3 in developing and maintaining the associated deliverable as well as participate in the quarterly meetings.

7. Lot 2: The multi-decadal to centennial multi-model component of the C3S operational water service

Lot 2 provides data and information based on multi-model climate projections at global and regional scale, for hydrological modeling. The main objective of Lot 2 is to deliver **a multi-model climate forcing framework and a methodology for hydrological climate projections**, encompassing all necessary steps, any applicable: selection of multiple climate models, ensembles, scenarios, bias adjustment, downscaling, common grids, standardized formats, and quality control. For the choice of the climate models, it is recommended to follow ECMWF guidance to ensure consistency with the ECMWF strategy and data quality filtering, including for example to be aligned with the models used in the C3S Climate Atlas, wherever possible (see: https://atlas.climate.copernicus.eu and https://cds.climate.copernicus.eu/cdsapp#!/dataset/projections-climate-atlas?tab=overview).

Additionally, **the objective is to apply the climate forcing to a subset of pre-defined hydrological model simulations to illustrate the methodology and pre-compute a set of associated hydrological indicators.** The framework should be robust in capturing the climate uncertainty due to internal variability, to different radiative forcing scenarios and to different modeling tools, while also identifying how other downstream hydrological models (including machine learning-based ones) may contribute to the hydrological multi-model setting for specific user-defined applications. The choice of hydrological models will also ensure a certain level of diversity to quantify uncertainty arising from hydrological assumptions. **The output will include a protocol that allows downstream users to contribute to the multi-model hydrological variables and indicators to be included in the CDS and enrich the multi-model**.

The contract will be implemented in work packages (WPs). Preliminary list of WPs and timetable of major deliverables are proposed below. These work packages and deliverables are indicative at this stage and Tenderers are free to propose a more refined work package list and timetable.

7.1. WP0: Management and Coordination

WP0 specifications are the same for the three Lots and are described in section 9.1 below.

7.2. WP1: Climate forcing fields

The successful Tenderer will be required to fulfill the following tasks:

Task1: Define and justify selection criteria of global and regional climate projections (from CMIP and CORDEX), ensemble members, scenarios (including historical simulations), and the global warming level outputs. These details will be collaboratively established with ECMWF, ensuring alignment with the C3S strategy for generating climate indicators and information for various sectoral activities or based on user requirements (Lot 3). The selection of climate models will be extensive enough to facilitate the assessment of regional uncertainty through different downstream methods, for different types of applications including storyline approach, if required by users. This task will contribute to understanding how many models/differing types of models (and resolutions) are needed to provide a scientifically robust multi-model product for climate-water applications. Alignment to the choice of models for the C3S Climate Atlas and agreement with ECMWF is recommended to ensure consistency with the ECMWF strategy of offering access to climate projections. Additionally, the successful Tenderer will select the climate variables (to be used as forcing data for the hydrological simulations), their spatial and temporal resolutions, to be agreed with ECMWF and based on selected user requirements (Lot 3). The spatiotemporal outputs should enable the computation of a variety of downstream key indicators. To summarize, **the selection of multi-model ensemble of global and regional simulations, based on CMIP and CORDEX, (and the selected resolution) has the purpose to sample the matrix of climate forcing better spanning the uncertainty in the projected variables of best interest to the water sector users and fit for the selected regional area and, at the same time, to align with the C3S strategy in operationally serving climate projections to a wider community of users.** Those choices shall be carefully documented and fully traceable.

Task2: Propose and implement one or more methods for skill metrics, bias adjusting, regridding on common grids, and downscaling the climate forcing fields, if appropriate, suitable for the hydrological simulations, grounded in established scientific literature and including description of any proposed reference datasets. Given that various methods yield different outcomes and may be suitable for distinct downstream applications, the selected methods will be integrated, accompanied by guidance outlining limitations and recommendations for users. The delivered documentation will provide support and direction for downstream users wishing to implement their own or an alternative approach within their hydrological modeling chain (see also Task 4).

Task 3: Preparation of the climate forcing fields and any other forcing data for the purpose of the hydrological modeling, including any downscaling, regridding and bias adjustment process. Generate the selected climate forcing variables based on the selected multi-model climate simulations. Significant updates to the climate forcing may be needed (see section ***Further recommendations*** at the end of WP1) and will then require an update to the hydrological simulations in WP2. The successful Tenderer is responsible for implementing these updates in the climate forcing fields. Please note that a limited number of major updates are foreseen, as they will require the rerunning of the entire or part of the workflow, including the hydrological models (see D2.5). Based on the proposed strategy to archive the information, the user requests, the selected resolution and the chosen models and scenarios, the prepared climate forcing fields (or a selection of those) ready to use for hydrological simulations will be accessible through the CDS and properly documented.

Task 4: This task aims to facilitate the selection process for downstream users by offering multiple climate models, various scenarios, ensemble members, and different adjustment techniques. This approach enables users to generate comprehensive multi-model statistics and choose from the available options in diverse ways. **The primary objective is to guide users effectively through their selection process**. This guidance is designed to assist these types of users:

- those who need to choose a subset of climate forcing generated in WP1 for running their own hydrological model suite,
- those who need to recompute climate forcing from a different selection of climate models and
- those working with precomputed hydrological outputs generated in WP2.

For the latter group, understanding the potential impact of different forcing conditions on their specific application is crucial. The deliverables will be used by Lot 3 to guide development of products.

By undertaking this task, users will be equipped with the necessary information to comprehend and navigate the complexities associated with using climate forcing data. This includes the selection of scenarios, ensembles, models, bias adjustment, and downscaling best fit for a specific set of user needs. The provision of clear user guidance will highlight the impact of different methods for combining climate forcing data in hydrological modeling. Concrete examples, collaboratively defined with Lot 3, will further enhance user understanding. The user guidance through concrete examples will be supported by Jupyter notebooks.

Expected deliverables:

D1.1: At Month 4, the successful Tenderer will deliver the selection criteria of climate models, ensemble members, scenarios, climate variables, skill metrics, space-time resolutions (criteria incorporate feedback from Lot 3). This list may be revised and updated if new model simulations become available (e.g. CORDEX6, or CMIP7) or at ECMWF's request. This deliverable will include the description of the relevant bias adjusting and downscaling techniques, (including proposed reference datasets), their limitations and context of use, based on current scientific literature and guidance to their use.

D1.2: Deliver the software code for bias adjustment and downscaling of the climate forcing variables, and detailed user guidance. The code will be delivered as a set of standalone python packages, to be placed within an ECMWF GitHub repository.

D1.3: Delivery of selected climate data and associated comprehensive documentation accessible through the CDS (data may be hosted at the successful Tenderer's premises). The delivery will encompass the final data location, data quality strategy, and the results of the applied quality control, demonstrating that basic quality control measures have been applied to the dataset. (Expected between month 12 and month 18, version 1 and by month 24 version 2, including major updates if relevant; by M30 any final major update to the service)

D1.4: User guidance to assist in navigating the complexity of climate forcing for hydrological modeling purposes, including applications within concrete examples.

D1.5: Implementation of one or more workflows supporting the specified examples, co-defined with Lot 3. The implemented workflows will be delivered as a collection of Jupyter notebooks. Notebook delivery should follow guidelines set by ECMWF, for examples of the standards we expect for notebooks please refer to the C3S (https://ecmwf-projects.github.io/copernicus-training-c3s) and CAMS (https://ecmwf-projects.github.io/copernicus-training-cams) training material. This approach is taken such that the notebook[s] may be published either within an existing ECMWF JupyterBook (library of notebooks) or in a new JupyterBook dedicated to the contract. This decision should be made in consultation with an ECMWF representative.

Further recommendations: *This work package aims to generate a subset of climate forcing fields. The implemented methodology should be adaptable for updates in the event of new global or regional simulations becoming accessible; different climate forcing models selected downstream; new methodologies to select*

combinations of global and regional simulations, proven to add value in the context of this Tender; the emergence of novel bias-adjustment and downscaling methods (including those based on artificial intelligence); or in response to significant user requests. ***The entire workflow, spanning from climate forcing data generation (in this WP) to the indicator production (WP2 and WP3), should exhibit the flexibility to be rerun with modifications made to specific components of the workflow.***

7.3. WP2: Hydrological variables

The goal of WP2 is **to produce multi-model hydrological simulations at global and regional scale** (across different regions, to be proposed by the Tenderer and included in the available Atlas regions), utilizing climate forcing generated in WP1 and to subsequently make these simulations accessible through the CDS. Users should have the capability to easily access and generate a multi-model ensemble statistic of hydrological variables for their downstream analysis.

The successful Tenderer will be required to fulfill the following tasks:

Task 1: Hydrological Model Selection:

In the effort to simplify the complexity associated with hydrological/climate forcing combinations, the service cannot offer a large number of these combinations, especially without a clear understanding of the added value of such an extensive exercise. The focus of Lot 2 is to provide a comprehensive set of climate forcing for downstream multi-model hydrological applications through WP1, WP2 serves as a benchmark and a demonstrator illustrating how downstream applications requiring hydrological information under climate change scenarios can be developed robustly. This is achieved by offering a selected number of hydrological outputs. Tenderers will justify their selection of hydrological models, to ensure a certain level of diversity for uncertainty quantification. These outputs are intended to provide an initial set of multi-model hydrological information at the climate projection scale for the following groups:

- Users who require pre-computed hydrological information to develop downstream solutions;
- Users who need to generate their own ensemble of multi-model hydrological information and who need these pre-computed outputs for inclusion in their ensemble;
- Users who need guidance on generating, using, and interpreting hydrological multi-model ensemble information at climate projection timescales.

This task's objective is **to choose a set of multi-hydrological models and output variables, along with their resolutions, at global and selected regional scales, and the hydrological variables.** The selection is done including selected user requirements (Lot 3). Users should obtain robust hydrological climate projections, best fit for the global scale and the proposed regions. The successful Tenderer may propose how to achieve this for a specific region (e.g. if for the Mediterranean area, for example, it is better to use downscaled CMIP6 / CORDEX Mediterranean / CORDEX Europe climate forcing plus a specific combination of hydrological models, robustly validated in that region). This selection serves several purposes:

- **Sufficient Number**: Ensure the inclusion of a minimum number of models to facilitate the demonstration on how to construct an adequate multi-model composition and span (part of) the uncertainty in the projected variables associated to the hydrological model selection. Considering the uncertainties arising from different climate models, emission scenarios, and post-processing methods (as discussed in WP1), it is essential to account for the local-scale internal variability affecting the hydrological variables, which can significantly contribute to uncertainty in hydrological projections. The chosen space-time resolution of the hydrological models should enable downstream hydrological impact assessments and computation of hydrological indicators at regional or catchment levels (or both, depending on the successful Tenderer's proposed strategy and user needs from Lot 3) under future climate conditions, including their associated uncertainties. Those computations are done both by Lot 2 in WP3, but also by Lot 3 and users downstream of the service.

- **Quality:** The choice of models should be based on their quality, particularly in supporting a broad range of water management needs under climate scenarios, as indicated by scientific literature. The intended user is in the fields of, for instance, water allocation, flood management, ecological status and industrial water use, but the provided services and information is also relevant in adjacent sectors, such as Energy and Agriculture.
- **Inclusion of Specific Models**: The multi-model set **must include JRC LISFLOOD and ECMWF ECLand**, open-source models made available by ECMWF to the successful Tenderer.
- **Consistency with Lot 1**: Maintain a certain level of consistency with Lot 1, ensuring that a subset of core hydrological models remains the same. This consistency facilitates an easier comparison between the "reanalysis" and historical climate data. In cases where it is challenging to ensure consistency with Lot 1 models, an offline methodology should be provided to allow for the comparison of the reanalysis period with the projections, for example by using a common river routing scheme (see Lot 1, WP3).
- **Maintenance and operational runs**: The successful Tenderer is responsible for maintaining and running the selected multi-models, and making the data available in the CDS with ECMWF overseeing the upkeep of the ECMWF open-source models.
- **Guidance**: Users often need a methodology to navigate the complexity arising from the cascade of uncertainty from the climate projection forcing to the more local scale impact. Through a set of examples, co-designed with Lot 3, this WP will serve as a benchmark and support the generation of guidelines and appropriate frameworks.

Task 2: Integration of Selected Hydrological Model Outputs into the CDS:

Generate hydrological variables at the chosen space and time resolution based on the selected multi-model climate simulations produced by WP1 and deliver the resulting data to the CDS. Delivery includes: model-by-model outputs; selected multi-model products and statistics; relevant quality metrics. The initial list of variables, multi-model statistics and metrics is proposed in the submitted Tender and it will be subject to updates, in collaboration with Lot 3.

Task 3: Protocol Development and integration in the CDS of downstream hydrological outputs:

This task involves developing a protocol allowing any user to run their hydrological model (including ML based ones) downstream of the service, using identical climate forcing, thereby contributing to the multi-model hydrological ensemble. The protocol shall outline the minimum specifications and all necessary steps for inclusion of new models, including quality assurance procedures and technical details for data inclusion in the CDS catalogue. Additionally, the definition of a flexible workflow to compute multi-model statistics coming from different models is included here. The successful Tenderer will also offer technical support for data inclusion in the CDS catalogue upon request.

Task 4: involves providing users with guidance on selecting climate models and hydrological combinations for various applications. Users frequently require a method to navigate the complexity resulting from uncertainty cascading from climate projection forcing to local-scale impacts. Through a series of examples, co-designed with Lot 3, this task will establish a benchmark and aid in generating guidelines and suitable frameworks.

Task 5: Any significant updates to the hydrological models (WP2) or climate forcing (WP1) will require an update to the hydrological simulations. The successful Tenderer is responsible for implementing these updates, with the potential for a few major updates during the contract period, necessitating the rerunning of either the entire workflow or parts of it.

Expected deliverables:

D2.1: At Month 4, the successful Tenderer is expected to provide a comprehensive list of hydrological models, hydrological variables, and space-time resolutions for the selected areas. This deliverable will encompass a thorough description of the models, incorporating relevant scientific literature, highlighting their strengths,

and outlining their limitations within the given context. This task will support a better understanding of how many (climate and hydrological) models/differing types of models/resolutions are needed to provide a scientifically robust multi-model product for a specific use / area. This will support Selection criteria include a description of how selected models address specific user requirements from Lot 3. Deliverable includes the definition of an evaluation protocol for hydrological outputs and any planned calibration and validation activities of the selected hydrological model(s).

D2.2: Delivery of data, skill metrics and associated comprehensive documentation to the CDS. The delivery will encompass the final data location, data quality strategy, and the results of the applied quality control, demonstrating that basic quality control measures have been applied to the dataset. (Expected between month 12 and month 18, version 1 and by month 24 version 2, including major updates if relevant; by M30 any final major update to the service).

D2.3: The protocol to run and contribute additional elements to the multi-model hydrological outputs and their statistics and deliver them to the CDS.

D2.4: Guidance on selecting climate models and hydrological combinations for various applications. This may be designed as a live document, to be regularly updated and enriched.

