ECMWF Copernicus Procurement

Invitation to Tender

Copernicus Climate Change Service

Advancing an Ensemble-Based, Multi-Scale Ocean Data Assimilation System for Climate Applications

Volume II: Specification of Requirements

ITT Ref: C3S2_601_bis
ISSUED BY: ECMWF Administration Department Procurement Section
Date: 16 June 2025
Version: Final

Funded by the European Union

Implemented by ECMWF

Table of Contents

1 Introduction

ECMWF, as the Entrusted Entity for the Copernicus Climate Change Service (C3S), invites tenders to help advance the ocean data assimilation methodology in support of climate applications, specifically Earth System reanalyses and initialisation of seasonal forecasts, key elements of the C3S. More information on C3S and its global reanalysis and seasonal forecast services can be found at following webpages:

- https://climate.copernicus.eu/about-c3s
- https://climate.copernicus.eu/seasonal-forecasts
- https://climate.copernicus.eu/products/climate-reanalysis

The developments within this tender build on developments carried out in previous C3S contracts (C3S_321b and C3S2_601, relevant technical reports may be made available upon reasonable request) to enable an ensemble of data assimilation (EDA) for ocean reanalyses (see Chrust et al., 2021, Zuo et al., 2024 and Chrust et al., 2025). The main goal of this activity is to further develop the data assimilation (DA) methodology required for the service to better use the available observations and to develop the next generations of climate reanalyses. The overarching goal is to develop a more reliable and statistically self-consistent multi-scale ocean EDA system. The activity within this contract is expected to contribute to the following production streams:

- ERA6-Ocean: multi-decadal uncoupled ocean reanalysis for climate studies and initialization of seasonal/decadal coupled forecasts. This will use the NEMO ocean model forced by ERA6 surface forcing, and the latest version of NEMOVAR. The work tendered will help with the configuration of ERA6-Ocean. ERA6-Ocean will also serve as reference and anchor for ERA7, described next. The production of ERA6-Ocean is intended to start Q1-2028.
- ERA7: the next generation of C3S's Reanalysis System is expected to employ a coupled data assimilation methodology to provide a monitoring capability for the Earth System, including atmosphere, land, ocean, sea-ice and ocean waves. The work tendered intends to advance the ocean and data assimilation methodology to ensure improved exploitation of surface observations.

Ocean data assimilation will be based on the NEMO ocean model and on the NEMOVAR ocean data assimilation system. The successful tenderer shall run experiments using the ECMWF supercomputer and software infrastructure, and work closely with ECMWF experts on ocean/coupled DA. This document describes the scope and technical requirements for the services tendered.

The specific objectives and technical requirements are described in section 2. General performance requirements are presented in section 3. Information about the tender format and content is in section 4. Section 5 contains a list of acronyms and reference documents.

2 Technical Requirements

2.1 Scope of Service

In recent years, substantial progress has been made in the development of the NEMOVAR ocean data assimilation system. These advances include development of a multi-scale background error covariance matrix model, the implementation of a tangent linear and adjoint model to enable 4D-Var, and development of a correlated observation error covariance matrix model for along-track altimeter observations. These developments, integrated into the ECMWF ensemble-variational system, have demonstrated the potential to improve the assimilation of satellite altimeter-derived sea level anomalies (SLA) and sea surface temperature (SST) observations. The objective of this tender is to further advance these capabilities to allow their implementation in an operational service.

The successful Tenderer is expected to deliver in the following key areas:

- Integration of mature ocean data assimilation capabilities into the ECMWF reanalysis system, supporting the transition to an operational service.
- Refinement of ensemble generation techniques to produce a reliable ensemble of ocean data assimilations system.
- Enhancement of multi-scale data assimilation methods to improve the temporal consistency of multi-decadal ocean reanalyses.
- Implementation of a scientifically robust and computationally efficient 4D-Var system, suitable for the production of multi-decadal ocean reanalyses.
- Modelling of correlated observation errors to improve both ensemble generation and assimilation of surface observations, with a focus on SST and SLA.

The successful Tenderer shall:

- Use the ECMWF IFS git environment for code integration, document developments using JIRA, and provide reports and code documentation, as required.
- Perform, where applicable, impact assessment experiments using ECMWF's High-Performance Computing facility.
- Collaborate closely with ECMWF experts.
- Undertake regular working visits to ECMWF as required to support the progress of the contract.

