ECMWF Copernicus Procurement

Invitation to Tender

Copernicus Climate Change Service Volume II

C3S Global Reanalysis - Variational Bias Correction for ERA6

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1 Introduction

ECMWF as the Entrusted Entity for the Copernicus Climate Change Service (C3S) invites tenders for a service related to bias correction of observations in support of climate services development. The 6th ECMWF reanalysis (ERA6) will use the (C++ based) Object-Oriented Prediction System (OOPS) and there is a requirement to optimise the variational bias correction system under OOPS. This document describes the scope and technical requirements for the services tendered.

The ERA5 reanalysis is based on the Integrated Forecasting System (IFS) cycle 41r2 which has been in operations from 08-Mar-16 to 22-Nov-16. The IFS is mainly encoded in Fortran. The next generation of reanalysis, ERA6, will be based on a future IFS cycle which will include at least the developments introduced in cycles 43r1 and 45r1. In these IFS cycles, the variational bias correction (VarBC) has been reviewed with the introduction of the constrained VarBC (CVarBC) scheme and the weak constraint 4D-Var formulation. In addition, VarBC will now be embedded in the OOPS structure, and this will necessitate some development for reanalysis. This is because the requirements of Numerical Weather Prediction (NWP) and reanalysis are different, albeit with some overlap, and the new analysis system which has been developed for NWP is unlikely to be optimal for retrospective analysis. NWP analysis systems are developed for the present global observing network and they may not work well for past periods when the global observing network was more limited. This means that some work is necessary to ensure that ERA6 benefits from the latest developments introduced in operations. A similar situation happens in some regional model configurations, many of which run at higher resolution (so comparatively observation data is sparse) and have always had difficulty applying methods directly developed for global models. Therefore, some of the problems to be solved for regional NWP are similar to those for past global reanalysis.

Recently the VarBC and weak-constraint 4D-Var have been developed at ECMWF in these key areas:

1. Constrained VarBC (CVarBC). This prevents predictor coefficients taking unrealistic values. It allows data normally excluded from VarBC, such as AMSU-A channel 14 and infrared ozone channels, to be included. The new approach leads to a better consistency of the analysis with other observations and to a more robust system with benefits for maintenance, particularly for reanalysis applications. This has the advantage that inter-satellite biases are removed, thus eliminating artificial jumps in the analysis between orbits of different satellites, and at the end and start of life of new satellites.
2. VarBC in the Object-Oriented Programming System (OOPS). OOPS is a new technical infrastructure that has been developed at ECMWF to allow specific functionality to be defined as objects, allowing easy re-use and also ease of plugging in alternatives to perform (hopefully better) the same function. This has been developed for data assimilation. Future operational reanalyses will benefit from using OOPS, but there are issues relating to the pre-conditioning of VarBC to be resolved.

3. Weak constraint 4D-Var. This formulation computes an analysis taking into account the error from the model. Its introduction in operations has improved the quality of the analysis reducing the misfit with GPS-RO, AMSU-A and radiosondes measurements. The weak constraint 4D-Var formulation is also very promising for reanalysis as it computes an analysis which has a more constant quality over the assimilation window (Figure 1).

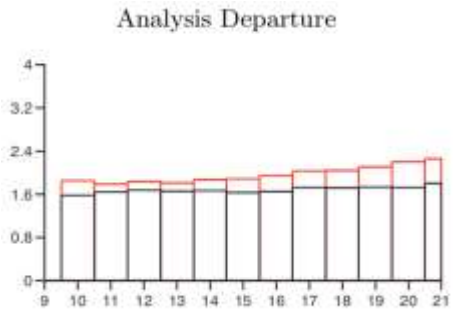

Figure 1 Wind speed analysis departure from radar wind profilers for the weak constraint 4D-Var (black) and the strong constraint 4D-Var (red). The weak constraint 4D-Var computes a more consistent analysis with the same quality over the assimilation window.

The OOPS-IFS system provides a framework for VarBC and generalised weak constraint 4D-Var, in which a full evaluation of the suitability of such a framework for reanalysis can be evaluated for different observing systems. However, the OOPS approach raises questions that need to be addressed, specifically for pre-conditioning of the VarBC system, interaction between VarBC and weak constraint 4D-VAR, performance of CVarBC, implementation of the generalised weak constraint 4D-Var, speed-up from the saddle point algorithm and longer data assimilation windows. It is critically important to evaluate these aspects in the context of older observing systems, which may not provide a strong enough constraint to run systems like CVarBC and weak constraint, under OOPS, for ERA6.

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, and section 0 contains a list of acronyms and reference documents.