D2.5: Delivery of updated hydrological output (version 2), if necessary. A few major updates and reruns may be scheduled during the contract period, with a final major update expected by month 30.

7.4. WP3: Climate and Water Impact Indicators

This WP objective is to provide multi-model climate impact indicators tailored for the water sector. These indicators are generated on both a global and regional scale, encompassing historical data and projections up to 2100. This is achieved by leveraging the ensemble of climate and hydrological models provided in WP1 and WP2, respectively.

The calculated indicators, derived from climate model forcing in WP1 and the multi-model hydrological impact modeling system in WP2, are designed to cater not only to users within the water sector but also to those in interdisciplinary fields such as agriculture and energy. The indicators are computed as daily, monthly, annual, seasonal or multi-decadal means over the reference periods. Additionally, they may be presented as variations over future periods under different Representative Concentration Pathways (RCPs) and scenarios for global mean temperature increase (e.g., 1.5, 2.0, and 3.0 °C above pre-industrial conditions). The covered indicators span various hydrological and terrestrial Essential Climate Variables (ECVs).

Task 1: Definition, computation, and delivery of predefined climate and hydrological impact indicators for water management across various application sectors based on selected multi-model hydrological simulations.

The task involves defining, computing, and delivering a predetermined set of climate and hydrological impact indicators crucial for water management in diverse application sectors. The selection of indicators will be refined in collaboration with Lot 3 and will consider current indicators available in the CDS (such as those for runoff, river discharge, soil moisture, aridity, and water quality), as well as new indicators arising from specific requirements outlined by ECMWF and C3S adaptation activities.

The chosen indicators will be integrated into the CDS infrastructure, and their computation will leverage earthkit packages whenever applicable. The code to develop the impact indicators will be implemented and maintained in a way that also allows other C3S users to re-use the workflows and apply them to other reanalysis and projections data according to their own needs. The successful Tenderer is encouraged to use existing earthkit python packages where possible. In cases where a required functionality is not present in earthkit, the successful Tenderer should either contribute to code to an appropriate existing earthkit package or develop a new python package hosted in an ECMWF GitHhub repository. This decision should be made in consultation with an ECMWF representative. In the case of a new python package, the successful Tenderer

should use an ECMWF package template and adhere to the coding standards included in the template package and include readthedocs documentation with notebook examples. This approach is taken with the anticipation that these developments might become part of earthkit in the future. This strategy allows the successful Tenderer the freedom to swiftly and autonomously develop tools outlined in the contract, with the potential to contribute to existing tools.

In instances where the successful Tenderer produces a novel output which is to be served to users directly (e.g. a new dataset or product, a plot or visualisation or a simple numeric result), delivery should be accompanied by a Jupyter notebook which demonstrates how to reproduce the output. Notebook delivery should follow the guidelines detailed at Appendix 1 (How to submit Jupyter Notebook based training material to the CDS/ADS/CADS).

This approach is taken such that the notebook[s] may be published either within an existing ECMWF JupyterBook (library of notebooks) or in a new JupyterBook dedicated to the contract. This decision should be made in consultation with ECMWF.

Task 2: Expanded Documentation of Indicators and Illustrative Use Cases for Selected Scenarios: This task centers on enhancing the documentation of indicators and developing use cases, in coordination with Lot 3, to showcase their practical application. Lot 3 will take the lead in defining the use cases, with technical integration support from Lot 1 for incorporating pertinent workflows into the infrastructure.

Expected Deliverables

D3.1: Live document, with the list of indicators, co-defined with Lot 3, maintained as a dynamic document updated every 12 months (First version at month 4).

D3.2: Jupyter notebooks facilitating and explaining the computation of the indicators. Any code to develop the impact indicators delivered.

D3.3: Indicators and associated comprehensive documentation, including selected quality metrics, accessible as an entry catalogue dataset in the CDS. Results of quality checks delivered. (expected between month 15 and month 21; any major update by month 26; by M30 any final major update to the service)

7.5. WP4: Cross Lot Coordination Activities

Lot 1, Lot 2 and Lot 3 form an interconnected framework and coordination between the Lots is critical to the success of the C3S water service. The objective of this work package is to establish effective communication between the Lots to coordinate activities, decisions and ultimately define and implement the C3S water service. Please, also refer to Table 3 provided in section 9.2.

WP4 enables the effective communication between the contracts to define an implementation strategy to respond to the user requirements collected and analysed by Lot 3. The work package will develop and cross-lot workplan, that will be kept ‘live’ over the duration of the 36-month contracts.

This work package is common to all three Lots; however, Lot 3 will be tasked with coordinating the delivery of WP4 deliverables, though these deliverables will include contributions from all Lots.

The activities that require seamless co-ordination between the Lots, include, but are not limited to:

- Technical feasibility and priority of addressing user requirements based on available resources and time frames of the contract.
- Selection of climate & hydrological models, variables, and their space-time resolution
- Definition of indicators, multi-model statistics and quality metrics
- Definition of use cases to demonstrate the utilization of indicators and hydrological information in user workflows and applications.
- Common revision of applications and their correct use

- Potential use of common river routing scheme (e.g., use the C3S defined river networks) and/or a common set of catchments to allow multiple hydrological models at differing spatial resolutions to be compared across the service.
- Consistency in the products being implemented across the Lots, including standardization of model output variables.
- Management of critical dependencies between Lots
- Data and metadata management
- Consistent guidance for users to assess fitness for purpose of information produced and used within the C3S water service, including guidance documents to use and select climate and hydrological products in the user domain.
- Software standards and management and implementation strategy
- Emerging requirements, user feedback and updates to the service
- Limitations & fitness for purpose of data for users and Lot 3 applications
- Material to support C3S water service microsite

Lot 3 is tasked with developing a cross Lot workplan, which is kept 'live' over the duration of the contract. The deliverable ensuring the service's adaptability to address requirements, thus maintaining a user-oriented approach. This workplan should include the critical dependencies, timelines for interactions with the Lots, specifying how user requirements will be addressed within the contract's timeframe. It should also clearly identify those requirements that can be met during the contract period, including those dependent on new variables from projections or models evolution, as well as those that might be addressed in potential future (post-contract) developments. To accomplish this, the successful tenderer must work with all Lots to assess the practicalities (including scientific), impact, cost, effort, and time required to address these requirements.

Bi-annual updates, (every six months), are anticipated to reflect the integration of new high-priority datasets or service elements to support the objectives of the other Lots.

Lot 2 needs to ensure there is sufficient effort allocated to WP4 to provide relevant inputs to support Lot 3 in developing and maintaining the associated deliverable, as well as participate in the quarterly meetings.

8. Lot 3: User orientated Elements of the C3S operational water service

Lot 3 is focused on 'delivering the last mile', which involves defining, implementing, and showcasing the data and interfaces developed within the C3S water service to the user community and stakeholders.

- Lot 3 will utilise the data streams produced in Lot 1 and Lot 2, and will lead, in close collaboration with users, the co-design of the indicators, applications, and use cases to ensure the uptake of C3S water service.
- Lot 3 has the responsibility to present the C3S water service and all its components in a holistic way.
- Furthermore, Lot 3 provides feedback to Lot 1 and Lot 2, to ensure all the relevant information is available and correctly presented.

The high-level goals of Lot 3 will be to:

- Define and implement a process to collect user requirements and prioritise them in the service offering. The successful Tenderer should ensure that requirements are included from users across the water sector, including those requiring services to support water allocation, flood management, ecological status, and industrial water use, but also ensure the C3S water service is also relevant in adjacent sectors, such as Energy and Agriculture. This process must work with other user engagement activities being undertaken within C3S (National Collaboration Programme Coordination Office, User Intelligence activities), as well as those coming from other C3S activities and core users, such as the European Environment Agency (EEA), European Investment Bank (EIB), Union for Mediterranean (UfM), however, these requirements will be managed and brokered via ECMWF.

- Develop interactive user-oriented application(s) that build on the CDS. The application(s) will allow an easy and appealing exploration of the data and information in the broader user context.
- Working with C3S users, publish use cases that demonstrate the added value of the C3S water service to added user needs.
- Present the C3S water service and all its components to the broad water-service audience.

To achieve these goals, the successful Tenderer under Lot 3 will need to meet the following objectives:

- With Copernicus User Engagement team co-define and implement a 'user engagement strategy', building on policy users, networks, established users, and broader stakeholder community.
- Ensure all user requirements are recorded and managed according to the activities performed in the user intelligence / EQC activities – with entries made into the User Requirements DataBase (URBD) and user requirement analysis database (URAD). Requirements should be managed proactively; identifying gaps, and instances where requirements have been met.
- Assess user needs and requirements to inform ECMWF and Lots 1 and 2 of perceived gaps in the service offering; this mechanism allows the service to evolve over the duration of the contract. This will require close co-ordination with Lots 1 and 2.
- Utilise links with user communities and key stakeholders to ensure the water activities products and services are aligned with user priorities, needs and requirements.
- Exploit the data from Lots 1 and 2 to create user-oriented applications and further processed information, taking advantage of the CDS infrastructure.
- Ensure that any software developed within Lot 3 is consistent with ECMWF software strategy and where appropriate, earthkit. Any tools, libraires and scripts should be coded in python, all with high-quality supporting notebooks, documentation, and training materials.
- Engage with key stakeholders to develop 'use cases', showcasing how C3S activities can support and add value to users requiring timely and high-quality climate information in the water management sector.
- Working with Copernicus User Engagement and training activities, to develop bespoke training and outreach materials to showcase the developments in the C3S water service.
- Generate and maintain a microsite as the main entry point to the C3S operational water service.

The contract will be implemented in work packages (WPs). Preliminary list of WPs and timetable of major deliverables are proposed below. These work packages and deliverables are indicative at this stage and Tenderers are free to propose a more refined work package list and timetable.

8.1. WP0: Management and Coordination

WP0 specifications are the same for the three Lots and are described in section 9.1 below.

8.2. WP1: Assessment of User Needs and Requirements

Knowing from users how they intend to apply hydrological information at seasonal and climate timescales and for which purpose is essential to understand the type of information they really need. In this context, WP 1 will gather user needs and requirements for the C3S water service. Lot 3 will define a strategy to collect user requirements from a variety of user communities that have a need for high-quality climate information for the management of water resources.

The successful Tenderer will perform a gap analysis of user requirements against the current C3S data products and applications (available in the Climate Data Store), as well as relevant indicators related to water sector in other C3S services (IPCC Climate Atlas, EEA ECDE etc.). This report shall provide a detailed description of the requirements that shall be considered in this contract and their priority as identified by stakeholders in the water sector.

Expected deliverables:

D1.1: User needs and requirements analysis, with gap analysis report (version 1 due M2, version 2 due M12 and version 3 M24)

The success of the C3S water service, like all C3S services, is related to ensuring the datasets and application developed are relevant and useable by the community. To this end, Lot 3 will undertake comprehensive assessment of user needs and gather user requirements over the first 24 months of the contract.

This activity will incorporate requirements, amongst other sources, from those gathered in the Copernicus User intelligence contracts, ESOTC[24], WMO hydrological activities (e.g. WMO HydroSOS[25]), EU policy, ECMWF and other C3S activities such as those providing indicators to support EEA, EIB, and energy and agricultural sectors.

Version 1, due M2, will be based on a desk-based study and assessment of relevant requirements collected withing the C3S User Requirements Data Base, highlighting the needs and requirement of key users. This deliverable will form the basis of the C3S water service specification therefore it is imperative that the deliverable clearly articulates and maps the user requirements to data requirements as well as functional requirements of the applications.

Using the existing hydrological indicators and applications published in the CDS as a baseline, the deliverable will include a thorough gap analysis, highlighting the indicators, application functionalities and other requirements that will underpin the C3S water service.

Version 1 of the D1.1 is due M2. The deliverable will be used by Lots 1 and 2 to define model selection.

Versions 2 and 3 of the deliverables, due M14 and 24, will be updated following dedicated interactions with key stakeholders and users. The engagement will be driven by a dedicated user engagement strategy and the gap analysis will be based on the evolving C3S water service offering.

D1.2: User engagement strategy (M6)

Working with Copernicus User Engagement team and the User Intelligence contract, the successful Tenderer will provide detailed plan how the contract will gather needs and requirements from key stakeholders across the water sector, including policy, conservation/biodiversity, intermediaries, …. . This strategy seeks to build on pre-existing activities in both research, policy and C3S, in addition to undertaking workshops and surveys (if required).

At the proposal phase, the Tenderer is asked for a preliminary version of the user engagement strategy, identifying key users, the timelines, processes to ensure their needs and requirements are captured. Dedicated engagement activities are expected to fulfil this, as well as using existing meetings and conferences where practical.

The user engagement strategy will be used to access the evolving needs and requirements of the users and will be used to update D1.1.

M1.1: Milestone – transfer requirements to the URBD (Completed M3, with updates coinciding with user feedback activities and updated to D1.1)

The milestone is associated with the completion of requirements transferred to the User Requirements Database (URDB), a repository to track user requirements managed by the User intelligence contract. It is expected that the requirements will be collated over the duration of the contract, with (at least) biannual updates to the URDB.

[24] https://climate.copernicus.eu/ESOTC
[25] https://wmo.int/activities/hydrosos

8.3. WP2: Development of Sectoral Applications

This work package will build on the outcomes of WP1; and develop user-oriented applications utilising the data produced in Lots 1 and 2.

Task 1: Application Specification and Service Definition

Using D1.1, the User needs, requirements analysis & gap analysis report and the reports provided by Lots 1 and 2, (delivered at M4) that defined the selection criteria of models, variables, ensembles that will define the seasonal and climate projections data products produced from Lots 1 and 2. These deliverables from Lots 1 and 2 define the skill, indicators and provide a description of the datasets that will be produced in the seasonal and climate projections data streams. Lot 3, within Task 1, will utilise the data streams from Lots 1 and 2, will define the 'added value' products and services as required by the C3S user community. This service definition should include, but is not limited to:

- Reference periods
- Aggregated statistics (return periods, percentiles etc.)
- User oriented skill metrics
- User oriented thematic applications and associated functionality
- Non-application based hydrological data products, such as seasonal bulletins and plots.

This task needs to be underpinned by best practice and be scientifically robust.

This activity will inform ECMWF staff and developers the code planned to be used and developed within the contract. This software strategy will detail the code being developed within Lot 3, highlight how existing tools can be used, pinpoint development gaps and priorities, and outline a timeline for development and publication. To facilitate this, successful Tenderer will receive earthkit backend development plans and inventory of current functionalities.

The software plan is expected to be kept 'live' through the contract's implementation phase, with regular updates which will reflect new emerging requirements and priorities.

To minimize duplication of effort, the successful Tenderer needs to liaise closely with stakeholders contributing to ongoing software development that support C3S activities.