2.2 Specification of Work

2.2.1 WP1: Improved ensemble generation

2.2.1.1 Activities

This work package aims to enhance the reliability of the ensemble used in the ECMWF ocean ensemble data assimilation (EDA) system by improving the representation of the uncertainties in ocean and sea ice components. Activities include the development and integration of techniques to perturb observations (their values) in a manner that is consistent with their specified error covariance matrix, to calibrate the ensemble through ensemble inflation methods, and to improve the ensemble generation for sea ice variables in the multi-category sea ice model SI3. Specifically, the successful Tenderer is expected to undertake the following activities:

- Design and implementation of an observation perturbation scheme that applies perturbations using the square root of the observation error covariance matrix. Ensure compatibility with the NEMOVAR system and integrate this scheme into the ECMWF ocean data assimilation suite. Assess the impact of the new scheme on ensemble spread and reliability metrics.
- Development of ensemble calibration techniques to correct for underestimation of uncertainty and to improve ensemble reliability. This may include the implementation of adaptive or posterior inflation methods, which should be tested and tuned using ocean EDA scout experiments. Evaluation of the scientific benefit and computational feasibility of each method. Provision of recommendations.
- Improvement of ensemble generation methods for the sea ice component of the ocean EDA by developing perturbation strategies that account for uncertainties in multi-category variables (e.g., ice concentration and thickness). In particular, the incorporation of stochastics physics in the sea-ice model and development of strategies for observation perturbation. These strategies shall support the extension of the Ocean EDA to include sea ice variables (such as sea ice concentration [SIC] and sea ice thickness [SIT]).

2.2.1.2 Deliverables required

- **WP1.1** Develop tools/software to implement the observation value perturbation scheme that employs the square root of the observation error covariance matrix (that is compatible with that defined in NEMOVAR) and introduce such an option in the ECMWF ocean data assimilation suite. Ensure that this option is complementary to the existing location-perturbation scheme, and both methods can be used together to address different sources of observation uncertainty. Document the effects of perturbing observation values with respect to the current perturbation method on the Ocean EDA reliability. *Nature of deliverable: software and report.*
- **WP1.2** Develop an ensemble calibration algorithm allowing to compensate for unrepresented sources of errors in the ocean EDA system. This may involve developing posterior ensemble inflation or adaptive background error variance inflation strategies. Implement the proposed solution in the ECMWF ocean data assimilation suite and provide recommendations based on testing carried out using the ECMWF ocean EDA system. *Nature of deliverable: software and report.*
- **WP1.3** Develop/ tune ensemble generation techniques for the sea ice model to produce a reliable ensemble to support the assimilation of multi-category sea ice variables (concentration/thickness) in the Ocean EDA system. Document the proposed techniques and their impact on ensemble reliability. Produce a multi-year dataset to compute climatological background error parameters required in WP2.3. *Nature of deliverable: software and report.*

Below is a summary of the nature of deliverables, criteria for evaluation, and metrics.

#	Deliverable Name	Criterion	Metric and Tolerances	Deliverable Deadline
WP1.1	Software and report	Software accepted in ECMWF repository. Report accepted.	ECMWF experts able to configure and run experiments with observation value perturbation scheme following the documentation. Documented demonstration of correct implementation for various observation types, including with correlated errors.	T+18m
WP1.2	Software and report	Software accepted in ECMWF repository. Report accepted.	ECMWF experts able to configure and run experiments with ensemble calibration following the documentation.	T+12m
WP1.3	Software and report	Software accepted in ECMWF repository. Report accepted.	Improved ensemble reliability for the sea ice model demonstrated. Recommendations provided.	T+24m

Table 1: WP1 Deliverables

2.2.2 WP2: Modelling of the background error covariance matrix

2.2.2.1 Activities

This work package focuses on advancing the modelling of the background error covariance matrix in the ECMWF variational ocean data assimilation system. It targets three key enhancements: the incorporation of anisotropic, multi-scale error structures, the extension of control variables to include horizontal ocean velocity components and the extension of EDA to sea-ice variables. The activities will contribute to a more physically realistic and dynamically consistent representation of the background error covariance matrix, leveraging information from ensemble statistics derived from ORAS6. Specifically, the activities include:

- Adaptation of the existing multi-scale background error covariance matrix model to account for anisotropic spatial correlation structures that better represent the nature of ocean dynamics. Estimation of both single- and multi-scale anisotropic correlation matrices using the ORAS6 ensemble. Demonstration of the scientific benefits of this enhanced modelling in multi-year assimilation experiments over the pre-Argo (1993 onwards) and Argo period.
- Extension of the NEMOVAR control variable to include horizontal velocity components (U/V), enabling the assimilation of direct velocity observations and supporting 4D-Var. Modification of the ECMWF suite that is used to compute background error statistics for these new variables based on climatological ensemble datasets. Computation of climatological parameters using the ORAS6 ensemble.
- Extension of the ocean EDA to sea-ice variables. Modification of the ECMWF suite that is used to compute background error statistics based on climatological ensemble datasets to sea-ice variables. Computation of climatological parameters using ensemble generated in WP1.3.

2.2.2.2 Deliverables required

- **WP2.1** Adapt the multi-scale background error covariance matrix model to handle anisotropic correlation structures. Estimate the parameters of single/multi-scale anisotropic covariance matrix from ORAS6 ensemble and demonstrate their impact in a multi-year experiment over the pre-Argo (1993 onwards) and Argo period. *Nature of deliverable: software and report.*
- **WP2.2** Extend the NEMOVAR control variables to include the horizontal components of the velocity field U/V to support 4D-Var/assimilation of velocity observations. Adapt the ocean data assimilation suites to allow for the computation of the relevant background error covariance matrix parameters from a climatological ensemble. Diagnose the U/V climatological background errors from ORAS6 ensemble. Assess the impact of introducing U/V assimilation on the performance of ECMWF Ocean DA system with experiment (at least 1-year) over the Argo period. *Nature of deliverable: software, data and report.*
- **WP2.3** Extend the ocean EDA to sea-ice variables and diagnose climatological background errors from the ensemble dataset produced in WP1.3. Assess the performance with experiment (at least 4-years) over the Argo period. *Nature of deliverable: software, data and report*.

Below is a summary of the nature of deliverables, criteria for evaluation, and metrics.

#	Deliverable Name	Criterion	Metric and Tolerances	Deliverable Deadline
WP2.1	Software, data and report	Software accepted in ECMWF repository. Data accessible to ECMWF experts. Report accepted.	ECMWF experts able to configure and run cycling experiments with anisotropic multi-scale background error correlation model following the documentation. Scientific impact documented.	T+24m
WP2.2	Software, data and report	Software accepted in ECMWF repository. Data accessible to ECMWF experts. Report accepted.	Control variables extended to include U and V. Climatological background error statistics for U and V computed using ORAS6 ensemble. Additional controls over U and V available in prepIFS.	T+12m
WP2.3	Software, data and report	Software accepted in ECMWF repository. Data accessible to ECMWF experts. Report accepted.	Improved reliability of the sea-ice model ensemble. EDA for the sea-ice variables set up.	T+30m

Table 2: WP2 Deliverables

2.2.3 WP3: Development of 4D-Var

2.2.3.1 Activities

This work package aims to extend and optimize the 4D-Var ocean data assimilation capability within the ECMWF system, enabling improved use of observations and more dynamically consistent ocean analysis. The activities will enhance the scientific formulation of the 4D-Var method through inclusion of additional state variables, improved specification of background errors, and enhanced computational efficiency. In particular, the following activities will be carried out:

- Enhance the computational performance of the 4D-Var implementation by identifying and applying code-level optimizations, ensuring scalability across modern high-performance computing platforms, implementing and assessing the applicability of multi-grid approaches to improve minimization efficiency. Benchmark and document improvements in speed and scalability.
- Extend the existing NEMOVAR 4D-Var implementation to compute sensitivities with respect to the horizontal velocity components (U/V), thereby enabling direct assimilation of velocity-related observations and improved flow-dependent adjustments. Evaluate the scientific impact of this extension through a one-year assimilation experiment over the Argo period, comparing results against current 4D-Var and 3D-Var FGAT approaches.
- Review and revise the background error covariance matrix settings used in 4D-Var, including the error magnitudes and the structure of the balance operator. Conduct sensitivity experiments over a one-year period to evaluate how different B matrix configurations affect the performance of the system and develop recommendations for an improved default setup.

