ECMWF Copernicus Procurement

Invitation to Tender



Copernicus Atmosphere Monitoring Service

Volume II

Developments for reactive gases and aerosol in the global system

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1 Introduction

Some of today's most important environmental concerns relate to the composition of the atmosphere. Ozone distributions in the stratosphere influence the amount of ultraviolet radiation reaching the surface. In the troposphere, aerosols, ozone and other reactive gases such as nitrogen dioxide determine the quality of the air around us, affecting human health and life expectancy, the health of ecosystems and the fabric of the built environment. The variable abundance of the reactive gases change the oxidation capacity of the atmosphere and control therewith also the abundance of long-lived greenhouse gases. The composition of the troposphere and the associated deposition fluxes are major components of the biogeochemical cycles of carbon, nitrogen and sulphur and iron, which effect the land- and marine eco systems. Dust, smoke and volcanic aerosols affect the safe operation of transport systems and the availability of power from solar generation, the formation of clouds and rainfall, and the remote sensing by satellite of land, ocean and atmosphere.

The increasing concentration of the greenhouse gases and the various aerosol-weather feedbacks are prominent but often uncertain drivers of climate change. In the wake of the agreement signed in Paris at the UNFCCC's 21st Conference of the Parties (COP-21) in December 2015, the need to monitor and to inform about the effectiveness of mitigation efforts for anthropogenic emissions of key greenhouse gases has become more acute and prominent. With its global coverage (or regional in the case of geostationary platforms), Earth Observation has a decisive role to play within such a monitoring system, complementing ground-based observations, "bottom-up" estimates of the emissions (included in official reporting) and atmospheric transport modelling.

To address these environmental concerns there is a need for data and processed information. The Copernicus Atmosphere Monitoring Service (CAMS) has been developed to meet these needs, aiming at supporting policymakers, business and citizens with enhanced atmospheric environmental information.

Within its first phase (2015 - 2020), Cop1, the Service consolidated many years of preparatory research and development to deliver a range of operational services. In its second phase (2021 - 2027), Cop2, these services are further consolidated, improved and expanded to address all the existing and emerging societal needs related to the atmospheric environment. The CAMS service portfolio consists of the following service elements:

- a) Daily production of real-time analyses and forecasts of global atmospheric composition;
- b) Reanalyses providing consistent multi-annual global datasets of atmospheric composition with a stable model/assimilation system;
- c) Daily production of real-time European air quality analyses and forecasts with a multi-model ensemble system;
- d) Reanalyses providing consistent annual datasets of European air quality with a frozen model/assimilation system, supporting in particular policy applications;
- e) Products to support policy users, adding value to "raw" data products in order to deliver information products in a form adapted to policy applications and policy-relevant work;
- f) Solar and UV radiation products supporting the planning, monitoring, and efficiency improvements of solar energy production and providing quantitative information on UV irradiance for downstream applications related to health and ecosystems;
- g) Greenhouse gas atmospheric inversions for CO₂, CH₄ and N₂O net surface fluxes, allowing the monitoring of the evolution in time of these fluxes;
- h) Climate forcing from aerosols and long-lived (CO₂, CH₄) and shorter-lived (stratospheric and tropospheric ozone) agents;

- i) Anthropogenic and natural emissions, based on inventory data and modelling, for the global and European domains;
- j) Observation-based emission estimates of atmospheric pollutants for the global and European domains;
- k) Observation-based anthropogenic emission estimates of CO₂ and CH₄ for the global domain and emission hotspots.

This Invitation to Tender (ITT) is mainly targeting the CAMS service elements described under items (a), (b) and (f).

1.1 Definitions

Definitions specific for this ITT are defined below.

Global Service Provider: ECMWF is the provider of global products

Global Production System: the modelling and data assimilation infrastructure used to provide the CAMS global analyses and forecasts of atmospheric composition.

2 Contract Summary

The Successful Tenderer shall deliver improvements to the aerosol and chemistry schemes and the related parameterisations of source and sink processes in the Global Production System, to develop new products, and to prepare memoranda and reports that support the code development. The Successful Tenderer will also advise Global Production System team at ECMWF on matters of aerosol and chemistry modelling and contribute to the testing and evaluation of the scheduled upgrades of the Global Production System. The ITT targets organisations with considerable experience in the field of modelling of aerosols and reactive gases in the atmosphere.