Task 2: Development of Applications

The successful Tenderer will develop user-oriented demonstrator applications and/or summary charts based on data from Lots 1, 2 as well and the summary indicators defined and produced within Lot 3. These user interfaces should be underpinned by user needs and requirements and maximise user experience. It is expected that different user communities / stakeholders will require various channels to explorer the C3S water service according to their specific requirements. At the proposal phase, the Tenderer is requested to propose novel user-interfaces to be developed within this contract – using the published C3S water applications as inspiration, as well as other C3S user oriented services, such as the Copernicus Interactive Climate Atlas[26] (developed on the new CDS Engine infrastructure), or seasonal forecast charts[27].

At present, in the CDS there are two demonstrator applications serving the hydrology sector, one utilising seasonal forecasts data[28] stream (Figure 2), and the other uses the current bias adjusted climate projections dataset[29] (Figure 3). The current applications published in the CDS will be retired along with the current operational infrastructure in mid-2024. The existing applications should be replaced with the applications developed in Lot 3, which will utilise the new applications framework and infrastructure being implemented

[26] https://atlas.climate.copernicus.eu/atlas
[27] https://climate.copernicus.eu/charts/packages/c3s_seasonal/
[28] https://cds.climate.copernicus.eu/cdsapp#!/software/app-hydrology-seasonal-forecast-explorer?tab=app
[29] https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-hydrology-variables-derived-projections?tab=overview

in 2024 – the 'CDS Engine infrastructure'. The contract will develop two replacement applications utilising the seasonal information from the current C3S seasonal hydrological forecast and bias adjusted hydrological variable from climate projections. These are expected at M6.

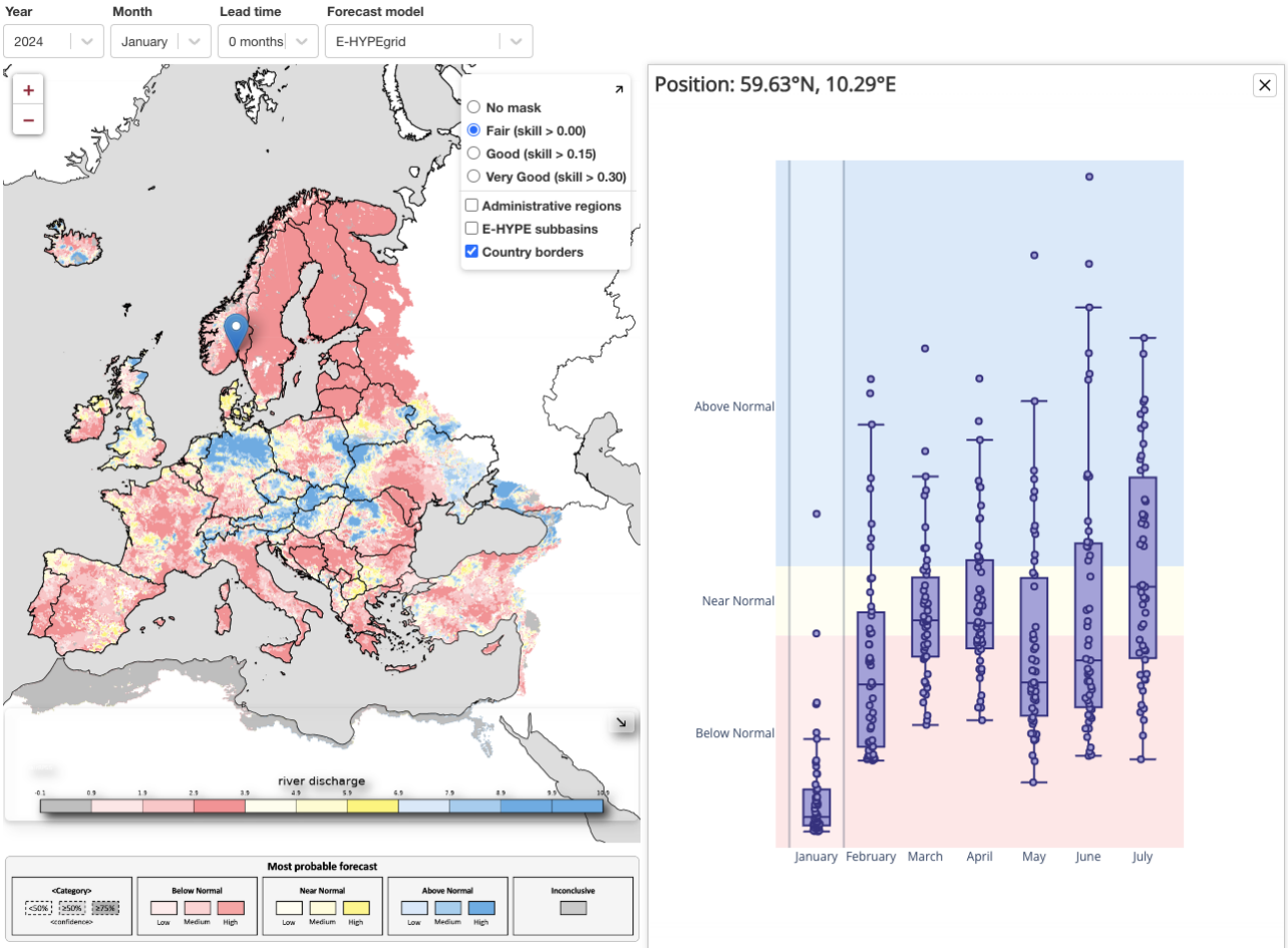

Figure 2: C3S operational multi-model seasonal hydrological prediction service. The above right plot Is the 7-month river discharge forecast from January 2024 for River Drammen in Norway

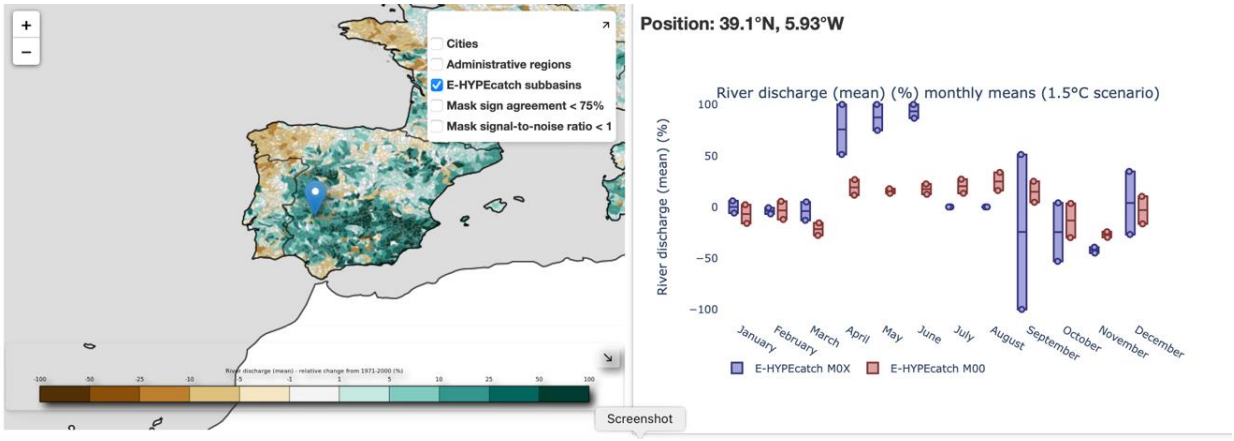

Figure 3: Monthly mean river discharge for a Spanish e-hype subbasin for the 1.5 degree warming scenario as shown in the European hydrology and climate data explorer application published in the CDS.

Interactive web-applications will use JS-react for the front-end and will be deployed as Docker Images within a Kubernetes framework. The applications should follow the guidelines described at Appendix 2 (Application Style Guide), which includes instructions on the components libraries to use. Any new components developed should be written generically such that they could be added to an ECMWF components library. The

applications should be appropriately documented with a view that this documentation may also be published on user facing websites.

In case agreed, cloud resources may be requested. All requests for cloud resources are submitted via ECMWF's Jira system and must include a data management plan following the guidelines provided by ECMWF.

All applications should have undergone extensive debugging and internal review to ensure delivery of quality applications which are optimised in terms of performance prior to final review and publication by technical teams at ECMWF. This review process will cover many aspects including evaluation of adequateness of the application in terms of usability, accuracy, description of input and output variables, appearance, coding standards and style, functionality, and scientific quality. The Tenderer shall ensure that a sufficient provision is made to cover this activity.

As with datasets to be published, all applications are to be delivered through the ECMWF's Jira system specifying the project CDSAPP in the first field of the form, with the (prime) successful Tenderer or an assigned person in charge of making the publication request and acting as the responsible party to ensure that the material provided is fit for the purpose. The delivery of an application or set of applications does not grant the publication itself, and is influenced by the usability, relevance to user communities and outcome of the review process. At the time of writing this Tender, the new EQC for applications is being drafted. It is envisaged that the EQC will play a key role in the review and assessment of all applications to be published by C3S. The details of the EQC process will be provided in the negotiation phase to the preferred bidder.

All published applications will be accompanied by clear and easy to follow user guidance. The application user guides need to be delivered at the same time as the applications. No apps will be published without user guidance materials, and therefore the C3S contracts producing services all need to ensure that the user guidance is considered as a core component of any service. These guides should be self-contained, use information from Lots 1 and 2, and allow users to clearly assess the fitness for purpose of the applications for their own usage.

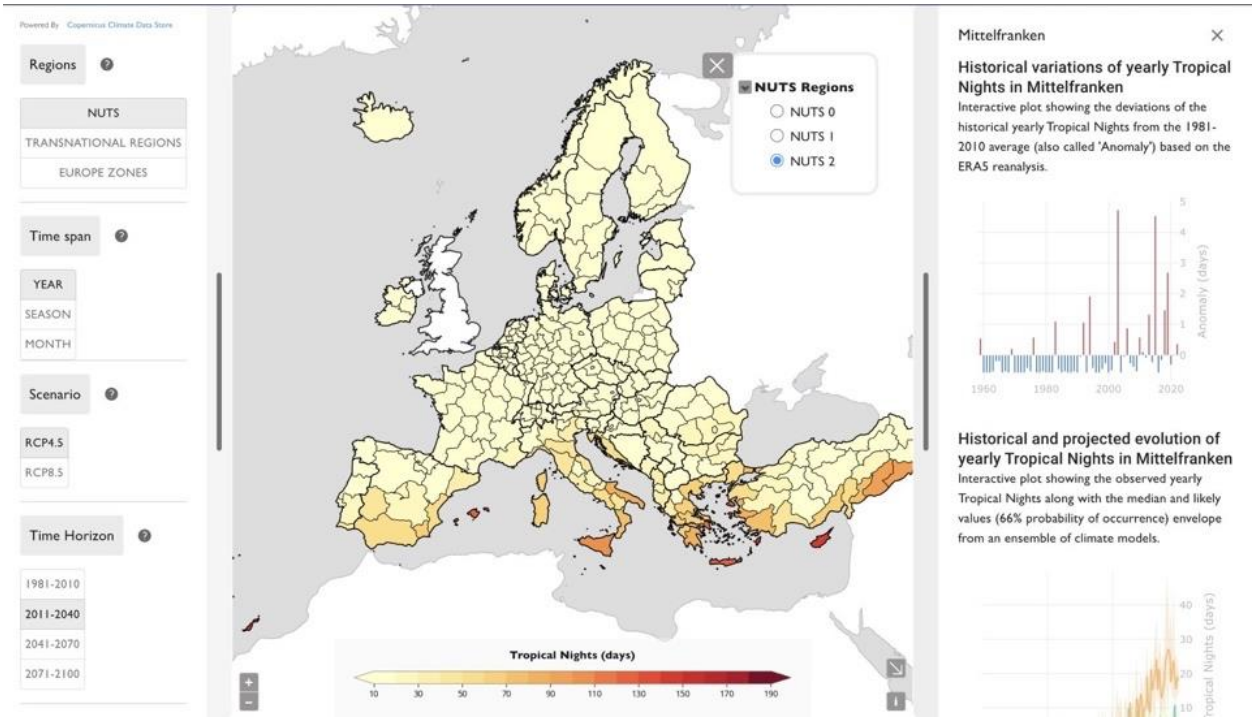

Figure 4: Example application based on the new CADS. This 'Tropical Nights' application is one that makes up the European Climate Explorer and is underpinned by earthkit backend and open-source javascript component frontend. Note, the interactive application development libraries will be finalized during 2024.

Expected Deliverables:

D2.1: Application Specification and Service Definition - Due M5

D2.2: Applications & product user guides, due M6, and updated thereafter following the release of new datasets (expected M12, M18, M24).

8.4. WP3: Use Cases and Communication

Collaborate with engaged stakeholders to develop three 'use cases', showcasing how the C3S water service can leverage additional value to users in need of timely and high-quality climate information across the water management sector. The use cases should clearly demonstrate how C3S products and services are being used by (engaged) users, whether for implementing or informing water policy, enhancing existing workflows, or aiding in the management of water resources across Europe, and other regions, based on Lot 1 and Lot 2 data availability, spanning various time scales (for example climate hazard assessment, seasonal outlooks, future resource planning).

The case studies should cover a variety of user communities and will showcase how the activities from the C3S water service (Lots 1-3) can add value to users. An indication of the proposed case studies to be developed within the contract shall be provided in the proposal. Case studies shall be refined at the early stage of the contract with input from ECWMF technical officer, the Copernicus User Engagement team and the Communication team. The use case activities can be planned according to the availability of the required indicators, products, applications developed within the C3S water service.

The C3S Climate Intelligence Team will be a key stakeholder in the C3S water service – the contract will support ECMWF internal climate monitoring activities and should aim to support C3S climate intelligence activities with operational data (including climate impact indicators). In addition, the successful Tenderer is expected to support data requests, as well as providing scientific leadership on water related storylines in the 'State of the Climate' and Monthly Bulletin reports.

The successful Tenderer will be responsible for content for the C3S water service microsite (part of https://climate.copernicus.eu/). This site will be the gateway for the water user community, showcasing service background, data services, applications, use cases, etc. The site is expected to be periodically updated as the service evolves, ensuring the material is reflecting service status and is current.

Lot 3 needs to ensure data and information services respond to user requirements, and this extends to the communication, user guides and user-oriented elements in WP3. Lot 3 will assess user requirements for additional guidance to maximise update and usability of the service. This assessment should include whether additional guidance is required in addition to the Product User Guides delivered that accompany the datasets and applications. Based on user requirements, WP3 could also provide interpreted Seasonal outlooks, with support from Lot 1. This aspect needs to be further explored within the contract.

Lot 3 will also support ECMWF through the provision of content specific input to user-oriented communication material such as slides, story maps and user testimonials. In addition, requests from Copernicus communication team will need to be realised; such materials can include social media posts, press releases associated with major contractual milestones, support preparation of material for workshops and conferences etc.

A small, dedicated budget shall be allocated in the pricing table to support ECMWF Copernicus communication needs. Details on the expected activities and the budget shall be refined during the negotiation phase with the preferred bidder.