2.2.3.2 Deliverables required

- **WP3.1** Extend the NEMOVAR 4D-Var formulation to produce sensitivities to the horizontal velocity field components U/V and assess the impact on the performance of the ECMWF ocean data assimilation system (with respect to the present formulation of 4D-Var and 3D-Var FGAT) in an experiment (at least 1 year) over the Argo period. *Nature of deliverable: software and report.*
- **WP3.2** Review the specification of the background error covariance matrix , including the specification of its parameters and the configuration of the balance operator, to improve the scientific performance of 4D-Var. Evaluate and document the impact of various settings in the ECMWF ocean data assimilation experiments (at least 1-year long experiments over the Argo period). Provide recommendations. *Nature of deliverable: report*.
- **WP3.3** Optimize the computational performance (code optimizations/scalability/multi-grid) of 4D-Var to achieve improved time to solution and scalability. Demonstrate the optimized 4D-Var system with long integration (at least 5 years) assimilation experiment and compare its performance with 3D-Var FGAT. *Nature of deliverable: software and report.*

Below is a summary of the nature of deliverables, criteria for evaluation, and metrics.

#	Deliverable Name	Criterion	Metric and Tolerances	Deliverable Deadline
WP3.1	Software and report	Software accepted in ECMWF repository. Report accepted.	ECMWF experts able to configure and run cycling 4D-Var experiments producing sensitivities to U and V following the documentation. Impact study conducted and documented.	T+18m
WP3.2	Report	Evaluation of the specification of the background error covariance matrix specification on the	Impact studies conducted and documented. Recommendations provided.	T+24m

		performance of the 4D-Var based data assimilation system documented.		
WP3.3	Software and report	Software accepted in ECMWF repository. Report accepted.	Improved computational performance of 4D-Var demonstrated and documented.	T+30m

Table 3: WP3 Deliverables

2.2.4 WP4: Modelling of the observation error covariance matrix

2.2.4.1 Activities

This work package focuses on advancing the treatment of observation errors in the ECMWF ocean data assimilation system by developing methods to model correlated observation error covariance matrices for key observation types. The activities will enhance the realism of data assimilation by allowing improved specification of observation uncertainties and the implementation of variational quality control mechanisms for conventional observations. These developments will directly support both deterministic and ensemble assimilation streams. The following activities will be undertaken:

- Develop and implement diagnostic tools to estimate observation error covariance structures, including off-diagonal (correlated) components, for a range of ocean observation types including conventional and satellite instruments. These tools will support both empirical diagnostics from innovation statistics and specification of correlated covariance models compatible with the NEMOVAR framework.
- Enable the assimilation of along-track satellite altimetry observations using a correlated observation error covariance matrix model. Conduct and document multi-year assimilation experiments (minimum four years over the Argo period) to evaluate the impact of correlated errors on the quality and consistency of ocean analyses.
- Develop a model for the correlated observation error covariance matrix of sea surface temperature (SST) observations. Assess the effect of using this model within the ECMWF ocean EDA system, particularly in the context of observation perturbation using the square root of the covariance matrix. Evaluate changes in ensemble spread and reliability in multi-year experiments.
- Implement a variational quality control (VarQC) algorithm at the outer loop level in NEMOVAR to better identify and appropriately weight or inflate suspect conventional observations. Validate the algorithm's performance in multi-year experiments with conventional observations and assess its impact on analysis performance.

2.2.4.2 Deliverables required

- **WP4.1** Develop and document software tools to diagnose and prescribe in NEMOVAR observation error covariances for the different observing systems used in in the ECMWF ocean data assimilation system (including for observations with correlated errors). *Nature of deliverable: software and report.*
- **WP4.2** Demonstrate the ability to assimilate the along-track altimeter observations with a correlated observation error covariance matrix (specified using tools developed in WP4.1) in the ECMWF ocean data assimilation suite in a multi-year (at least 4 years) experiment over the Argo period. Document the results. *Nature of deliverable: software and report.*
- **WP4.3** Develop a correlated observation error covariance matrix model for SST observations. Demonstrate the impact of accounting for correlated observation errors when using the square root of the observation error covariance matrix for perturbing the observation values in the EDA system on the ensemble spread in a multi-year (at least 4 years) experiment over the Argo period. Document the results. *Nature of deliverable: software and report.*
- **WP4.4** Implement and document a variational quality control algorithm (at the outer loop level) for conventional observations in NEMOVAR. Demonstrate the ability to correctly identify and inflate suspect

observations in the ECMWF ocean data assimilation suite in a multi-year (at least 4 years) experiment over the Argo period. Document the results. *Nature of deliverable: software and report.*

Below is a summary of the nature of deliverables, criteria for evaluation, and metrics.