Major areas of the required model developments of the Global Production System are:

- improved coupling of the aerosol and chemistry schemes with focus on inorganic and organic aerosols in the troposphere as contribution to surface Particulate Matter (PM).
- development of an aerosol and chemistry representation in the stratosphere suited for operational implementation
- gradual improvements of scientific and computational performance and maintenance of the implemented aerosol and chemistry schemes
- improved simulation of wet and dry deposition processes
- on-line modelling of natural emissions and the variability of anthropogenic emissions

Besides the progressing improvements of the current Global Production System, the Successful Tenderer shall contribute to CAMS product development efforts as required by the Global Service Provider in response to user requirements. The required contributions are efforts to:

- advance the global deposition products from the current experimental stage to a qualitycontrolled product ready to be distributed to users
- develop global diagnostic air quality products that improve the agreement with air quality observations for PM, ozone, NO₂ and SO₂.
- work towards providing uncertainty information based on multi-chemistry-scheme simulations.

Finally, the successful Tenderer is required to contribute to the process-oriented evaluation of the Global Production System with specific observational data sets and application software.

3 Technical Specification

3.1 General Requirements

3.1.1 System Overview

The CAMS Global Production System is ECMWF's Integrated Forecasting System (IFS). It is used to provide global real-time forecasts and analyses of atmospheric composition as well as to provide reanalysis products.

Modules for atmospheric composition and related physical processes have been integrated in the IFS. This integration makes it possible (i) to use the detailed meteorological representation of the IFS for the simulation of the atmospheric transport and sink, source and conversion processes of constituents, (ii) to use the IFS variational data assimilation system to assimilate satellite observations of atmospheric composition, and (iii) to simulate feedback processes between atmospheric composition and meteorological variables.

The IFS can be run with several chemistry schemes covering both the troposphere and the stratosphere. The chemistry schemes currently integrated in the IFS are: (i) the tropospheric chemistry mechanism CB05 as implemented in the TM5 Chemical Transport Model (CTM), (ii) the stratospheric mechanism from the BASCOE model, which can also be run in conjunction with CB05, and the chemical schemes of the (iii) MOCAGE and (iv) the MOZART-3 CTMs, which cover both the troposphere and the stratosphere. Each chemistry scheme applies its own parameterisations of the photolysis rates. The implementation of (i) and the overall structure of the IFS for the simulation of atmospheric composition is documented in Flemming et al. (2015). The chemistry schemes (i) to (iv) are documented in more detail in Huijnen et al. (2016) and Huijnen et al. (2019).

Similarly for aerosol, the IFS is designed to run with multiple aerosol schemes covering both the troposphere and stratosphere allowing full flexibility in terms of development of the aerosol processes. The current operational aerosol scheme (AER) is documented in Rémy et al. (2019). The operational chemistry and aerosol schemes are coupled to enable the simulation of secondary aerosols. The simulation of wet and dry deposition is currently carried out in separate modules but using similar methods that justify a more unified approach.

The core of this ITT is the further development of the chemical and aerosol schemes and the related parameterisations for removal processes and surface fluxes in the IFS. The current operational chemical schemes, CB05 and AER, shall be maintained throughout the duration of the contract. The sustainable long-term support and maintenance of alternate chemical schemes in the IFS shall be ensured by (a) maintaining a link between the implementation in the IFS and the external development efforts of the original schemes and (b) aiming at a more unified implementation of the different schemes as an integrated part of the composition modules in in the IFS.

While data assimilation of atmospheric composition using the IFS is a key component of CAMS, major contributions to improvements of data assimilation aspects are not subject of this contract. However, exploratory developments of the adjoint and tangent-linear formulations of relevant IFS code for atmospheric composition, which will be used in the 4D-Var data assimilation method, are required.

The current configuration of the CAMS Global Production System operates at a resolution of about 40x40km for the forecasting system and at 80x80 km for the reanalysis system. Scientific experimentation can also be carried out at lower resolutions (80km, 160km) but it has to be

demonstrated that the findings are valid for the operational resolutions. The Global Service Provider aims to increase the horizontal resolution of the above applications during the duration of the contract. The successful Tenderer shall therefore also contribute to the scientific and computational testing with respect to these resolution upgrades.