Expected Deliverables:

D3.1: C3S water service microsite with user-oriented content – M6

Part of https://climate.copernicus.eu/, the C3S water service microsite will showcase the data, products, and services, included use cases developed over Lots 1-3. This deliverable should be updated as new water service products are developed / released. V1 is due M6, coinciding with the release of the first applications, with regular updates thereafter.

D3.2: Use case definition report – Due M15

Report outlining potential use cases – the user, stakeholders, engagement plan, technical summary and roadmap and expected outcomes / impact.

D3.3: Detailed Use case report – detailed report on the implementation of the selected use cases. Outlining the technical developments, user journey (use of data in workflow, implementation, impacts)

D3.4: Communication material to support use cases – in coordination with ECMWF communication team, prepare materials to communicate the value of the use cases – focusing on user needs, requirements, value of C3S data and impacts.

D3.5: Service evaluation & recommendations report – Due M33

Detailed report on the impact and uptake of the products and services implemented in the C3S water service (Lot 1-3). This report will critically summarise the success of the activities in addressing user requirements. The report will collate feedback from users to ensure that the views of the stakeholders are included in a set of recommendations for the evolution of the service.

D3.6: Scientific paper describing the C3S water service, including user needs and requirements process and how this leads to the development of a value added and user-oriented climate service. Due before the end of the contract to ensure editorial process is completed before end of contract. The Tenderer can define timeline for drafting and publication in the Tender.

8.5. WP4: Cross Lot Coordination Activities

Lot 1, Lot 2 and Lot 3 form an interconnected framework and coordination between the Lots is critical to the success of the C3S water service. The objective of this work package is to establish effective communication between the Lots to coordinate activities, decisions and ultimately define and implement the C3S water service. Please, also refer to Table 3 provided in section 9.2.

WP4 enables the effective communication between the contracts to define an implementation strategy to respond to the user requirements collected and analysed by Lot 3. The work package will develop and cross-lot workplan, that will be kept 'live' over the duration of the 36-month contracts.

This work package is common to all three Lots; however, Lot 3 will be tasked with coordinating the delivery of WP4 deliverables, though these deliverables will include contributions from all Lots.

The activities that require seamless co-ordination between the Lots, include, but are not limited to:

- Technical feasibility and priority of addressing user requirements based on available resources and time frames of the contract.
- Selection of climate & hydrological models, variables, and their space-time resolution
- Definition of indicators, multi-model statistics and quality metrics
- Definition of use cases to demonstrate the utilization of indicators and hydrological information in user workflows and applications.
- Common revision of applications and their correct use
- Potential use of common river routing scheme (e.g., use the C3S defined river networks) and/or a common set of catchments to allow multiple hydrological models at differing spatial resolutions to be compared across the service.

- Consistency in the products being implemented across the Lots, including standardization of model output variables.
- Management of critical dependencies between Lots
- Data and metadata management
- Consistent guidance for users to assess fitness for purpose of information produced and used within the C3S water service, including guidance documents to use and select climate and hydrological products in the user domain.
- Software standards and management and implementation strategy
- Emerging requirements, user feedback and updates to the service
- Limitations & fitness for purpose of data for users and Lot 3 applications
- Material to support C3S water service microsite

Milestones:

- Quarterly meetings between the Lots are expected to ensure close co-ordination and implementation of the C3S water service.
- Minutes of quarterly meetings

Expected Deliverables:

D4.1: Cross Lot workplan

This deliverable involves establishing a structured mechanism for Lot 3 to collect feedback from both Lot 1 and Lot 2, ensuring the service's adaptability to address requirements, thus maintaining a user-oriented approach.

Based on the cross-Lot discussions, Lot 3 is responsible for the delivery of a detailed workplan that clearly outlines the service offering and the associated implementation schedule for the C3S water service.

This workplan should include the critical dependencies, timelines for interactions with Lot 1 and Lot 2, specifying how user requirements will be addressed within the contract's timeframe. It should also clearly identify those requirements that can be met during the contract period, including those dependent on new variables from projections or models evolution, as well as those that might be addressed in potential future (post-contract) developments. To accomplish this, the successful Tenderer must work with all Lots to assess the practicalities (including scientific), impact, cost, effort, and time required to address these requirements.

Bi-annual updates, (every six months), are anticipated to reflect the integration of new high-priority datasets or service elements to support the objectives of the other Lots.

With version 1, delivered M6, with the purpose of defining the initial set of indicators and variables and models which can be used to initiate the planning and implementation of the C3S water service.

9. Other Requirements, common to all Lots

9.1. Description of WP0: Management and Coordination

The following management aspects shall be briefly described in the proposal:

Meetings:

- Kick-off meeting
- Organise monthly progress review meetings (by videoconference), prepare corresponding summary minutes of these meetings and maintain a list of agreed actions and their status.
- ECMWF organises annual C3S General Assemblies. The successful tenderer is expected to attend these meetings and contribute to discussions related to the topic of this ITT.

- Tenderers can propose additional project internal meetings, as they deem needed, as part of their response.

Quality assurance and control: the quality of reports and Deliverables shall be equivalent to the standard of peer-reviewed publications. The timely delivery as well as final quality check of the deliverables shall be ensured by the successful tenderer (in terms of content, use of ECMWF reporting templates for deliverables and reports (Microsoft Word), format, deliverable numbering and naming, typos…); all reports in this project shall be in English. Unless otherwise specified the specific contract Deliverables shall be made available to ECMWF in electronic format.

Communication management (incl. external and internal communication). Any external communication activity must be agreed with the ECMWF Copernicus Communication team in advance. This includes, but not exhaustively, communication planning, branding and visual style, media outreach, website and social media activity, externally facing text and graphical content and events. Agreed activity would also need to be evaluated and reported on once complete so that success measures and KPIs could be provided to the European Commission (cf. Clause 2.4.6 of the Framework Agreement)

Set of Key Performance Indicators (KPIs) suitable for monitor contract performance. The proposed KPIs shall be SMART (specific, measurable, actionable, realistic and time bound). The successful tenderer shall report to ECMWF on these KPIs as part of the Quarterly and Annual Implementation Reports. The proposed set of KPIs is expected to be updated regularly with ECMWF during the contract.

Risk Management: The proposal shall include a risk register that describes identified risks for each work package, along with a mitigation strategy for each of the identified risks. This mitigation strategy shall be composed by both preventive and corrective measures. The risk register shall be updated regularly by the successful tenderer, and any update (related to new risks, likelihood or impact) shall be reported during the progress review meeting, as well as part of the quarterly and annual implementation reports.

Resources planning and tracking using the appropriate tools.

Subcontractor management, including conflict resolution, e.g. the prime contractor is responsible for settling disagreements, although advice/approval from ECMWF may be sought on the subject. A list of contractors describing their contribution and key personnel shall be provided, as well as backup names for all key positions in the contract. Tenderers shall describe how the Framework Agreement; in particular Clause 2.9 on Sub-contracting has been flowed down to all their subcontractors.

Management of personal data and how this meets the requirements of Clause 2.8 on Personal Data Protection and Annex 6 of the Framework Agreement.

List of minimum deliverables and milestones required as part of WP0, covering the contractual and financial reporting obligations towards ECMWF in line with the Terms and Conditions of the Framework Agreement (cf. Clause 2.3 and Annex 5):

WP0 Deliverables		
Deliverable#	*Title*	*Due*
D411.0.1.1.QX	Quarterly Report QQ YYYY; *QQ YYYY being the previous quarter*	Quarterly on 15/04, 15/07 and 15/10
D411.0.1.2.YYYY	Annual Report YYYY [Part 1]; *YYYY being the Year n-1*	Annually on 15/01
D411.0.1.3.YYYY	Annual Report YYYY [Part 2]; *YYYY being the*	Annually on 28/02
D411.0.1.4	Final implementation report	End date of the contract
D411.0.1.5.YYYY	Annual Implementation Plan YYYY; *YYYY being*	Annually on 30/09
D411.0.1.6.YYYY	Copy of prime contractor's general financial statements and audit report YYYY; *YYYY being the Year n-1*	Annually

WP0 Milestones			
Milestone#	*Title*	*Means of verification*	*Due*
M411.0.1.1.MX	Progress Review meeting with ECMWF	Minutes of meeting	Monthly
M411.0.1.2.MX	Kick off meeting	Minutes of meeting	Month 1
M411.0.2.1	Updated KPIs (list, targets…) after review with ECMWF	Technical note	One year after start of contract

9.2. Critical dependencies across Lots

This table provides an indicative timeline for major tasks to facilitate coordination and dependencies across the three Lots. This timeline is approximate and focuses **solely on tasks and deliveries subject to critical dependencies across lots**. The month specified in the table denotes the expected deadline for task completion/delivery. The green colour signifies expected start/end period of the significant contractual tasks. For instance, in Lot 2, "Indicators co-defined with Lot 3" at "M4" indicates the expectation for the final list and precise description of the indicators, including feedback from Lot 3, to be delivered by Lot 2 at month 4. Similarly, "Delivery of data and product user guides - climate & hydro v1," with "M12-M18, highlighted in green," implies that data delivery is expected to commence in Month 12 and conclude by Month 18. Lot 3 requires this information to initiate testing and development of applications and use cases.

		Year 1				Year 2				Year 3		
	Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Lot 1 - Seasonal												
Selection criteria/workplan for v1	**M2**											
Hydro data at current level - v1				**M12**								
Update selection criteria/workplan for v2		**M4**			**M15**							
New seasonal climate data on CDS - v2						**M18**						
New seasonal hydro data on CDS - v2								**M24**				
Operational user support				**M12**								**M36**
Lot 2 - Climate change												
Selection criteria of models, variables, ensembles, including report about consistency with Lot 1		**M4**										
Delivery of data and product user guides - climate & hydro v1				**M12**		**M18**						
Indicators co-defined with Lot 3		**M4**										
Indicators v1 delivered to the CDS					**M15**		**M21**					
Data v2, including major updates if relevant								**M24**				

Indicators v2 delivered to the CDS, including major updates if relevant									**M26**			
Final major update of the Service										**M30**		
Operational user support				**M12**								**M36**
Lot 3 - User												
User requirements and gap analysis (used by Lot 1 & 2)	**M2**			**M12**				**M24**				
User Oriented Applications		**M6**								**M30**		
User case development					Start						end	
Service evaluation report & recommendations											**M33**	
Cross Lot work plan v1		**M6**		**M12**		**M18**		**M24**		**M30**		

Table 3: Indicative timeline for major tasks

9.3. Provision of data to the Climate Data Store

Data delivery includes the provision of data and files containing abstracts, detailed descriptions of dataset, variables, etc., following the integration process detailed at Appendix 3 (Guidelines for Data Integration).

9.4. Bug fixing and maintenance of all service elements

The successful Tenderer shall be responsible of debugging and maintaining the datasets, the applications as well as updating relevant user guides and associated documentation, as required.

The successful Tenderer will ensure **quality of all scripts and tools** used to generate and publish C3S datasets and applications, through an internal quality control procedure to be delivered together with datasets and applications. As detailed above, workflow quality includes aspects such as optimised performance of the software, adequateness of the applications and workflows in terms of usability, accuracy, description of input and output variables, appearance, coding standards and style, functionality, and scientific quality.

9.5. Support to user engagement activities

While user engagement and training activities are not part of the scope of this contract (except for those described under Lot 3), Tenderers shall accommodate for eventual needs in providing technical and scientific expertise in support of these activities. Tenderers shall specify in their proposal the experts intended to be allocated to provide this support.

Requests to support activities may be raised on, for example:

- Contribute with content specific input to training, education, and capacity building material: development and/or review of learning resources in the domain of the contract, participation in train-the-trainer events and MOOCs.
- Contribute with content specific input to user-oriented communication material such as slides, story maps and user testimonials.
- Contribute and attend User Uptake workshops and stakeholder meetings. Presentations in languages other than English (e.g. mother tung of named experts) may be asked to be provided.

- Input to the C3S collection of user requirements (template will be provided to the successful Tenderer at the start of contract), as well as sharing needs and aspirations as raised by potential new user communities.
- Provide input to conceptional assessments and developments of specific user engagement plans and actions as launched by ECMWF.
- Provide input to user stories and user testimonials.

A small, dedicated budget shall be allocated in the pricing table to accommodate for these needs. Details on the expected activities and the budget shall be refined during the negotiation phase with the preferred bidder.

9.6. Contribute to L2 support to Copernicus User Support Team

Quality control procedures shall be put in place to check the quality of data before transmission to ECMWF. The precise methods should be proposed by Tenderers and will be agreed on as part of the negotiations. In the case of ECMWF detecting potential problems with the data, providers are required to give timely support to resolve problems quickly, and at the latest 24 hours before the product release date. Each data and application version needs to be documented, at a level which defines how the data/application were produced and allows users to understand version changes. The data providers will be responsible for making this documentation available as required.

The contract shall provide support to C3S on several fronts.

1. Technical support to the CDS team, on matters related to the operation of the infrastructure. As this is a service with operational status, this means timely responses in case of problems detected using an efficient workflow to get the answer and possible fixes quickly.
2. Support to specific user questions which relate to the hosting, archiving and the quality control of the original data and which go beyond the expertise of Copernicus User Support (CUS). A procedure should be defined and implemented to accommodate such requests and provide timely answers. Level-2 support is provided through the Copernicus User Support (operating a Jira ticketing system) with agreed Key Performance Indicators (KPIs; for example, 85% of Level-2 tickets should be resolved within 15-working days). The successful Tenderer shall provide an email address which acts as the single contact point.
3. The successful Tenderer is requested to provide and maintain user documentation where appropriate. User documentation is an integral part of the CDS catalogue entries and should be key to answering users' questions about the products/services provided by the successful Tenderer. Copernicus User Support will provide template and guide the successful Tenderer on creating and updating such documentation. For the time being, documentation is managed using Atlassian Confluence and is in the HTML format.
4. Support is also required for related C3S activities, including communication and outreach. While for most such cases the needs on this contract are expected to be minimal, consideration should be given to allowing resources to cover these aspects. Any communication activity related to this work must be agreed with the ECMWF Copernicus Communication team in advance. This includes, but does not exhaustively cover, communication planning, branding and visual style, media outreach, website, and social media activity, externally facing written and graphical content and events.
5. Provide support to users through the user forum upon request.

The contract management activities shall be managed in a separate work package; the structure and content expected from this work package are described in section 9.1 above.

9.7. Evaluation and Quality Control

Evaluation and Quality Control (EQC) is a central component of C3S to establish the service as a trusted source of climate information, delivering quality-assured and authoritative service outputs such as datasets and applications that are traceable and reproducible. In parallel to this ITT, another ITT will be issued regarding EQC for tools, applications and derived data including indicators.

EQC checks are independent from data providers and SIS successful Tenderers, hence no specific commitment is expected. However, the EQC programme provides the general requirements framework and independent technical and/or scientific evaluation of the delivered services (datasets, applications, indicators etc.). The successful Tenderer shall foresee providing support to the EQC function as necessary.

9.8. Data and IPR

It is a condition of EU funding for Copernicus that ownership of any datasets/software developed with Copernicus funding passes from the suppliers to the European Union via ECMWF. Ownership will pass from the date of creation of the datasets/software. Suppliers will be granted a non-exclusive license to use the datasets/software which they have provided to Copernicus for any purpose.