#	Deliverable Name	Criterion	Metric and Tolerances	Deliverable Deadline
WP4.1	Software and report	Software accepted in ECMWF repository. Report accepted.	ECMWF experts able to use the observation error diagnostic tools following documentation. Report with recommendations.	T+6m
WP4.2	Software and report	Software accepted in ECMWF repository. Report accepted.	Along-track altimeter correlated observation errors diagnosed and documented. Impact study conducted and documented. Report with recommendations.	T+18m
WP4.3	Software and report	Software accepted in ECMWF repository. Report accepted.	L2 SST observations correlated observation errors diagnosed and documented. Impact study conducted and documented. Report with recommendations.	T+24m
WP4.4	Software and report	Software accepted in ECMWF repository. Report accepted.	ECMWF experts able to configure and run cycling experiments with variational quality control following the documentation. Impact study conducted and documented.	T+18m

Table 4: WP4 Deliverables

2.2.5 WP5: Assimilation of L2 SST observations

2.2.5.1 Activities

This work package aims to establish the foundations for the direct assimilation of Level 2 Sea Surface Temperature (L2-SST) observations in the ECMWF ocean data assimilation suite. L2 observations offer improved spatial resolution and more direct use of raw satellite data but require careful handling of biases, errors, and quality control. The activities will develop an end-to-end workflow that includes data ingestion, pre-processing, assimilation, and validation. Specifically, the following tasks will be undertaken:

- Develop and implement the technical infrastructure required to interface L2-SST observations with the ECMWF data repository and preprocessing pipelines, ensuring the data can be efficiently ingested and used in the assimilation suite.
- Design and integrate a bias correction scheme appropriate for L2-SST data, addressing both systematic sensor-specific and regional biases. Implement quality control procedures tailored to L2 data characteristics, ensuring reliable use in operational and research settings.
- Conduct a multi-year assimilation experiment (minimum four years over the Argo period) using the enhanced system and evaluate the performance of the L2-SST assimilation versus the currently used Level 4 SST observations. Verification should be carried out using independent surface drifter observations and other reference datasets to assess accuracy and consistency of the SST analysis.

2.2.5.2 Deliverables required

- **WP5.1** Develop a proof-of-concept of end-to-end assimilation of L2-SST in the ECMWF ocean data assimilation suite, including interface with the ECMWF data repository, bias correction, quality control and verification against drifter data. Demonstrate the capabilities of the L2-SST assimilation in the ECMWF system in a multi-year experiment over the Argo period. Document the results. *Nature of deliverable: software and report.*

Below is a summary of the nature of deliverables, criteria for evaluation, and metrics.

#	Deliverable Name	Criterion	Metric and Tolerances	Deliverable Deadline
WP5.1	Software and report	Software accepted in ECMWF repository. Report accepted.	ECMWF experts able to configure and run cycling experiments with L2 SST assimilation following the documentation.	T+30m

Table 5: WP5 Deliverables

2.2.6 WP0: Management and Coordination

2.2.6.1 Activities

This work package includes overall responsibility for day-to-day service management and coordination.

The following contract management aspects shall be considered and as needed briefly described in the proposal:

- **Management, planning and coordination** of the different Work Packages activities and corresponding resources, including the appropriate tools used to monitor them.
- **Contractual obligations** as described in the Volume V Framework Agreement Clause 2.3 “Reporting and Planning” and its Annex 5 “Report content”.
- **Meetings organisation and/or attendance** (classified as tasks and listed in a separate table as part of the proposal):
  - Organise a Kick-Off Meeting during the first month of implementation of the contract.
  - Organise quarterly teleconferences to discuss C3S service provision, service evolution and other topics.
  - Organise Progress Review Meetings (teleconferences), linked to Payment Milestones. The Successful Tenderer will prepare corresponding summary minutes of these meetings and maintain a list of agreed actions and their status.
  - Tenderers can propose additional contract internal meetings (e.g. kick-off meeting, regular meetings to monitor contract performance) as part of their response. Most such meetings should be held by remote participation.
- **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**. Proactive and dynamic communication towards and between all parties involved in the contract. 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 subcontractors 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.