3.1.2 Cycle upgrades and code submissions

The development of the operational CAMS Global Production System (o-suite) is organised in version upgrades (cycles) following the IFS development schedule that occur every 6 to 18 months. Each cycle upgrade is linked to a fixed timeline for the submission of new code and a testing period with the combined new developments (e-suite). The code submission deadline is usually several months before the planned implementation date. The global service provider will communicate the relevant dates as soon as they are known and it will provide guidance on the required testing and evaluation protocol. The successful Tenderer is required to supply the contracted developments intended for o-suite upgrades in packages that allow testing of the candidate options by the Global Service Provider. The submitted code has to be tested in forecast and data assimilation mode before the code submission deadline. Further to these direct o-suite contributions, all contracted code developments have to be tested and submitted at the contractually agreed deliverable due dates. All code developments shall be carried out in accordance with the relevant ECMWF guidelines and procedures regarding coding standards and the use of version-control and issue-tracking systems.

3.1.3 Annual development plan meetings

The development of the Global Production System is a flexible process that requires responding to specific environmental events as well as to a changing scientific and computing environment. The successful Tenderer shall have annual meetings with ECMWF to discuss the planned developments for each development work package before they are submitted as part of the annual implementation plans. This process shall make it possible to adjust the contracted developments in response to new or modified requirements, results and priorities within CAMS. These meetings shall not be included as Deliverables or Milestones, but be listed as part of the proposal in a separate table summarizing all required meetings.

3.1.4 Scientific publications

Besides the contractually agreed deliverable reports and documentation, the successful Tenderer is required to write peer-reviewed publications on model development and model applications resulting from this contract. At least two scientific publications are required to be submitted before the end of the contract.

3.1.5 References

Flemming, J., Huijnen, V., Arteta, J., Bechtold, P., Beljaars, A., Blechschmidt, A.-M., Diamantakis, M., Engelen, R. J., Gaudel, A., Inness, A., Jones, L., Josse, B., Katragkou, E., Marecal, V., Peuch, V.-H., Richter, A., Schultz, M. G., Stein, O., and Tsikerdekis, A.: Tropospheric chemistry in the Integrated Forecasting System of ECMWF, Geosci. Model Dev., 8, 975-1003, https://doi.org/10.5194/gmd-8-975-2015, 2015.

Huijnen, V., Flemming, J., Chabrillat, S., Errera, Q., Christophe, Y., Blechschmidt, A.-M., Richter, A., and Eskes, H.: C-IFS-CB05-BASCOE: stratospheric chemistry in the Integrated Forecasting System of ECMWF, Geosci. Model Dev., 9, 3071–3091, https://doi.org/10.5194/gmd-9-3071-2016, 2016.

Huijnen, V., Pozzer, A., Arteta, J., Brasseur, G., Bouarar, I., Chabrillat, S., Christophe, Y., Doumbia, T., Flemming, J., Guth, J., Josse, B., Karydis, V. A., Marécal, V., and Pelletier, S.: Quantifying uncertainties

due to chemistry modelling – evaluation of tropospheric composition simulations in the CAMS model (cycle 43R1), Geosci. Model Dev., 12, 1725–1752, https://doi.org/10.5194/gmd-12-1725-2019, 2019.

Rémy, S., Kipling, Z., Flemming, J., Boucher, O., Nabat, P., Michou, M., Bozzo, A., Ades, M., Huijnen, V., Benedetti, A., Engelen, R., Peuch, V.-H., and Morcrette, J.-J.: Description and evaluation of the tropospheric aerosol scheme in the European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecasting System (IFS-AER, cycle 45R1), Geosci. Model Dev., 12, 4627–4659, https://doi.org/10.5194/gmd-12-4627-2019, 2019.