All software and products used by the successful Tenderer to produce the Copernicus datasets/software will remain the property of the successful Tenderer, except for those components which are acquired or created specifically for Copernicus purposes, with Copernicus funding, and which are separable and useable in isolation from the rest of the successful Tenderer's production system. The identity and ownership of such exceptional components will be passed to the European Union annually. The successful Tenderer will be granted a non-exclusive license to use them for any purpose.

9.9. Implementation Schedule

Tenderers shall provide a detailed implementation plan of proposed activities for the full period of the contract.

9.10. Deliverables and Milestones

Deliverables should be consistent with the technical requirements specified in this document. A deliverable is a substantial, tangible or intangible good or service produced because of the contract. In other words, a deliverable is an outcome produced in response to the specific objectives of the contract. Deliverables are subject to acceptance by the technical contract officers at ECMWF. All contract reports and documentation for this ITT shall be produced in English. The quality of reports and deliverables shall be equivalent to the standard of peer-reviewed publications and practice. Unless otherwise specified in the specific contract, deliverables shall be made available to ECMWF in electronic format (PDF/Microsoft Word/Microsoft Excel or HTML) via the Copernicus Deliverables Repository portal. The details will be agreed at the negotiation stage.

Each Deliverable shall have an associated resource allocation (person-months and financial budget). The total of these allocated resources shall amount to the requested budget associated with payroll.

Milestones should be designed as markers of demonstrable progress in service development and/or quality of service delivery, as applicable. They should not duplicate deliverables.

Tenderers shall complete the relevant table in Volume IIIA as part of their Tender, which includes the details of deliverables and milestones for all work packages and the schedules for each work package. Volume IIIA will be used by Tenderers to describe the complete list of deliverables, milestones, and schedules for each work package. All milestones and deliverables shall be numbered as indicated. All document deliverables shall be periodically updated and versioned as described in the tables.

9.11. Key Performance Indicators

The successful Tenderer shall report to ECMWF on a set of Key Performance Indicators (KPIs) suitable for monitoring various aspects of service performance (by using the template included in Volume IIIB). The KPIs shall be designed to quantify various aspects of quality of service against the requirements described in this document. As part of the Tender, Tenderers shall specify a proposed set of KPIs appropriate for the service, e.g., relating to operational service delivery, quality, data access, user support, user satisfaction, etc., aligned with the requirements expressed above. These initial specifications shall be refined together with ECMWF during the first 6 months of the contract.

10. Tender Format and Content

General guidelines for the Tender are described in Volume IIIB. This section describes specific requirements to prepare the proposal for this particular Tender, along with guidelines for minimum content expected to be included in the proposal, additional to the content described in the general guidelines of Volume IIIB. This is not an exhaustive description and additional information may be necessary depending on the Tenderer's response.

10.1. Page limits

As a guideline, it is expected that individual sections of the Tenderer's response do not exceed the page limits listed below. These are advisory limits and should be followed wherever possible, to avoid excessive or wordy responses.

Section	*Page Limit*
Executive Summary	2
Track Record	2 (for general) and 2 (per entity)
Quality of resources to be Deployed	2 (excluding Table 1 in Volume IIIB and CVs with a maximum length of 2 pages each)
Technical Solution Proposed	2 + 3 per Work package (Table 2 in Volume IIIB, the section on references, publications, patents and any pre-existing IPR is excluded from the page limit and has no page limit)
Management and Implementation	6 (excluding Table 4 and Table 5 in Volume IIIB) + 2 per each Work package description (Table 3 in Volume IIIB)
Pricing Table	No limitation

Table 4: Page Limits

10.2. Specific additional instructions for the Tenderer's response

The following is a guide to the minimum content expected to be included in each section, additional to the content described in the general guidelines of Volume IIIB. This is not an exhaustive description and additional information may be necessary depending on the Tenderer's response.

10.2.1. Executive summary

Tenderers shall provide an executive summary of the proposal, describing the objectives, team and service level.

10.2.2. Track record

Tenderers shall demonstrate for itself and for any proposed subcontractors that they have experience with relevant projects in the public or private sector at national or international level. ECMWF may ask for evidence of performance in the form of certificates issued or countersigned by the competent authority.

10.2.3. Quality of Resources to be deployed

Tenderers shall propose a team that meets at least the following requirements:

- A senior team member with more than 5 years of experience in managing activities related to this ITT (referred to as Service Manager). This person will be the point of contact on technical matters.
- A team member with experience of managing projects and contracts of this type and size (referred to as Contract Manager). This person will be the main point of contact for administrative matters.
- Team members with demonstrated experience in performing activities related to the various aspects of this ITT.

These team members shall be involved in the activities of this ITT at a minimum level of 10% of their total working time.

10.2.4. Technical Solution Proposed

Tenderers are expected to provide a short background to the proposed technical solution to demonstrate understanding of the solution proposed, as well as an exhaustive and detailed description of the proposed technical solution and its organisation into work packages.

10.2.5. Management and Implementation

As part of the general project management description, and in addition to the guidance provided in Volume IIIB, Tenderers shall consider the elements described in section 9.1 above.

11. Additional Information

11.1. Appendices

11.1.1. Appendix 1 How to submit Jupyter Notebook based training material to the CDS/ADS/CADS

Tenderers should refer to the separate document attached. Note that the document may include links to other ECMWF and/or web resources, some of which may not be publicly available. This document is provided to facilitate Tenderers' understanding of what is expected in terms of standards, content and the information and deliverables required for the submission of training material in the form of Jupyter Notebooks, as well as to facilitate the assessment and costing of resources which Tenderers should allocate in their response for any such activities. Full access to ECMWF internal resources shall be provided to the successful Tenderer at the start of the contract.

11.1.2. Appendix 2 Application Style Guide

Tenderers should refer to the separate document attached. Note that the document may include links to other ECMWF and/or web resources, some of which may not be publicly available. This document is provided to facilitate Tenderers' understanding of the general guidance that should be followed by contractors when designing Copernicus-branded web applications and to facilitate the assessment and costing of resources which Tenderers should allocate in their response for any such activities. Full access to ECMWF internal resources shall be provided to the successful Tenderer at the start of the contract.

11.1.3. Appendix 3 Guidelines for Data Integration

Tenderers should refer to the separate document attached. Note that the document may include links to other ECMWF and/or web resources, some of which may not be publicly available. This document is provided to facilitate Tenderers' understanding of the data integration process and to facilitate the assessment and costing of resources which Tenderers should allocate in their response for any such activities. Full access to ECMWF internal resources shall be provided to the successful Tenderer at the start of the contract.

C3S2_411 Volume II
Appendix 1

How to submit Jupyter Notebook based training material to the CDS/ADS/CADS

Copernicus Contractors

Exported on 04/25/2024

Table of Contents

1 Overview

So that users can make best use of the data available in the CDS/ADS/CADS, data providers can provide training material in the form of Jupyter Notebooks which can be included in the Copernicus training inventory[1], with accessible links added to the relevant dataset pages.

This page describes what is expected in terms of notebook standard and content and the information and deliverables required for the submission.

1 https://ecmwf-projects.github.io/copernicus-training-c3s/intro.html

2 Notebook contents and standards

All training material delivered by the contractors need to be compliant with the CDS/ADS/CADS standards. The ultimate aim of the delivery is to publish the training material on the Copernicus and CDS/ADS/CADS websites. In order to be published, the training material needs to be SWUMP:

- **Self-explanatory**
  - All steps are clearly, correctly and succinctly explained
- **Well structured**
  - The flow of the notebook should make logical sense and produce an aesthetically pleasing page
  - A good balance between markdown and code as you progress through the notebook
- **Usable**
  - The notebook MUST run to completion without errors
  - The notebook MUST only include output and widgets which are compatible with JupyterBooks, see below.
- **Meaningful**
  - The content of the notebook should be relevant and provide a meaningful application of the data
  - The training material should provide a use-case with added value to the data available in the CDS
- **Proficient**
  - The notebook MUST meet our code standards tests which can be checked prior to submission using the commands provided below

Code standards tests

```
# install necessary packages
pip install flake8-nb

# execute tests with CDS configuration options:
flake8_nb --max-line-length 100 --max-doc-length 100 $NOTEBOOK
```

2.1 Notebook templates

We recommend that you use one of the already published training notebooks[2] as a template to help you get started. It may even be useful to work through several of the Jupyter notebooks to help get a better understanding of what is expected.

2.2 Hint and tips

Widgets and output

The widgets and output included in the Notebook must be compatible with JupyterBooks. JupyterBooks do not have a running python kernel, threrefore they are not compatible with interactive widgets which require a running kernel, e.g. a number of ipywidgets, as documented here:

https://jupyterbook.org/en/stable/interactive/interactive.html?highlight=widgets#ipywidgets

Inline images

Any additional images included in the notebook should be added using markdown hyperlink syntax, html syntax does not work with our jupyter-books.

Example image link
`![](.images.png)`

2.2.1 Cross-references

Please avoid using within notebook cross-references, i.e. links between sections of the notebook. Due to platform differences they are not rendered correctly on JupyterBook pages and causes many compilation warnings and errors. This means it is much harder for us to identify real issues in the notebook, slowing down the integration process.

2 https://ecmwf-projects.github.io/copernicus-training-c3s/intro.html

3 Delivery

The method for delivering training material will be via ECMWF Contractors Portal (COPCO[3]), please select the Training Material option, or click this link[4]. You must have an ECMWF account to open a ticket, you can register HERE[5] .

As each piece of training material will have to go through the review process it is best to open a ticket for each piece submitted such that it is easier for everyone to follow the progress of submission.

The ticket should be created with the following information:

1. **Subject**
    - The proposed title of the training material.
2. **Description**
    - This should include the following:
        - Short description (1 or 2 sentences) of the contents of the notebook. This is for reference to help participants follow the progress of integration.
    - *Optional:* In lieu of an attached Jupyter notebook, you can provide a link to a github repository containing the Notebooks.
3. **C3S Contract category and number**
    - Select the contract category and number associated with this submission
4. **Request participant**
    - Any colleagues who may want to follow the progress of the submission. (They must also have an ECMWF account to be added as a participant)
5. **Attachment**
    a. Jupyter Notebook(s) containing training material
    b. Completed checklist
    c. Any other supporting documents and/or images?

The delivery of training material does not guarantee publication of the training material. All training material are subject to an internal review process which will ensure that the published content is of the standards expected (SWUMP).

3 https://jira.ecmwf.int/plugins/servlet/desk/category/cds-apps
4 https://jira.ecmwf.int/plugins/servlet/desk/portal/12/create/233
5 https://accounts.ecmwf.int/auth/realms/ecmwf/protocol/openid-connect/registrations?client_id=apps&response_type=code&scope=openid%20email&redirect_uri=https://www.ecmwf.int

4 Training material integration workflow

1. **The training material is developed inline with the objectives of the relevant contract(s)**
    - A technical officer will be assigned to ensure that the scientific and informative content of the training material is suitable.
    - The submitted version of the training material must be SWUMP
2. **The training material is delivered via a CDSAPP Jira ticket**
    - Please see the Delivery (see page 6) section
3. **The training material is checked and reviewed**
    - See TEMPLATE Training material checklist (see page 8)
    - The delivery is checked by the CDS team
        i. Have all required fields been provided
        ii. Does the notebook run to completion and meet the coding standards (Usable and Proficient)?
    - The training material is reviewed by 1/2 ECMWF members of staff
        i. Is the notebook Self-explanatory, Well structured and Meaningful?
        ii. We try to ensure reviewers are NOT specialist in the field to ensure that is understandable to non-experts
    - A final editorial decision is made
4. **The training material is published in the C3S/CAMS training library**

5 TEMPLATE Training material checklist for COPCO-???

JIRA	link for reviewing training material in the development pages

5.1 Note to Reviewers and Editors:

Instructions:

- To edit the page see the edit button at the top right
- If you are happy with an field (e.g. Title) just tick the box and move on
- If you are not happy with an element please list specific points that you would like address
- Start typing next to the checkbox, when you hit return you will get a new checkbox for a second point
- Leave these checkboxes unticked, this means the person responding to your review can tick them as they address the points
- The purpose of the review is to ensure that the content of the material is good enough, the CDS team will ensure that the notebook is functional and runs
- But don't let this stop you downloading and playing yourself if you are interested

5.2 Instructions to Contractors:

- Please respond to all the reviewer comments in the checklist table, unless there is a comment from the CDS team that states otherwise
    - When you have addressed the comment please tick the checkbox
    - If you have any comments please add them green below the relevant review comment
    - If you feel the review comment is not addressable please leave the box unchecked and provide an explanation why it has not been addressed.
- When you have completed the responses please inform your technical officer on the JIRA ticket.

5.3 Review Checklist

Instructions for reviewers: **If you are happy with a component please put a tick in the box.** **If you are not satisfied it is helpful if the comments are provided as a list of specific items which can be addressed. This is not to discourage general comments if, for example, a component is generally lacking in direction/purpose/clarity.**	**Technical Officer**	**Expert Review**	**User support**
Title ***Is the title concise and correct? good example:*** ***"Tutorial on climatologies using ERA5 data"***	☐	☐	☐
Introductory text ***Is the introductory text clear and understandable?*** ***It should explain what the notebook does and provide an outline of the order of computation***	☐		
Data description text ***Summary of the data used in the notebook***	☐	☐	☐
All other text in the notebook. Specific comments regarding any of the other text in the notebook, e.g. spelling, capitalisation and grammar or any other comments.	☐	☐	☐
Notebook flow ***Does the order of the Notebook make sense?*** ***Are the steps taken in an increasing order of complexity?***	☐	☐	☐

Notebook appearance ***Is the layout of the Notebook clear and well structured?*** ***Are the the plots/tables and other outputs of sufficient quality?***	☐	☐	☐
Notebook relevance ***Is the output produced by the Notebook meaningful, is it a useful application of the data?***	☐	☐	☐
Notebook self-description ***Is the Notebook self-explanatory, you do not need to go to other source to undertand the steps taken and why.*** ***This does NOT mean the data or underlying software has to be fully explained, just clear reasoing for thhe steps taken within the Notebook***	☐	☐	☐
Notebook code comments (Optional) **Please provide any comments you have regarding the code quality and structure.** **Please note that this is optional and all notebooks will be automatically screened for general code quality.**	☐	☐	☐
Contents side bar controls (right hand side) ***Do the controls on the right hand work and have sensible headings?***	☐	☐	☐
Any other comments	☐	☐	☐

Decision ***Review should choose one of the following:*** 1. ***Accepted - The resource will go straight to the Editorial board*** 2. ***Accept, minor changes - The resource will go to the Editorial board after your points have been addressed*** 3. ***Reject, major changes required - The resource will be returned to you for evaluation that your points have been adequately addressed***			

5.4 The components below this point are for internal CDS use only

5.4.1 Delivery/submission checklist (for CDS team)

Item ***This is to check that the provider has made a sufficient submisison prior to starting any review process. In some cases it will be best to make the changes***	**CDS Team member:**
Ready for review	☐
Jira Summary **"European energy and climate data explorer"**	☐
JIRA Description ***Is the description*** **good enought to follow progress** **Does the description provide the Chapter where the TM should live?**	☐
Labels	☐
Provider checklist complete	☐
Notebook visible in binder	☐

Notebook host links	☐
Notebook runs to completion	☐
Notebook uses permitted data access methods (cdsapi/cads-toolbox)	☐
Package install and import ***No output produced by package install. Packages should only be imported if they are used***	☐
Data access ***Accessing the data should follow our guidelines:*** 1. ***cdsapi to download, unzip with ZipFile, then open with xarray/pandas*** 2. ***cads-toolbox to do all of the above in a single step***	☐
Notebook passes code standard tests	☐
No references to local locations in Notebook	☐
Assign to appropriate chapter	☐
Give appropriate sidebar link title	☐
Any other business	

5.4.2 Editorial Board Decisions

The role of Editors is to ensure that: • **The training material provides added value to Copernicus (it is worth publishing)** • **The review process has been followed** **Comments and suggestions are still welcome**	
Agree on chapter and sidebar title (left)	☐
Decision	☐
Comments	

C3S2_411 Volume II
Appendix 2

Applications Style Guide

Copernicus Contractors

Exported on 04/25/2024

Table of Contents

1 Introduction

This page provides general guidance that should be followed when designing Copernicus-branded web applications. These guidlines are not necessarily meant to be interpreted as a set of hard-and-fast rules, but rather a series of recommendations and principles that should help maintain a **consistent look and feel** across Copernicus interactive web content.