2 Technical requirements

ECMWF intends to award *one Framework Agreement with a multi-annual service contract of 15 months* for services in support of variational bias correction.

2.1 Scope of service

The selected Tenderer shall:

- Work closely together with the ECMWF Research and Copernicus departments
- Adopt working standards and procedures that conform to those at ECMWF
- Use the IFS code management system as used at ECMWF
- Perform, where required, impact experiments using ECMWF's High Performance Computer.

2.2 Specification of work

WP1: Pre-conditioning of VarBC in the OOPS system.

In 2004, Dee showed that variational parameter estimation methods such as 4D-Var VarBC needs specific pre-conditioning. The OOPS system has not been designed with this requirement in mind. Initial evaluation confirms that VarBC is not performing as well in OOPS as in IFS. A range of pre-conditioning options will need to be tested, both in a data rich and data sparse context. The Tenderer is expected to propose the adequate level of person-months to design the prototype software, write it and test it.

Deliverables expected: Prototype IFS code implemented as an option in the OOPS system to enable appropriate pre-conditioning for VarBC (deadline T0+5)

WP2: CVarBC applied to data sparse situations.

In Cycle 43r3 the so called "constrained VarBC" was implemented in operations at ECMWF. CVarBC applies additional constraints to the bias corrections, allowing some data that was previously uncorrected to be included in VarBC. This may also prove very useful to constrain VarBC where modern "anchors" like GPS-RO may be missing. This will be evaluated by examining the behaviour of CVarBC in data sparse scenarios. The Tenderer is expected to propose the adequate level of person-months to setup experiments, maintain during run time, analyse and write up.

Deliverables expected: Implementation of a CVarBC IFS configuration for ERA6 that has been demonstrated to perform in the pre-RO era (deadline T0+10).

WP3: Radiosonde mask.

IFS has in the past had a capability to apply a radiosonde mask within VarBC so that only the analysis in regions of trusted radiosondes was highly influential in VarBC for globally available satellite radiances. Since radio-occultation observations have been available, this has no longer proven to be needed and the mask is no longer used. However, its re-introduction may improve

the performance of VarBC in the pre-RO era, since it will limit the detrimental aliasing of model bias into observation bias over large regions where radiosonde anchors are not available. The existing IFS code has never been made operational and has not been tested for a long time. Despite not being used operationally, the code remains available within the IFS system. The code will need to be analysed, amended as appropriate, and tested to ensure it is reliable running under Cycle 45r1 (and subsequent versions) of IFS and also adaptation within OOPS. The Tenderer shall propose the adequate level of person-months for this initial assessment.

Deliverables expected: Implementation of a working version of the radiosonde masking in IFS, configurable as an option for ERA6 (deadline T0+13).

WP4: Weak constraint 4D-Var under OOPS.

It is critical to evaluate weak constraint with various observation assimilation strategies, such that they reflect the evolution of observation coverage during the reanalysis period (1950-present). The Tenderer shall propose the adequate level of person-months to setup experiments, maintain during run time, analyse and write up.

Deliverables expected: A weak constraint configuration under OOPS suitable for ERA6 (deadline T0+15).

WP0: Contract Management and Technical Coordination

The Tenderer is requested to specify in the tender proposed contract management and technical coordination activities as well as a contract implementation plan (Gantt chart) and distribution of responsibilities and roles.

As part of the general project management description the Tenderer shall include, the following elements (this is not an exhaustive list):

- Quarterly, annual and final reports shall be provided in accordance with the Framework Agreement Clause 2.3.
- An implementation plan for the year N+1 shall be provided in February of the year N for ECMWF approval.
- Monthly teleconferences with ECMWF and a proposal for involvement of ECMWF in major project reviews shall be provided as part of the management plan (*cf.* Section 3).
- Participation of the C3S Assembly Meetings (*cf*. Section 3).
- A proposed payment plan shall be provided as part of the proposal. The payment plan shall be based on quarterly payments for routine services work packages and shall be based on milestones completion and associated deliverables for development related activities.
- If relevant, a list of sub-contractors and details of their contribution, key personnel, legal names and addresses shall be provided. The Tenderer shall describe how the Framework

Agreement, in particular Clause 2.9, has been communicated down to all their sub-contractors.

The table below provides the template to be used by the contractor to describe deliverables for this work package. All deliverables shall be numbered as indicated. Tenderers shall provide preliminary versions of the completed tables as part of their bid.