3.2 Work package 3510 – Aerosol modelling aspects

This work package comprises of developments of the IFS aerosol code to improve the performance of the CAMS Global Production System. The developments shall be pursued with the main objective to decrease the errors of CAMS products with respect to observations while maintaining operational constraints such as computational cost and stability. The successful Tenderer shall carry out developments in the following topical areas:

- Maintenance and further improvement of the AER aerosol scheme
- Development of a stratospheric aerosol scheme component as an extension of the AER tropospheric scheme with focus on the capability to simulate the fate of stratospheric aerosol following larger volcanic eruption in the operational CAMS forecasts. The scheme shall be coupled to the stratospheric chemistry developed in WP 3520
- Modelling of secondary organic and inorganic aerosol coupled to the tropospheric chemistry scheme
- Evolutionary improvements of the IFS dust and sea-salt representation and their emissions schemes
- Updates of aerosol optical properties and surface reflectance in line with current literature

WP3510 Deliverables				
#	Туре	Title	Due	
D1.y.z ¹	Report/Code	Stratospheric aerosol developments	annual	
D1.y.z	Report/Code	Secondary organic and inorganic aerosol developments	annual	

¹ Deliverables (and Milestones) shall be numbered as per the following format DX.Y.Z (MX.Y.Z), where X is the WP number, Y is the task number and Z is the Deliverable (Milestone) number in this task. Deliverables delivered annually should be numbered DX.Y.Z-yyyy, where yyyy is the year the Deliverable refers to (e.g. DX.Y.Z-2016, DX.Y.Z-2017). Deliverables delivered quarterly should be numbered DX.Y.Z-yyyyQx, where yyyyQx is the quarter of the year the Deliverable refers to (e.g. DX.Y.Z-2016Q1, DX.Y.Z-2016Q2). The same numbering format shall be applied for Milestones. Continuous deliverables at higher frequency can be labelled in the same way as quarterly deliverables.

D1.y.z	Report/Code	Improvements in desert dust modelling	annual
D1.y.z	Report/Code	Improvements in sea-salt modelling	annual
D1.y.z	Report/Code	Update of aerosol optical properties	Q3/2022

WP3510 Milestones				
#	Title	Means of verification	Due	
M1.y.z	Stratospheric AER extension ready for operational implementation	Report, code	Q4/2022	

3.3 Work package 3520 – Chemistry modelling aspects

This work package comprises of chemistry developments of the IFS code of the CAMS Global Production System. The developments shall be pursued with the main objective to decrease the errors of CAMS products with respect to observations while maintaining operational constraints such as computational cost and stability. The successful Tenderer shall carry out developments in the following topical areas:

- Maintenance and further improvement of the operational CB05 chemistry scheme
- Development of a stratospheric chemistry component of the CB05-BASCOE scheme ready for operational applications in forecast and data assimilation mode
- Development and maintenance of alternate chemistry schemes alongside the operational schemes. They should be sufficiently robust, contain interfaces to the AER aerosol scheme and efficient to run regularly alongside the operational system and achieve at least comparable scores.
- Support for organic and inorganic aerosol modelling in WP 3510 with focus on precursor gas modelling
- Including tropospheric halogenic chemistry in the operational chemistry scheme.
- On-line modelling of gas-phase natural and biogenic gas-phase emission variability in collaboration with the CAMS contract on global emissions and the Global Service provider.

WP3520 Deliverables				
#	Туре	Title	Due	
D2.y.z	Report/Code	Tropospheric gas-phase chemistry development	annual	
D2.y.z	Report/Code	Stratospheric chemistry developments	annual	

D2.y.z	Report/Code	On-line modelling of gas-phase natural and biogenic gas-phase emission	Q4/2023
,		biogenic gas-phase emission	.,

WP3520 Milestones					
#	Title	Means of verification	Due		
M2.y.z	Stratospheric chemistry scheme ready for operational implementation	Report, code	Q4/2022		
M2.y.z	Tropospheric halogenic chemistry extension of operational CB05 scheme implemented	Report, code	Q2/2023		

3.4 Work package 3530 – Integrated modelling aspects

This work package comprises of developments of the IFS code for atmospheric composition with the aim to improve the performance of the CAMS Global Production System. The developments shall further improve the coupling between chemistry and aerosol developments of WP3510 and WP3520. A unified modelling approach for processes that are common for aerosol and reactive gases such as natural emissions and dry and wet deposition shall be adopted. Finally, developments on tangent-linear and adjoint formulation of composition scheme components, which can be used in the IFS 4D-Var data assimilation method are required. These tangent-linear and adjoint code developments are of exploratory nature and are meant to support data assimilation developments by the Global Service Provider. The successful Tenderer shall also improve the computational performance of the aerosol and chemistry code. All chemistry and aerosol code shall run in single precision mode to enable the required computational gains.