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2 General Style

Copernicus applications should be **simple** and **clear**, and not **over-complicated**.

2.1 Colours

All application widgets should have a **white** background with **black** text.

2.2 Fonts

C3S-branded applications should use the font **Calibri**.

Content text should have a font size of **14px**; headings should have a font size of **18px**.

3 Controls and Settings

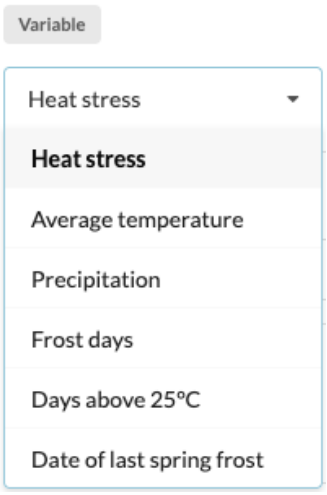
When developing control panels and user-input sections, consider how each component guides the user to find the information that's useful to them.

3.1 Dropdowns

Use a dropdown when:

- selection options are **naturally discrete**, e.g. data variables;
- the list of available options is **long** (>5).

Dropdowns hide non-selected options until the user interacts with them, creating a clear separation between each choice in the interface. This makes dropdowns most useful for input fields which are not intended for direct comparison.



3.2 Buttons

Use a series of buttons when selection options **naturally follow on from each other**, such as time horizons or emission scenarios - unless there is a long list of options available, in which case a dropdown might be more suitable.

Buttons show the user all available options at all times, encouraging interaction and comparison more than a dropdown would. Based on this principle, it's worth considering whether a series of buttons or a dropdown would be more appropriate for each input choice field.

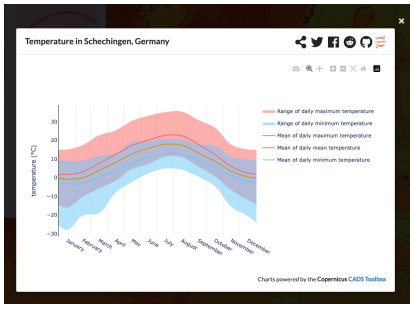
3.3 Modals

Use a modal to display **large blocks of text**, such as help or detailed information text.

Longer passages of text should always be delegated to modals where possible, to avoid cluttering the main interface with large amounts of text.

Modals should be **launched from buttons**; for example, instead of including a "How to use this application" section in the main interface, consider having a "How to use this application" button which triggers a modal containing the detailed text.

Modals can also be used for graphics and visualisations which demand lots of space or attention - for example, in some interactive map applications, clicking on a point can launch a modal to display statistics and graphs at the seleted point.

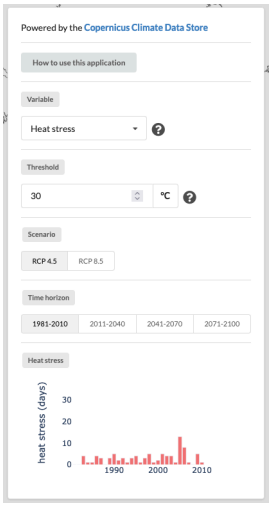


3.4 Side panels

Use a side panel in an **interactive map** when there are lots of user-selectable options.

Side panels should always appear on the **left-hand side** of interactive maps.

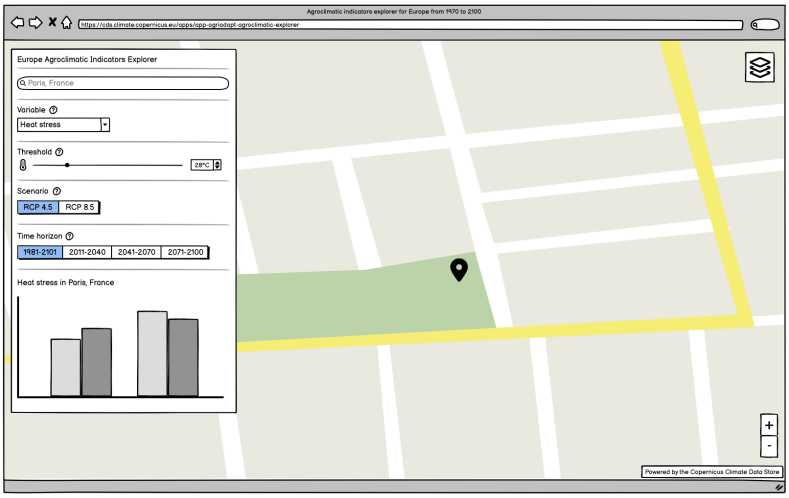
Side panels can contain plots and figures if appropriate - especially when it's important to see both the map and the figure in the same frame.



4 Interactive maps

4.1 General Layout

- Interactive maps should be **full screen** unless there is a very good reason not to be (for example if the map is not the main focus of the application).
- Interactive map **controls**, such as zoom and pan, should be placed in the **bottom right-hand corner**.
- **Layer selection options** should be placed in the **top right-hand corner**.
- If the application has user selection options (e.g. to change variables, temporal aggregations, statistics etc.), these should be placed in a **side panel** on the **left-hand side** of the map.



4.2 Mobile Layout

- Interactive maps should be **full screen** unless there is a very good reason not to be (for example if the map is not the main focus of the application).
- **Layer selection options** should be placed **at the top of the screen**. They should be **minimisable** in such a way that the selection remains visible, but the selection *widgets* are hidden so as to save space (see mockup below).
- In general, graphs, statistics and results returned from interacting with the application should appear in a **drawer** widget at the **bottom** of the application, much like Google Maps (see mockup below).

4.3 Interactivity

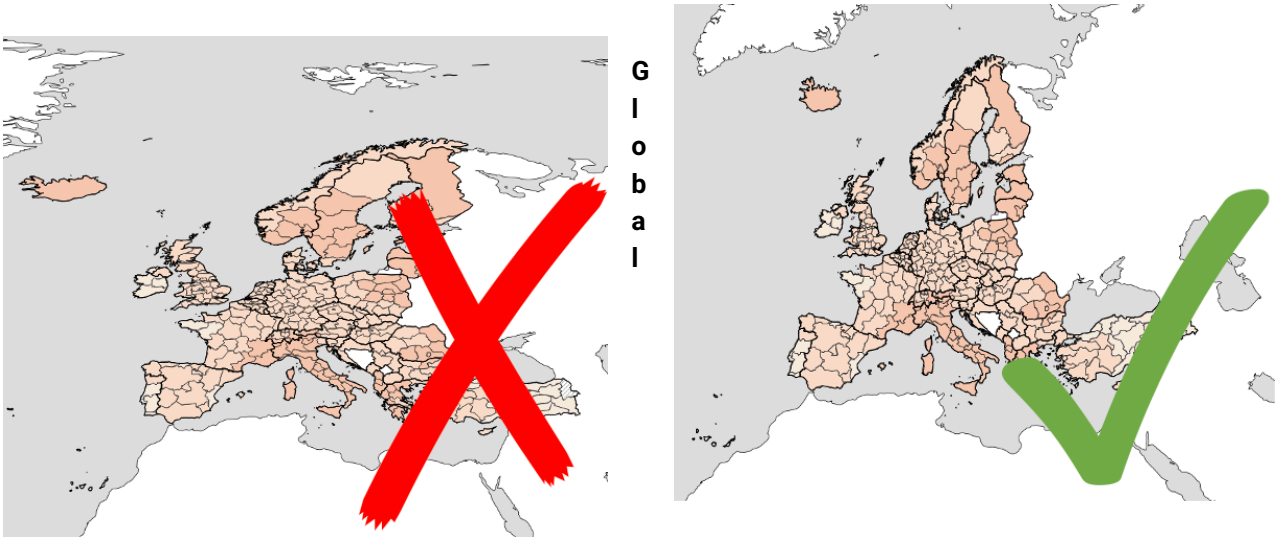
Interactive maps should always be **zoomable** and **pannable**, but appropriate limits should be set for maximum/minimum zoom - for example, if data is aggregated on European countries, the maximum zoom level should comfortably fit the smaller countries within the window.

4.4 Projections

Interactive maps should use a projection suitable for the data being visualised – for example, data focused on the North Pole should use a polar stereographic projection.

Projection choice is left to the discretion of the application designer, except for **European** and **Global** maps:

- **European** maps should use **EPSG:3035**



maps should use **EPSG:3857**

4.5 Visualisation Style

Data layers visualised on interactive maps should always be **opaque**, unless there is a very good reason for the layer to be transparent. Semi-transparent data layers on top of satellite/map layers are hard to interpret and often look messy.

Background map layers should have the **right level of detail** to compliment the data being visualised. In general, satellite/maps layers with roads, towns and buildings are **not** appropriate for use with climate model data, as the detail of these layers indicates a level of precision that is not consistent with the resolution and uncertainty in climate models.

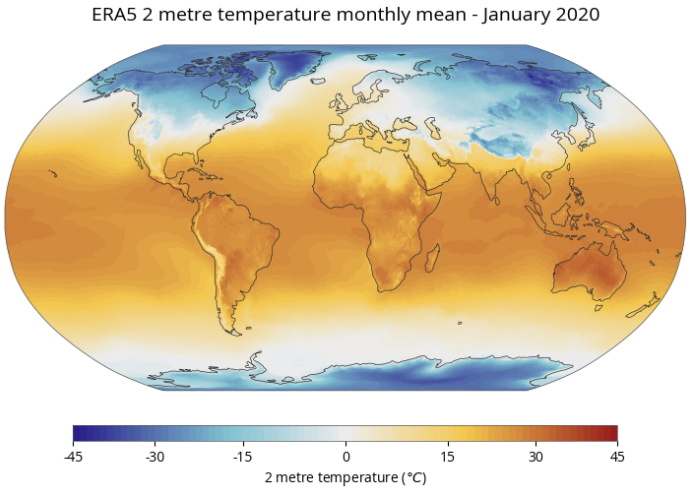
5 Static Maps

5.1 Software

Static maps should be generated using **earthkit-maps** or **matplotlib** and **cartopy**.

5.2 Projections

The same projection rules outlined for interactive maps above also apply to static maps - that is, the projection used should be suitable for the data being visualised. As with interactive maps, European maps should use **EPSG:3035** where possible; but global *static* maps should use the **Robinson** projection, as below.



6 Graphs and Plots

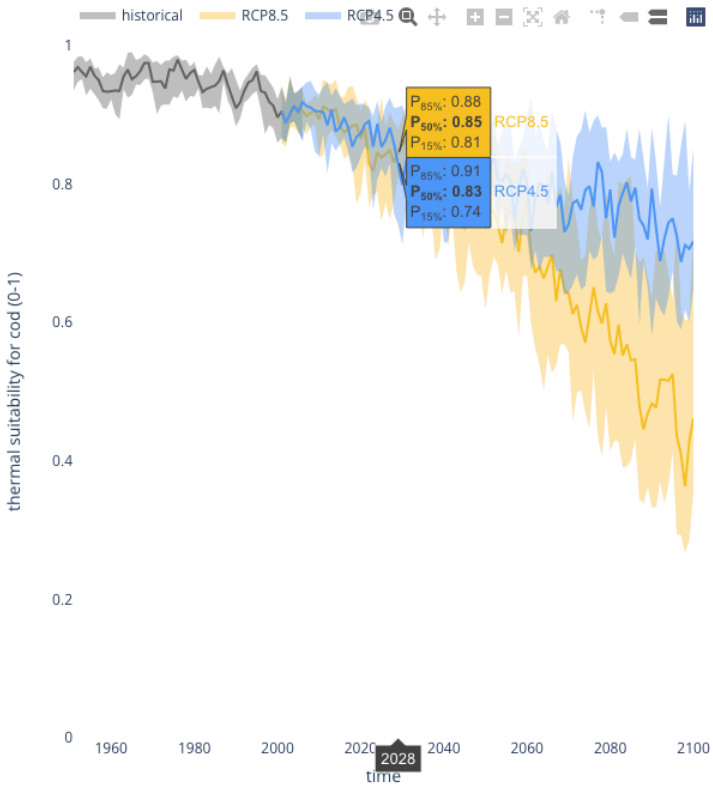
6.1 Software

Statistical graphs and plots should be generated using **earthkit-plots** or **Plotly**.

6.2 Climate Projections

Climate projection time series plots are one of the most common graphs produced in C3S applications. In order to maintain a consistent look and feel, and in order to help make our applications more directly comparable, we follow a style guide for these plots:

- each scenario should be represented by a **solid line** representing the multi-model "average" (usually the **50th percentile**) on top of a **semi-transparent shaded region** (40% opacity) representing the multi-model spread (usually the **15th - 85th percentile**)
- when using Plotly, the hover labels for climate projections should be **grouped** (see example below) - i.e. the labels for each percentile should be included in a single hover label for each emissions scenario. This is to avoid overcrowing the plot with hover labels (by default, 3 scenarios x 3 percentiles = 9 hover labels!)