Deliverables for this work package shall include the following reports:

WP0 Contractual Obligations Template				
#	*Responsible*	*Nature*	*Title*	*Due*
D0.y.z-YYYYQQ	Tenderer	Report	Quarterly Implementation Report QQ YYYY *QQ YYYY being the previous quarter*	Quarterly on 20/01, 20/04, 20/07 and 20/10
D0.y.z-YYYY	Tenderer	Report	Annual Implementation Report YYYY *YYYY being the Year n-1*	Annually on 28/02
D0.y.z	Tenderer	Report	Final report	60 days after end of contract
D0.y.z-YYYY	Tenderer	Other	Preliminary financial information YYYY *YYYY being the Year n-1*	Annually on 15/01
D0.y.z-YYYY	Tenderer	Report	Draft Implementation plan YYYY *YYYY being the Year n+1*	Annually on 28/02
D0.y.z-YYYY	Tenderer	Report	Finalised Implementation plan YYYY *YYYY being the Year n+1*	Annually on 31/10
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
D0.y.z-YYYY	Tenderer	Other	Letter from auditor specific to C3S contract YYYY *YYYY being the Year n-1*	Annually

ECMWF will provide the templates for reports and plans at T0.

The successful Tenderer is expected to keep reporting documents short and factual. Seeing the nature and anticipated workload, contract management and technical coordination is expected to stay limited to maximum 5% of the planned use of the resources.

2.3 Schedule

Activities shall be performed in the context of a 15 month Framework Agreement. The start of the contract (T0) is expected to take place in the second calendar quarter of 2018.
Work packages are all expected to start in T0 and run in parallel according to following time schedule:

Work Package 1: T0 + 5 months
Work Package 2: T0 + 10 months
Work Package 3: T0 + 13 months
Work Package 4: T0 + 15 months

3 General requirements

3.1 Schedule

The successful 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. The successful Tenderer has to report on a quarterly and annual basis (for more details please see Volume V Framework Agreement for this ITT).

3.2 Meetings

Every 18 months, ECMWF organises assembly meetings to bring together all C3S service providers. The successful Tenderer is expected to attend the meeting that falls within the contract period and needs to account for this meeting in its price. The Tenderer is also expected to attend monthly 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 expected are outlined in section 2. These will be in the form of reports and IFS code. Requirements for each type are described in the following subsections.

The number of milestones is not restricted, but they should be designed as markers of demonstrable progress in service development and/or quality of service delivery.

3.3.1 Documents and reports

All project reports 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 compatible).

3.3.2 IFS code

Contributions to the IFS code will be delivered into IFS branches that can be easily incorporated in the development branch for ERA6.

4 Tender format and content

General guidelines for the tender are described in Volume IIIB. Specific requirements to prepare the proposal for this particular tender are described in the next subsections.

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

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***
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	30 (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	10 (excluding Table 3, Table 5 and Table 6 in Volume IIIB) + 2 per each work package description (Table 4 in Volume IIIB)
Pricing Table	No limitation

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 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.

4.2.2 Quality of Resources to be Deployed

The Tenderer shall propose the necessary expert(s) providing the skills required for providing services that meet the technical requirements set out in section 2.

4.2.3 Technical Solution Proposed

The Tenderer shall give a short background to the proposed solution to demonstrate understanding of that solution and of the C3S context. This section shall also include information on any other third party suppliers that are used as part of the technical solution, and a statement of compliance for each requirement formulated throughout this document, describing how the proposed solution maps to the requirements.

4.2.4 Management and Implementation

The Tenderer shall provide a detailed implementation plan of proposed activities for the duration of the framework agreement. Deliverables and Milestones should be consistent with the technical requirements specified in section 2.

The Tenderer is requested to specify management and coordination activities within a dedicated Work Package (WP0).

5 Additional information

5.1 References

Dee, D. P. (2004), Variational bias correction of radiance data in the ECMWF system, Proceedings of the ECMWF workshop on assimilation of high spectral resolution sounders in NWP, Reading, UK, 28 June–1 July 2004, 97–112.

IFS documentation is available from https://www.ecmwf.int/en/forecasts/documentation-and-support/changes-ecmwf-model/ifs-documentation

Acronyms

4D-Var	Four-dimensional Variational data assimilation
AMSU-A	Advanced Microwave Sounding Unit-A
C++	Object-oriented programming language
C3S	Copernicus Climate Change Service
CVarBC	Constrained Variational Bias Correction scheme
ECMWF	European Centre for Medium-Range Weather Forecasts
ERA5	5th generation ECMWF global Reanalysis
ERA6	6th generation ECMWF global Reanalysis
EU	European Union
Fortran	FORmula TRANslation programming language
GPS-RO	Global Positioning System (GPS) Radio Occultation (RO)
IFS	Integrated Forecasting System
ITT	Invitation to tender
NWP	Numerical Weather Prediction
OOPS	Object-Oriented Programming language
PDF	Portable Document Format
VarBC	Variational Bias Correction scheme