The scientific and computational improvements by the developments of this work package and the integrated developments of WP3510 and 3520 shall be demonstrated in a measurable and robust way against observations as well as against the previous model versions both in forecast-only and data assimilation mode. The Global Service Provider will assist the experimentation in data assimilation mode. The successful Tenderer shall carry out developments in the following topical areas:

- Unification of the code-infrastructure in the IFS for dry and wet deposition
- On-line modelling of anthropogenic sectoral gas and aerosol emissions in collaboration with the CAMS contract on global emissions with focus on temporal variability and injection processes
- Improvement of aerosol and gas dry deposition and aerosol sedimentation processes, with focus on coupling to land surface modelling
- Improvements of stratospheric forecast and analysis products, especially for stratospheric aerosols following major volcanic eruptions and for ozone hole events.
- Improvements and harmonisation of aqueous phase chemistry and wet deposition
- Tangent linear and adjoint formulation of composition scheme components with focus on simplified chemistry schemes and loss processes by deposition.
- Computational performance improvements, also including single-precision mode for all chemistry and aerosol schemes

WP3530 Deliverables				
#	Туре	Title	Due	
D3.y.z	Report	Code unification plan (wet and dry deposition modules))	Q4/2021	
D3.y.z	Code	Unified wet deposition code	Q3/2022	
D3.y.z	Code	Unified dry deposition code	Q3/2022	
D3.y.z	Report/Code	Stratospheric chemistry and aerosol coupling developments	annual	
D3.y.z	Report/Code	Wet deposition and aqueous-phase developments	annual	
D3.y.z	Report/Code	Dry deposition developments	annual	
D3.y.z	Report/Code	On-line modelling of anthropogenic sectoral gas and aerosol emission	annual	
D3.y.z	Report/Code	Tangent and linear formulation of composition routines	Q3/2023	
D3.v.z	Report	Profiling of computational cost of chemistry and aerosol routines in the IFS and suggestions for	Q1/2022	
		improvements	Q1/2024	

WP3530 Milestones					
#	Title	Means of verification	Due		
M1.y.z	Aerosol and chemistry implementation for stratosphere ready for operational implementation	Presentation, Report, Data assimilation test	Q2/2023		
M3.y.z	Scientific paper to document model developments	Submission of paper	Q4/2024		
M3y.z.	Single precision operation for all chemistry and aerosol schemes	Successful single precision model runs completed	Q4/2024		

3.5 Work package 3540 – Development support activities

This work package comprises of development and evaluation of data sets produced from the output of the Global Production System, which has been improved based on the efforts in WP3510, WP3520 and WP3530. The development shall be driven by user requirements as communicated by the Global Service Provider and shall support improving the quality of the CAMS products.

The successful Tenderer is required to support the development of additional CAMS products that respond to specific requests from CAMS users. The two main product developments are: (i) extending the CAMS product portfolio to application-specific deposition flux products based on the developments in WP3530 and (ii) developing diagnostic air quality products that lead to better agreement of the global CAMS forecast with surface air quality observations.

Based on expressed user requirements, the Global Service Provider intends to increase the horizontal resolution of both the daily global forecasts and the next global reanalysis. The successful Tenderer shall systematically investigate the impact of these resolution upgrades on the scientific and computational performance of the Global Production System.

To complement the CAMS near-real-time forecast and re-analysis products, the successful Tenderer is required to carry out, evaluate and post-process model simulations with the IFS on a multi-month to multi-year time scale. The scope and configuration of the model runs will be coordinated together with the Global Service Provider. The aim of these model simulations is (i) to give targeted feedback on emission products and emission modelling developed by the CAMS contract on global emissions, (ii) to provide emission scenario boundary conditions for regional models, (iii) to contribute to intercomparison studies conducted by the scientific community, (iv) to estimate the long-term tracer mass conservation properties of the IFS and (v) to derive IFS cycle specific mean aerosol and gas model climatologies. The fact that multiple chemistry scheme can be used in the IFS shall also be exploited to quantify uncertainty and biases with respect to the choice of the chemical mechanism for the abovementioned model simulations.