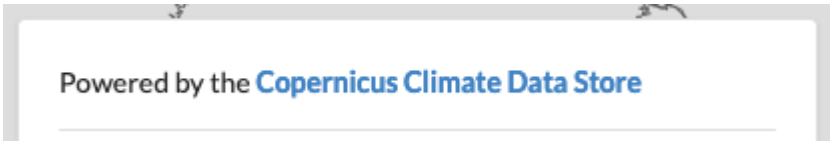
The colours selected above are **grey** (`#666666`) for **historical** data; **pink** (`#c31ff9`) for **low-emissions scenario** data (not shown above); **blue** (`#5197f8`) for **medium-emissions scenario** data; and **yellow** (`#f9c31f`) for **high-emissions scenario** data. These colours are not enforced, but have been selected to be **colourblind-friendly**, while also removing colour-emphasis from each scenario (i.e. plotting high-emission scenarios in red is likely to bias the interpretation of that scenario as "dangerous" or "hot", which should be avoided - even if accurate - because the data should speak for itself).

7 Logos and Attribution

All C3S-branded applications should include the text "**Powered by the Copernicus Climate Data Store**". Equivalently, all CAMS-branded applications should include the text "**Powered by the Copernicus Atmosphere Data Store**".

In interactive map applications, this text should be added to the standard "attribution" section in the bottom right-hand corner:

This text can also be placed at the top of a side panel, unless the application has a lot of controls and settings:



8 Disclaimers

In applications which show political boundaries, our legal department has recommended that we include the following text (usually best-placed inside a modal):

"The designations employed and the presentation of material on the map do not imply the expression of any opinion whatsoever on the part of the European Union concerning the legal status of any country, territory or area or of its authorities, or concerning the delimitation of its frontiers or boundaries."

C3S2_411 Volume II
Appendix 3

If you are a provider of data

Copernicus Services

Exported on 04/25/2024

Table of Contents

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About this page

Scope	This page describes the main steps needed to integrate data in the CDS Catalogue. It **does not describe** what is needed to integrate documentation, the role of the technical officers and other aspects that are very important for a successful integration but that are the scope of other wiki pages.
Intended audience	*Copernicus CDS data providers.*
Outline	*The focus of this page is on what the data provider needs to supply to the CDS team and how to do it.*
Disclaimer	*The information in this page is not guaranteed to describe exactly the actual processes which are subject to change from time to time.* *But, the CDS team intends to keep the information in this page as close as possible of the actual practices.*

1 Provider's role: summary

List of the expected contributions

The provider is expected to work closely with CDS team and the technical officer in order to resolve any issues that come up during the various stages of the publication process and afterwards. Communication is preferred through Jira ticket.
Below there is a list that had been laid out in chronological order with the main contributions.

1. Registers the Dataset: / Dataset registration[1] (*Integration process*)
2. Supplies the Information document: Information document template[2] *(Integration process*)
3. Supplies manifest file (See more about manifests below at *Manifest and pseudo-manifest files*. *Integration process.*)
4. Help the CDS team member to reply to the reviewer's and Editorial Board's comments (*Review process*)
5. Provide previous existent DOIs, licences and citations associated with each part of the data (see below: *DOI, citation and licence. Review process.)*
6. After entry published in the CDS Catalogue, the data provider should keep the manifest's filename and path exactly the same for the whole duration of the contract, even when the contents of the manifest is changed. (*Complementary processes: automatic updates*)
7. The data provider is expected to help the CDS team on keeping the entry working as expected when the data provider has the knowledge and the resources to do it (*Complementary processes: Maintenance)*
8. Follows CDS procedures for deprecating data (see below: *Versions, deprecation of entries, replacement of data.Complementary processes: Maintenance*)

1 https://confluence.ecmwf.int/pages/viewpage.action?pageId=402643456
2 https://confluence.ecmwf.int/display/COPSRV/Information+document+template

2 How to start the integration of your data in the CDS Catalogue

JIRA ticket, Information document and manifest file

Provider's role	Description
JIRA When asked by the CDS management registers the dataset[3] and create a JIRA ticket at https://jira.ecmwf.int/servicedesk/customer/portal/5	All information concerning the creation, modification, merging, updating, deprecation, additions of of data or documentation, DOIs, Citations, etc, is supposed to be managed through the JIRA ticket.
Manifest Have a pseudo-manifest file (or a manifest file) prepared.	This is the central piece of information needed by the CDS. So important that we have a whole section about it at the bottom of this page.
Information document Attach to the JIRA ticket an "Information document" filled in with the information associated to the data that you are delivering for publication in the CDS Catalogue. The template for the information document can be found here: Information document template[4].	The information document is the starting point for the integration process. In order to arrive at an agreed draft entry to submit for review, additional inputs may be required. The document contains fields and tables that should be completed with the information relevant for your data. Guidelines are provide along those fields and tables intending to help you to understand exactly which information is required and in which format.

3 https://confluence.ecmwf.int/display/COPSRV/Dataset+registration
4 https://confluence.ecmwf.int/display/COPSRV/Information+document+template

3 Main processes in which you are expected to participate

Pre-publication process

The aim of this step is to check and agree on the main inputs for the subsequent publication process:

- path and filename conventions,
- the size of the files,
- the number of variables per file,
- where the data will be stored,
- manifest file

The CDS team expects to have access to the information in the list above as soon as possible through a JIRA ticket and at least 2 month before the actual delivery of the data.

For data for which the contents and the container is still modifiable, the CDS team expects to interact with the provider in order to influence the way the data is stored making it more suitable for the needs of the Catalogue and the needs of the Toolbox.

Publication process

The process that goes from the initial trigger of the integration of your data, to the publication of the Catalogue entry in the public Catalogue, is referred as the "publication process".
The publication process has two processes in sequence: the integration process and the review process. Your role in these two processes is summarised below.

<table>
<tr><th>Provider's role</th><th>Process</th><th>Description</th></tr>
<tr><td>Creates JIRA ticket
Supplies the Information document
Supplies manifest file
Replies to CDS team queries</td><td>Integration process (analogous to creating a draft of a paper to be submitted to a scientific journal)</td><td>
<table>
<tr><td>Inputs</td><td>JIRA ticket and Information document</td></tr>
<tr><td>Outputs</td><td>Draft Catalogue entry judged to be good enough to be submitted to review by the CDS team, the technical officer and the data provider</td></tr>
<tr><td>Work</td><td>Based on the manifest file and the Information Document, a CDS team member (or associated) creates one or more possible drafts for the future entry in the Catalogue. When agreed that the draft is good enough to be submitted for publication this process ends.</td></tr>
</table>
</td></tr>
</table>

<table>
<tr>
<td>Help the CDS team member to reply to the reviewer's and Editorial Board's comments.</td>
<td>Review process (analogous to the review process of a paper submitted to a scientific journal)</td>
<td>
<table>
<tr><td>Inputs</td><td>Draft entry</td></tr>
<tr><td>Outputs</td><td>Modified entry reviewed and approved by the Editorial Board published in the public CDS Catalogue</td></tr>
<tr><td>Work</td><td>A CDS team member (or associated) runs an internal review process to guarantee that the entry respects the CDS expectations.</td></tr>
</table>
</td>
</tr>
</table>

Post-publication processes

After publication there are frequently some additions to be made or some issues to be addressed on the entry associated to your data. These are the two main processes where you may be asked to participate:

<table>
<tr><th>Provider's role</th><th>Process</th><th>Description</th></tr>
<tr>
<td>Keep the manifest's filename and path exactly the same. Contents of the manifest is expected to change. But new additions to the contents, other than time extensions, should be discussed with the CDS team. See more about manifests below at Manifest and pseudo-manifest files.</td>
<td>Automatic updates (Updates date and time related widgets in the download form. This allows the automatic release of time extensions of data. Does not work for other widget's updates like new variables. new versions etc.)</td>
<td>
<table>
<tr><td>Inputs</td><td>Entry already published in the Catalogue
Manifest file or equivalent
Update frequency agreed
EC-Flow suite implemented</td></tr>
<tr><td>Outputs</td><td>Entry updated with new dates</td></tr>
<tr><td>Work</td><td>EC-Flow suite will read the manifest file and run CDS scripts able to recreate the download form.</td></tr>
</table>
</td>
</tr>
</table>

<table>
<tr>
<td>The data provider is expected to help the CDS team on keeping the entry working as expected. The main observed issues with published datasets are:
download form not providing the expected data
documentation tab not providing the expected documentation
mismatch between data and documentation
When this or other issues are detected by the data provider, the CDS team will be grateful if the provider could notify the CDS team using the JIRA help desk (https://jira.ecmwf.int/servicedesk/customer/portal/5)

Sometimes these issues are detected by users or the CDS team itself, in which case the CDS team will ask the data provider to help to fix the issue only when the data provider has the knowledge or the resources to do it</td>
<td>Maintenance (new programmed versions, new documentation, deprecating data, unexpected issues with the data and the documentation, licences, etc)</td>
<td>
<table>
<tr><td>Inputs</td><td>Published entry
Request for modification of the published entry</td></tr>
<tr><td>Outputs</td><td>Modified entry</td></tr>
<tr><td>Work</td><td>A CDS team member (or associated) modifies the entry as requested. The CDS team evaluates when the required modification needs agreement from the Editorial Board.</td></tr>
</table>
</td>
</tr>
</table>

4 Manifests, deprecation of data, versions, DOI, citation, acknowledgement and licence

Manifest and pseudo-manifest files

Content of the Manifest

The manifest should contain the path and the file name for every file that the CDS catalogue is supposed to provide to the users. **Nothing more nothing else.** No empty lines, no comments.
For instance:

First lines of a manifest for cmip6 data saved in ESGF

```
- path: CMIP/NUIST/NESM3/historical/r1i1p1f1/Amon/evspsbl/gn/v20190705
  ds_id: c3s-
cmip6.CMIP.NUIST.NESM3.historical.r1i1p1f1.Amon.evspsbl.gn.v20190705
  var_id: evspsbl
  array_dims: time lat lon
  array_shape: 1980 96 192
  time: 1850-01-16T12:00:00 2014-12-16T12:00:00
  latitude: -88.57 88.57
  longitude: 0.00 358.12
- path: ScenarioMIP/CNRM-CERFACS/CNRM-CM6-1-HR/ssp245/r1i1p1f2/Amon/pr/gr/
v20191202
  ds_id: c3s-cmip6.ScenarioMIP.CNRM-CERFACS.CNRM-CM6-1-
HR.ssp245.r1i1p1f2.Amon.pr.gr.v20191202
  var_id: pr
  array_dims: time lat lon
  array_shape: 1032 360 720
  time: 2015-01-16T12:00:00 2100-12-16T12:00:00
  latitude: -89.62 89.62
  longitude: 0.00 359.50
- path: CMIP/CNRM-CERFACS/CNRM-CM6-1/historical/r1i1p1f2/Amon/tas/gr/v20180917
  ds_id: c3s-cmip6.CMIP.CNRM-CERFACS.CNRM-
CM6-1.historical.r1i1p1f2.Amon.tas.gr.v20180917
  var_id: tas
  array_dims: time lat lon
  array_shape: 1980 128 256
  time: 1850-01-16T12:00:00 2014-12-16T12:00:00
  level: 2.00 2.00
  latitude: -88.93 88.93
  longitude: 0.00 358.59
```

First ten lines of a manifest file for a dataset accessible through URL addresses

head ./Integration_of_satellite-earth-radiation-budget/manifest_c3s_312b_lot1_erb_c3s_icdr_latest.txt
http://gws-access.ceda.ac.uk/public/cds_c3s_cloud/c3s_312b_lot1/data/erb/c3s/icdr/r01/monthly/2017/01/C3S-312bL1-L3C-MONTHLY-ERB-SLSTR_ORAC_Sentinel-3a_201701_fv3.1.nc
http://gws-access.ceda.ac.uk/public/cds_c3s_cloud/c3s_312b_lot1/data/erb/c3s/icdr/r01/monthly/2017/02/C3S-312bL1-L3C-MONTHLY-ERB-SLSTR_ORAC_Sentinel-3a_201702_fv3.1.nc
http://gws-access.ceda.ac.uk/public/cds_c3s_cloud/c3s_312b_lot1/data/erb/c3s/icdr/r01/monthly/2017/03/C3S-312bL1-L3C-MONTHLY-ERB-SLSTR_ORAC_Sentinel-3a_201703_fv3.1.nc

http://gws-access.ceda.ac.uk/public/cds_c3s_cloud/c3s_312b_lot1/data/erb/c3s/icdr/r01/monthly/2017/04/C3S-312bL1-L3C-MONTHLY-ERB-SLSTR_ORAC_Sentinel-3a_201704_fv3.1.nc
http://gws-access.ceda.ac.uk/public/cds_c3s_cloud/c3s_312b_lot1/data/erb/c3s/icdr/r01/monthly/2017/05/C3S-312bL1-L3C-MONTHLY-ERB-SLSTR_ORAC_Sentinel-3a_201705_fv3.1.nc
http://gws-access.ceda.ac.uk/public/cds_c3s_cloud/c3s_312b_lot1/data/erb/c3s/icdr/r01/monthly/2017/06/C3S-312bL1-L3C-MONTHLY-ERB-SLSTR_ORAC_Sentinel-3a_201706_fv3.1.nc
http://gws-access.ceda.ac.uk/public/cds_c3s_cloud/c3s_312b_lot1/data/erb/c3s/icdr/r01/monthly/2017/07/C3S-312bL1-L3C-MONTHLY-ERB-SLSTR_ORAC_Sentinel-3a_201707_fv3.1.nc
http://gws-access.ceda.ac.uk/public/cds_c3s_cloud/c3s_312b_lot1/data/erb/c3s/icdr/r01/monthly/2017/08/C3S-312bL1-L3C-MONTHLY-ERB-SLSTR_ORAC_Sentinel-3a_201708_fv3.1.nc
http://gws-access.ceda.ac.uk/public/cds_c3s_cloud/c3s_312b_lot1/data/erb/c3s/icdr/r01/monthly/2017/09/C3S-312bL1-L3C-MONTHLY-ERB-SLSTR_ORAC_Sentinel-3a_201709_fv3.1.nc
http://gws-access.ceda.ac.uk/public/cds_c3s_cloud/c3s_312b_lot1/data/erb/c3s/icdr/r01/monthly/2017/10/C3S-312bL1-L3C-MONTHLY-ERB-SLSTR_ORAC_Sentinel-3a_201710_fv3.1.nc

First line of a manifest file for a dataset saved in MARS

head reanalysis-uerra-europe-soil-levels/mars.list
class=ur,expver=prod,levtype=sol,origin=eswi,stream=oper,type=an,param=260199/260360,levelist=1/2/3,time=00:00:00/06:00:00/12:00:00/18:00:00,date=1961-01-01/1961-01-02/1961-01-03/1961-01-04/1961-01-05/1961-01-06/1961-01-07/1961-01-08/1961-01-09/1961-01-10/1961-01-11/1961-01-12/1961-01-13/1961-01-14/1961-01-15/1961-01-16/1961-01-17/1961-01-18/1961-01-19/1961-01-20/1961-01-21/1961-01-22/1961-01-23/1961-01-24/1961-01-25/1961-01-26/1961-01-27/1961-01-28/1961-01-29/1961-01-30/1961-01-31
class=ur,expver=prod,levtype=sol,origin=eswi,stream=oper,type=an,param=260199/260360,levelist=1/2/3,time=00:00:00/06:00:00/12:00:00/18:00:00,date=1961-02-01/1961-02-02/1961-02-03/1961-02-04/1961-02-05/1961-02-06/1961-02-07/1961-02-08/1961-02-09/1961-02-10/1961-02-11/1961-02-12/1961-02-13/1961-02-14/1961-02-15/1961-02-16/1961-02-17/1961-02-18/1961-02-19/1961-02-20/1961-02-21/1961-02-22/1961-02-23/1961-02-24/1961-02-25/1961-02-26/1961-02-27/1961-02-28
class=ur,expver=prod,levtype=sol,origin=eswi,stream=oper,type=an,param=260199/260360,levelist=1/2/3,time=00:00:00/06:00:00/12:00:00/18:00:00,date=1961-03-01/1961-03-02/1961-03-03/1961-03-04/1961-03-05/1961-03-06/1961-03-07/1961-03-08/1961-03-09/1961-03-10/1961-03-11/1961-03-12/1961-03-13/1961-03-14/1961-03-15/1961-03-16/1961-03-17/1961-03-18/1961-03-19/1961-03-20/1961-03-21/1961-03-22/1961-03-23/1961-03-24/1961-03-25/1961-03-26/1961-03-27/1961-03-28/1961-03-29/1961-03-30/1961-03-31

Pseudo-manifest

Dataset suppliers to the CDS shall provide a comprehensive description of their data at least two months prior to delivery, using a data registration process established by ECMWF.
For the CDS team this means the delivery of a pseudo-manifest file.