2.2.6.2 Deliverables expected

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). All milestones and deliverables shall be numbered as indicated (see also guidelines in Section 4.2). All document deliverables shall be periodically updated and versioned as described in the tables below, and the corresponding due date defined in Volume IIIA for each iteration.:

WP0 Deliverables				
Deliverable#	*Responsible*	*Nature*	*Title*	*Due*
D0.y.z-YYYYQx	Tenderer	Report	Quarterly Implementation Report (QIR) YYYYQx YYYYQx being the previous quarter (e.g. 2024Q3 due on 15/10/2024)	Quarterly on, 15/04, 15/07 and 15/10
D0.y.z-YYYY-Part1	Tenderer	Report	Annual Implementation Report (AIR) for year YYYY [Part 1] *YYYY being the Year n-1. Shall include:* • Quarterly Implementation Report YYYYQ4 ; • *Preliminary financial information YYYY ;*	Annually on 15/01
D0.y.z-YYYY-Part2	Tenderer	Report	Annual Implementation Report (AIR) YYYY [Part 2] *YYYY being the Year n-1*	Annually on 28/02
D0.y.z-YYYY	Tenderer	Report	Annual Implementation plan YYYY *YYYY being the Year n+1*	Annually on 30/09
D0.y.z-YYYY	Tenderer	Other	Copy of prime contractor's general financial statements and audit report YYYY *YYYY being the Year n-1*	Annually around June (no associated cost)
D0.y.z	Tenderer	Report	Final report	60 days after end of contract

Table 6: WP0 Deliverables

WP0 Milestones			
Milestone#	*Title*	*Means of verification*	*Due*
M0.1.1.MX	Progress Review meeting with ECMWF / Payment milestones	Minutes of meeting	At each Payment Milestone due date (~every 6 months)
M0.1.2.MX	Kick off meeting	Minutes of meeting	Month 1

Table 7: WP0 Milestones

The successful Tenderer shall keep reporting documents short and factual. Contract management and coordination is expected to stay limited to approx. 7-10% of the planned use of the resources.

3 General Requirements

3.1 Implementation Schedule

ECMWF intends to award a single Framework Agreement for a period of maximum 30 months, which shall be implemented via a single multi-annual Service Contract expected to commence in January 2026 and with an end date not later than 30 June 2028.

The Tenderer is expected to provide a detailed time plan and schedule as part of the tender response. The proposed time plan and schedule shall address the main tasks, inputs, outputs, intermediate review steps, milestones, deliverables and dates. Regular progress meetings will be held with ECMWF during the contract to assess project status, risks and actions.

ECMWF has to prepare annual Implementation Plans, which must be approved by the European Commission before they can enter into force. The implementation plans will take full stock of service reviews, performed thoroughly on an annual basis, as well as of the continuously evolving user requirements and corresponding service specifications. The successful Tenderer shall therefore provide each year for ECMWF approval an updated detailed plan of proposed activities including Deliverables and Milestones, using the Work Package table template in Volume IIIB, which will form part of this Implementation Plan.

3.2 Meetings and working visits

It is expected that most of the work will be carried out remotely. Still, the Tenderer shall account for working visits to ECMWF (Reading, UK) to cover collaboration needs on each of the above-described technical work packages. For each work package, the Tenderer is expected to propose a working visit plan for the full duration of the contract and shall account for the linked travel and subsistence costs in the pricing table. ECMWF expects each working visit to last for one working week and that the total number of visits is limited to 3 per work package.

The successful Tenderer is expected to attend regular teleconference meetings to discuss the service provision and contractual aspects. The cost of organising and attending any additional meetings shall also be covered by the successful Tenderer and shall be included in the tendered price.

3.3 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 as a result 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 and shall not have an associated resource allocation, unless otherwise agreed.

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. The Tenderers shall provide a due date for each proposed deliverable and milestone (in accordance with those indicated in Section 2):

o The Tenderers shall ensure that the proposed due dates of deliverables and milestones are realistic and achievable. Any dependencies on input data (whose origin must be specified) shall be detailed and also accounted for in the risk table.

o It is advised to schedule the submission/completion of the last deliverables and/or milestones associated to a Payment Milestone not later than 15 days before the expected date of completion of the said Payment Milestone (i.e. when all deliverables have been submitted by the contractor and all milestones have been completed by the concerned parties).