An important further aspect of this work package is to improve the process-oriented evaluation efforts by using a wider range of atmospheric composition observations, developing verification (with observations) and diagnostic (with previous model results) procedures and software tools. The successful Tenderer shall explore a wide range of observations not yet included in the evaluation efforts in CAMS with focus on scientific development and product evaluation. Examples of these data sets are scientific campaign observations of volatile organic compounds, satellite retrievals of NH₃ and HCHO, aerosol mass spectrometry, air quality networks worldwide and a wide range of dry and wet deposition flux and precipitation chemistry observations. The successful Tenderer shall make these data sets available for the wider usage by the Global Service Provider and by the contract on global evaluation and quality control, preferably in prescribed data formats that allow a harmonised usage of the observations in CAMS. The evaluation efforts shall be shared and aligned within evaluation efforts by the Global Service Provider and the CAMS contracts on evaluation and quality control.

The successful Tenderer shall carry out activities in the following topical areas:

- Development of deposition flux products with application-specific aggregation with respect to time, land-use type and species
- Development of improved surface PM2.5, PM10, ozone, NO₂ and SO₂ diagnostics, especially considering vertical downscaling to the observation reference heights (2-3 m)
- Supporting the evaluation of emission data sets, also with multiple chemistry schemes

- Quantification of the impact of horizontal resolution changes on modelling results and computational cost
- Uncertainty estimation derived from multiple chemistry scheme simulations
- Compilation of modelled climatologies for aerosol and key chemistry species valid for each new IFS cycle
- Contribution of model results to international inter-comparison studies
- Access to new evaluation data sets and support development of software tools

WP3540 Deliverables				
#	Туре	Title	Due	
D4.y.z	Report	Deposition products for nitrogen and sulphur components and PM from model simulations	Q3/2023	
D4.y.z	Report	Deposition products for desert dust from model simulations	Q2/2022	
D4.y.z	Report	Diagnostic surface PM, ozone and NO2 forecast products from operational CAMS forecasts (analysis and model simulation)	Q1/2024	
D4.y.z	Report	CAMS model response to emission inventory updates	new emission data available*	
D4.y.z	Report	CAMS model response to GFAS fire emissions updates	new GFAS version available*	
D4.y.z	Report	CAMS model response to resolution upgrade	To be defined by GSP, once in the contract period*	
D4.y.z	Report	Multi-chemistry scheme uncertainty developments	Q3/2023	
D4.y.z	Data set	Atmospheric composition model climatology for new IFS cycles	6 month after IFS cycle release*	
D4.y.z	Report	Inventory of additional composition observation data to be acquired by CAMS 35	Q4/2021	
D4.y.z	Data set	New observational data sets, formatted according to Service providers specification	Q1/2023,Q1/2024	
D4.y.z	Software	Evaluation software required to process the new observational data sets (python)	Q1/2024, Q1/2024	

* Tenderer to include a realistic due date in the Proposal

WP3540 Milestones					
#	Title	Means of verification	Due		
M4.y.z	Scientific paper to document product developments	Submission of paper	Q4/2024		
M4.y.z	Dry and wet deposition product for nitrogen and sulphur components and desert dust available for distribution to users	Report, multi-year sample dataset available	Q2/2023		
M4.y.z	Diagnostic air quality product available for distribution to users		Q4/2023		

3.6 Work package 3550 – Operational system support

This work package comprises the efforts to support the scheduled upgrades of the CAMS Global Production System and its computing environment as well as the production of a new version of the CAMS reanalysis of atmospheric composition.

The model developments of WP 3510, WP3520 and WP 3530 that are candidate options for the upgrade of the Global Production system shall be provided tailored to the IFS upgrade procedures. It is required that they are provided as packages that are switchable to allow a step-wise testing of candidate configurations. It is also important that the submission of the final code for an e-suite has to follow the strict deadlines communicated in advance by the Global Service Provider.

Besides the contribution of code developments, the successful Tenderer shall also actively contribute to the preparation of resolution upgrades and changes of the operationally-used chemistry and aerosol schemes, if required by the Global Service Provider.