A pseudo-manifest is a manifest file with expected path and filenames for the expected data to be created. Note that the pseudo-manifest should be as close as possible of the final delivery but the CDS team understands that modifications may be needed.
If a pseudo-manifest is provided, then a Catalogue entry can be created and its design agreed and tested. Filenames and paths can be checked to see if they allow a good building of the download form.

Name of the manifest and updates of the contents of the manifest

The manifest should be named "manifest_<Contract tag>_<ECV_name_tag or SIS_name_tag>_<optional_tag>_yyyymmdd.txt" where yyyymmdd is the date where this manifest was created.
It is expected that the providers replace the strings <...> in the manifest filename with the actual names for the dataset they are providing.

When a new manifest file is added to the the providers site, that manifest should also be copied to "manifest_<Contract tag>_<ECV_name|SIS_name>_<optional_tag>_**latest**.txt".
Remove the date and leave just the string "latest".

This convention is central for the CDS computers to find and access the correct manifest.

Where to save the manifest file:

The manifest should be in a directory named http://web[5] address/c3s_manifest/ accessible through wget and http(s)f or the CDS computers to automatically download/check it.
Old manifest files may be removed from the providers site. The idea is to store 2 or 3 previous manifest files to track back any issues.
At least one manifest file should be always present and that providers site: the latest manifest file.

Why the CDS values so much the manifest file:

For the Catalogue a dataset is a manifest file. Not the description in the contracts, not overviews.
Nothing else is so central and important than the manifest: it tells the CDS computers what should be present in the public Catalogue.

How the download form is directly related with filenames and paths in the manifest?

The widgets in the download pages of the CDS Catalogue are the way by which the user builds the name and the path of the file that corresponds to the data the user wants to download.
In other words, there is a direct link between the filename and path convention and what we can offer for the user to click in the download form.
To see it better let's consider the CIMP5 datasets which has addressed like:

:/output1/NOAA-GFDL/GFDL-CM3/historical/day/atmos/day/r3i1p1/ua/v20120227/ua_day_GFDL-CM3_historical_r3i1p1_19800101-19841231.nc[6]

the path and filename convention is:

/output1/(?P<__organisation>[\-\w]+)/(?P<model_1>[\-\w]+)/(?P<experiment_1>[a-zA-Z0-9]+)/(?P<frequency>[a-z0-9]+)/(?P<__realm>\w+)/(?P<__cmor_table_1>[a-zA-Z0-9]+)/(?P<ensemble_member_1>[a-z0-9]+)/(?P<variable_1>[a-zA-Z]+)/(?P<__version>[v0-9]+)/(?P<variable_2>[a-zA-Z]+)_(?P<__cmor_table_2>[a-zA-Z0-9]+)_(?P<model_2>[a-zA-Z0-9\-]+)_(?P<experiment_2>[a-zA-Z0-9]+)_(?P<ensemble_member_2>[a-z0-9]+)_(?P<period>\d{8}-\d{8}).nc.

When one looks at https://cds.climate.copernicus.eu/cdsapp#!/dataset/projections-cmip5-daily-pressure-levels?tab=form it is easy to notice that the widgets on that download page are the ones defined in the convention.
By clicking on the boxes the user is in fact providing values to each part of the convention and building the name of the file that will be downloaded. Each part of the convention will eventually lead to a widget in the Catalogue for the dataset.

CDS preferences:

The CDS prefer long names than short names. We prefer understandable than smart. For instance we prefer L3-U.nc[7] than L3U.nc[8] since in the first case it is clear that 2 things are at play.

5 http://web/
6 http://ua_day_gfdl-cm3_historical_r3i1p1_19800101-19841231.nc/
7 http://l3-u.nc/
8 http://l3u.nc/

Filenames should follow conventions. More than one convention is OK. Different main variables should be preferably in different files.

Examples of what would be desirable for the filename conventions:

If possible, in the filenames the underscore "_" should be used to split between place holders and hyphen "-" to say that different words belong in fact to the same placeholder.
For instance:
sfcWind_climatology_prevailing/01/sfcWind_climatology_prevailing_01_v0.0.nc[9]
would be better as:
sfcWind-prevailing_climatology/01/sfcWind-prevailing_climatology_01_v0.0.nc
[10]By using this grouping and splitting *this will help to design more well organised filenames that will be easier to use by the CDS scripts.*

Warning:
The same thing should be named in the same way whenever it is referenced.
For instance, for a computer "version_0.0" is different from "v0.0". If we mean the same thing then the string should be exactly the same, no differences in capitalisation, or more letters or less letters. One can choose either v0.0 or version_0.0 or another string one finds convenient but should then keep it the same everywhere when the same thing is meant.

Versions, deprecation of entries, replacement of data

Amount of data to deprecate	**Provider's role**	**CDS team**
Large amount of data	• Provide old and new data in the same updated manifest file • Keep old and new data • Remove deprecated data and corresponding lines from the manifest at the end of the deprecation period	• Deprecate the whole entry and create a new one. The deprecated entry will not be searchable in the CDS, but API request will continue to work. (This prevents new users to find and download deprecated data, allowing at the same time scientific traceability and reproducibility), Example: Deprecated SST[11]. New entry with corrected data: Corrected SST[12] • Remove the deprecated data after 1 to 3 year deprecation period

9 http://global-shipping.copernicus-climate.eu/shipping_metocean_variables_monthly_climatology/v0.0/sfcWind_climatology_prevailing/01/sfcWind_climatology_prevailing_01_v0.0.nc_
10 http://global-shipping.copernicus-climate.eu/shipping-metocean-variables_monthly-climatology/v0.0/sfcWind-prevailing_climatology/01/sfcWind-prevailing_climatology_01_v0.0.nc
11 https://cds-test.climate.copernicus.eu/cdsapp#!/dataset/satellite-sst-esa-cci?tab=overview
12 https://cds.climate.copernicus.eu/cdsapp#!/dataset/satellite-sea-surface-temperature?tab=overview

Small amount of data	• Create new files with a different version tag for the corrected data • Include those files in the manifest • Manifest should contain both old and new versions • Remove deprecated data and corresponding entries in the manifest at the end of the deprecation period	• Deprecate the version of the data corresponding to the wrong data • Modify overview to explain the deprecation or use a new widget called "Known issues" under the Documenation tab • Modify the download form making clear the deprecated version of the data. (When the CDS will have the tools to do it: the deprecated data will only be accessible through the API). • Remove the deprecated data after 1 to 3 year deprecation period

DOI, citation, licence and acknowledgement

DOI

Type of data in the CDS Catalogue entry	**Provider's role**	**CDS team**
Data **without** DOI issued before the publication in the CDS Catalogue	• No active role	• Provides a DOI to the Catalogue entry (which can be see as a DOI for the data themselves) Example: https://cds.climate.copernicus.eu/cdsapp#!/dataset/cems-glofas-reforecast?tab=overview

Data **with** DOIs issued before publication in the CDS Catalogue	• Provides a mapping between the data and the previous DOIs	• Create a DOI box allowing for multiple DOIs.
		• DOI's box will show
		  • all the DOIs supplied by the data provider (with a clear association to which data they refer to)
		  • the DOI of the Catalogue entry itself
		Example: https://cds-test.climate.copernicus.eu/cdsapp#!/dataset/satellite-total-column-water-vapour?tab=overview https://cds-dev.copernicus-climate.eu/cdsapp#!/dataset/satellite-cloud-properties?tab=overview

Mixing of data **with and without** DOIs issued before the publication in the CDS Catalogue	• Provides a mapping between the data and the DOIs	• Create a DOI box allowing for multiple DOIs.
		• DOI's box will show
		  • all the DOIs supplied by the data provider (with a clear association to which data they refer to)
		  • the DOI of the Catalogue entry itself
		  • data with no DOI attribute will be associated with the string: "no specific DOI"
		Example: https://cds-dev.copernicus-climate.eu/cdsapp#!/dataset/satellite-surface-radiation-budget?tab=overview

Citations

Citations are like file formats, there are a few available, no one better than all the others in all situations.
The "Citation" link in the Catalogue entry **does not say how** people should cite the data, that depends on the journal, site and publisher where the data will be cited.
The "Citation" link in the Catalogue entry **is the Catalogue citing** the contents that it is exposing.
In this way it also shows how to cite the data, but that is just an example of how to cite the data and contents from where **people can extract all information** required to cite the data using other formats in other places.

Type of data in the CDS Catalogue entry	**Provider's role**	**CDS team**
Data **without** citation issued before the publication in the CDS Catalogue	• Interact with the CDS team on this. Most probably you will be asked for the names of the authors of the data.	• Interact with the provider and create a Citation following the Catalogue citation format

Data **with** citation issued before publication in the CDS Catalogue	• Provides those citations to the CDS team	• Create a Citation box allowing for multiple citations.
		• Citation's box will show
		  • all the Citations supplied by the data provider (with a clear association to which data they refer to)
		  • the Citation of the Catalogue entry itself
		
		Example:
		https://cds-test.climate.copernicus.eu/cdsapp#!/dataset/satellite-total-column-water-vapour?tab=overview
		https://cds-dev.copernicus-climate.eu/cdsapp#!/dataset/satellite-cloud-properties?tab=overview

Mixing of data **with and without** citations issued before the publication in the CDS Catalogue	• Provides those citations to the CDS team	• Create a Citation box allowing for multiple citations.
		• Citation's box will show
		  • all the Citations supplied by the data provider (with a clear association to which data they refer to)
		  • the Citation of the Catalogue entry itself
		Example:
		https://cds-dev.copernicus-climate.eu/cdsapp#!/dataset/satellite-surface-radiation-budget?tab=overview

Licence

Provider's role	**CDS team**
Provide all licences related to the data and a mapping between the licences and the parts of the data they are related to	For datasets with multiple licences use a "Origin" button in the download form making related to the name of the licence Example: https://cds-dev.copernicus-climate.eu/cdsapp#!/dataset/satellite-surface-radiation-budget?tab=form

Acknowledgement

Provider's role	**CDS team**

No active role but may want to have a look at: How to acknowledge and cite a Climate Data Store (CDS) catalogue entry and the data published as part of it[13] https://cds-test.climate.copernicus.eu/cdsapp#!/dataset/satellite-total-column-water-vapour?tab=overview	For datasets with multiple licences use a "Origin" button in the download form making related to the name of the licence Example: https://cds-dev.copernicus-climate.eu/cdsapp#!/dataset/satellite-surface-radiation-budget?tab=form

13 https://confluence.ecmwf.int/display/CKB/How+to+acknowledge+and+cite+a+Climate+Data+Store+%28CDS%29+catalogue+entry+and+the+data+published+as+part+of+it

5 Publishing under FAIR principles[14]

14 https://confluence.ecmwf.int/display/PS/Publishing+under+FAIR+principles

Publishing under FAIR principles

Production Section

Exported on 04/25/2024

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Search

1 Core interpretation of the FAIR principles

The core principles of the FAIR guidelines have not changed since they were first published in 2016 (*), and have since been widely adopted by the scientific community as a way to improve the quality and usability of research data. However, the principles are intended to be flexible and adaptable, and different organizations and communities may have different interpretations and implementations of the principles. It's also possible that the principles may be updated or refined over time as the field of data science and technology evolves.

FAIR principles are a set of guidelines for making data more Findable, Accessible, Interoperable, and Reusable:

1. Is the data Findable?
   Can the data be easily discovered by those who need it, using relevant keywords and metadata?
2. Is the data Accessible?
   Can the data be accessed, read, and understood by a machine or a human? Is it available in a widely used, open format?
3. Is the data Interoperable?
   Can the data be easily integrated with other data sources, using common standards and formats?
4. Is the data Reusable?
   Can the data be used and reused for multiple purposes, without significant effort or additional licensing restrictions?

If the data meets all of these criteria, it can be considered "FAIR." It's important to note, however, that the FAIR principles are guidelines rather than strict rules, and different organizations and communities may have different interpretations and implementations of the principles.

(*) Wilkinson, M., Dumontier, M., Aalbersberg, I. *et al.* The FAIR Guiding Principles for scientific data management and stewardship. *Sci Data* **3**, 160018 (2016). https://doi.org/10.1038/sdata.2016.18

Source : Australian National Data Service (ANDS)
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2 ECMWF data: Extending the FAIR principles to all our data

At the ECMWF, we are committed to making our data as useful and accessible as possible. That's why we aim to publish all our data in accordance with the FAIR principles.

Our data is carefully curated and described using relevant metadata, that provides detailed information about the variables and parameters included in the data. For each variable, we provide a clear definition, specify the units, and include any relevant notes or caveats that users should be aware of, ensuring that the data can be used accurately and reliably.

We use DOIs (Digital Object Identifiers) to provide persistent, stable links to our data, allowing users to easily find and access the data they need. We also use open, standardized formats for our data and provide API (Application Programming Interface) access, allowing users to easily integrate our data with other systems and applications.

And we provide clear licensing information, enabling users to freely reuse and repurpose the data for their own purposes.

By following the FAIR principles, we are helping to make our data more valuable and useful for a wide range of users, from meteorologists and researchers to policymakers and the general public. We are proud to be part of the growing community of organizations that are working to make data more FAIR (*).

(*) OGC FAIR Climate Services: ECMWF is co-chair for the OGC Climate Resilience Domain Working Group[1]

- Decommissioning plan of ECMWF public datasets service[2]

1 https://www.ogc.org/blog/4460
2 https://confluence.ecmwf.int/display/PS/Decommissioning+plan+of+ECMWF+public+datasets+service