The submission of the final deliverables and/or milestones shall be scheduled no later than 60 days before the end of the Service Contract to allow sufficient time for review prior to its expiration.

ECMWF will provide the templates for reports and plans at the beginning of the contract. Reporting documents should be short and factual, following the guidance which will be provided by ECMWF during negotiations with the Successful Tenderer. Contract management and technical coordination is expected to amount to approx. 7-10% of the planned use of the resources.

3.4 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.

3.5 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.

3.6 Payment Plan

Tenderers can propose a Payment Plan in ITT Volume IIIA "Pricing and deliverables" (cf. Excel spreadsheet "Payment Plan preparation"):

- The Payment Milestones should relate to the deliverables and milestones delivered during the corresponding Payment Milestone period (e.g. the payment covering the period January-June would only relate to the deliverables and milestones whose due dates are part of the same period).
- The frequency of Progress Review Meetings might be adapted to synchronise with the anticipated date of completion of each Payment Milestone.
- In case of request for a payment at contract signature, please note that this should be duly substantiated (e.g. in terms of necessary investment prior to implementation or during first weeks/months for ensuring the initial set up of the project). It is necessary to relate this payment to activities subject to other Payment Milestones.

3.7 Ad hoc Support

Whilst communications and user engagement, training and support activities are not part of the scope of this ITT, the Tenderer shall make provisions for possible requirements for technical and scientific expertise in ad hoc support of these activities. The Tenderer shall specify in the Tender the experts available to provide this support. If applicable, a small budget may be proposed to cover such resources.

4 Tender Format and Content

General guidelines for the Tender are described in Volume IIIB of this ITT. 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.

4.1 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 8: Page limits

4.2 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.

4.2.1 Executive summary

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

4.2.2 Track Record

The Tenderer 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.

4.2.3 Quality of Resources to be Deployed

The Tenderer 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.

4.2.4 Technical Solution Proposed

The Tenderer is 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.

4.2.5 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 2.2.6 above.

5 Additional information

5.1 References

Chrust, M., M.A. Balmaseda, P. Browne, M. Martin, A. Storto, A. Vidard et al., 2021: Ensemble of Data Assimilations in the ocean for better exploitation of surface observations. *ECMWF Newsletter* **No. 168**, 6-7. https://www.ecmwf.int/en/newsletter/168/news/ensemble-data-assimilations-ocean-better-exploitation-surface-observations

Zuo, H., Balmaseda, M.A., de Boisséson, E., Browne, P., Chrust, M., Keeley, S., Mogensen, K., Pelletier, C., de Rosnay, P. and Takakura, T., 2024: ECMWF's next ensemble reanalysis system for ocean and sea ice: ORAS6. . *ECMWF Newsletter* **No. 180**, 30-36. https://www.ecmwf.int/en/newsletter/180/earth-system-science/ecmwfs-next-ensemble-reanalysis-system-ocean-and-sea-ice

Chrust, M., Weaver, A.T., Browne, P., Zuo, H. & Balmaseda, M.A. (2025) Impact of ensemble-based hybrid background-error covariances in ECMWF's next-generation ocean reanalysis system. *Quarterly Journal of the Royal Meteorological Society*, 151(767), e4914. Available from: https://doi.org/10.1002/qj.4914

5.2 Acronyms

3D-Var	Three-dimensional Variational data assimilation
4D-Var	Four-dimensional Variational data assimilation
AR(1)	Autoregressive model of the first order
C3S	Copernicus Climate Change Service
DA	Data Assimilation
ECMWF	European Centre for Medium-Range Weather Forecasts
EDA	Ensemble of Data Assimilation
EU	European Union
Fortran	FORmula TRANslation programming language
HPC	High Performance Computer
IFS	Integrated Forecasting System
ITT	Invitation to Tender
L2/3/4	Level 2/3/4
NEMO	Nucleus for European Modelling of the Ocean
NEMOVAR	Variational Data Assimilation for NEMO
SIC	Sea Ice Concentration
SIT	Sea Ice Thickness
SST	Sea Surface Temperature
SSH	Sea Surface Height