The successful Tenderer is required to actively contribute to the evaluation of the e-suite candidate configurations within the implementation time line. The focus shall be on using observations not included in the evaluation procedure of the Global Service Provider, especially with the new observation acquired in WP 3540.

Another specific task of the work package is the processing of the global emissions inventory data from the CAMS contract on emissions to a harmonised standard for the chemistry and aerosol species of all chemistry schemes and the provision of the applied software tools. The Global Service Provider intends to take sole responsibility for emission data processing by the end of the contract.

Finally, the Successful Tenderer shall provide its expertise and technical knowledge to respond to issues related to the relocation of the ECMWF data centre and to any upgrade of the ECMWF's High Performance Computing Facilities within the contract period.

The successful Tenderer shall carry out the following duties:

- Provide tested and packaged code for IFS cycle updates before the relevant deadlines
- Contribute to the e-suite evaluation with specific data sets not included in ECMWF evaluation protocol
- Support to processing of global emission data to the data formats required by the Global System Provider, in particular the mapping of chemical species between the emission inventories and chemical schemes
- Support model development specific for the next CAMS reanalysis such as the preparation of emission data sets, top and surface boundary conditions for long-lived trace gases, and specific contributions to the IFS-code branch used for the reanalysis production
- Support the transition to the new HPC used for the Global Production
- Support the Global Service Provider in the case of issues occurring during the CAMS operational production related to aerosol and chemistry modelling

Tenderers shall complete the relevant table in Volume IIIA as part of their bid, which shall include the deliverables and milestones for this work package already indicated in the tables below. Volume IIIA will be used by the Tenderer 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.

WP3550 Deliverables				
#	Туре	Title	Due	
D5.y.z	code	Emissions pre-processing code	Q1/2022	
D5.y.z	Report	Candidate model upgrade suggestions for next IFS cycle	3 month prior to code submission deadline*	
D5.y.z	Report/ Code	Support for CAMS reanalysis	Annually	

*Tenderer to include a realistic due date in the Proposal

WP3550 Milestones				
#	Title	Means of verification	Due	
M5.y.z	Code provision for cycle upgrade	Code delivered and accepted, evaluation documented	Submission deadline date specified by Global Service Provider, communicated at least 4 month in advance	
M5.y.z	Processed global emissions	Emission delivered	Within two month after new emissions are available.	
M5yz	Support to HPC upgrade	Request fulfilled	HPC upgrade	

3.7 Work package 3560 – User support and documentation of service

The objective of this work package is to provide support to users of the delivered products and services.

ECMWF has established a centralised Copernicus Service Desk to provide multi-tiered technical support to all users of CAMS data, products, tools and services. The Service Desk handles user queries through a ticketing system and distributes these queries to specialists when needed. Dedicated staff at ECMWF provide basic support in the form of self-help facilities (FAQs, Knowledge Base, online Forum, tutorials etc.) as well as individualised support on technical queries related to the Atmosphere Data Store (ADS), data formats, data access etc. In addition, ECMWF staff provide specialised scientific support to address questions related to its industrial contributions to CAMS, e.g. in the areas of global forecasting of atmospheric composition.

All CAMS contractors are required to contribute to the delivery of multi-tiered technical support for the data and/or services they provide. Such specialised user support shall take the form of direct response to individual user queries via the Service Desk facility, as well as contributions to FAQs, Knowledge Base, and user guides. Contractors may also be requested by the CAMS Service Desk to contribute to support questions in the online Forum.

Tenderers shall describe the level of user support service on Service Desk tickets as a specific Key Performance Indicator (KPI) with a target value of 80% of the assigned specialised user queries being resolved within 15 days after being informed by the CAMS Service Desk.

Tenderers shall also address development of user guides. Documentation of the CAMS services is an integral part of the service provision and is directly linked to the Atmosphere Data Store. The technical and scientific specification of each service shall be documented in the CAMS Knowledge Base as linked from the Atmosphere Data Store (see example for the CAMS global reanalysis at https://ads.atmosphere.copernicus.eu/cdsapp#!/dataset/cams-global-reanalysis-eac4?tab=doc), and, if more detail is required, in reports that will be available to users through the CAMS web site. The successful Tenderer shall therefore produce documentation describing in detail the methodologies and products they deliver for this ITT. The documentation in the Knowledge Base shall be targeted at the general external user community, while the additional detailed reports shall address the needs of expert users.

WP3560 Deliverables				
#	Туре	Title	Due	
D6.y.z-YYYY	Other	Contribution to CAMS Knowledge Base to document products and services based on global reactive gases and aerosol aspects developments		
D6.y.z-YYYY	Report	Contribution to documentation of products and services based on global reactive gases and aerosol aspects developments		

WP3560 Milestones				
#	Title	Means of verification	Due	
M6.y.z				

3.8 Work package 3500 – Management and coordination

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

- Contractual obligations as described in the Framework Agreement Clause 2.3 on reporting and planning.
- Meetings (classified as tasks and listed in a separate table as part of the proposal):
 - ECMWF will organise annual CAMS General Assemblies. The successful Tenderer is required to attend these meetings with team members covering the various topics that are part of this ITT.
 - ECMWF will host monthly teleconference meetings to discuss CAMS service provision, service evolution and other topics. The Prime Investigator appointed by the successful Tenderer will represent the successful Tenderer in such meetings.
 - ECMWF will organise six-monthly project review meetings (linked to Payment milestones).
 - Tenderers can propose additional project internal meetings (kick-off meeting, annual face-toface meeting and monthly teleconferences) 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 final quality check of the deliverables should be made by the prime contractor (contents, 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 (ECMWF, stakeholders, internal communication).
- Resources planning and tracking using the appropriate tools.
- Implementation of checks, controls and risk management tools for both the prime contractor and subcontractors.
- 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 back-up names for all key positions in the contract. The Tenderer shall describe how the Framework Agreement, in particular Clause 2.9 has been flowed down to all their subcontractors.
- Management of personal data and how this meets the requirements of Clause 2.8 and Annex 6 of the Volume V Framework Agreement.

WP3500 Deliverables				
#	Responsible	Nature	Title	Due
D0.y.z-YYYYQQ	Tenderer	Report	Quarterly Implementation Report QQ	Quarterly on 15/01,

			YYYY QQ YYYY being the previous quarter	15/04, 15/07 and 15/10
D0.y.z-YYYY	Tenderer	Report	Annual Implementation Report YYYY YYYY being the Year n-1	Annually on 28/02
D0.y.z-YYYY	Tenderer	Other	Preliminary financial form YYYY YYYY being the Year n-1	Annually on 15/01
D0.y.z	Tenderer	Report	Final report, including letter from auditor specific to CAMS contract YYYY YYYY being the last year of the contract	60 days after end of contract
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	Tenderer	Other	Updated KPIs (list, targets) after review with ECMWF	One year after start of contract

WP3500 Milestones				
#	Responsible	Title	Means of verification	Due
M0.y.z-Px	Tenderer	Progress review meetings with ECMWF / Payment milestones	Minutes of meeting	~ Every 6 months

4 General Requirements

4.1 Implementation schedule

The Framework Agreement will run from 1 September 2021 to 28 February 2025. The Tenderer shall provide a detailed implementation plan of proposed activities for the full period.

4.2 Deliverables and milestones

Deliverables should be consistent with the technical requirements specified in section 3. A deliverable is a substantial, tangible or intangible good or service produced as a result of a project. In other words, a deliverable is an outcome produced in response to the specific objectives of the contract and is subject to acceptance by the technical contract officers at ECMWF. When defining deliverable please **consolidate their numbers** against a specific deadline where possible. All contract 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) via the Copernicus Deliverables Repository portal.

Each Deliverable shall have an associated resource allocation (person-months and financial budget, resource type: payroll only). 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. They should not duplicate deliverables. Apart from the payment milestone review meetings, all foreseen meetings shall not be classified as milestones but listed in a separate overview table for each work package.

4.3 Acquisition of necessary data and observations

The Successful Tenderer shall closely interact with the Global Service Provider and the provider for the Global and regional a posteriori EQC activities for the exchange of relevant data sets related to the implementation, development and testing of numerical code for modelling and data assimilation as covered by this ITT. The Successful Tenderer shall also closely interact with the provider(s) for the Global and regional emissions activities, who are responsible for delivering the anthropogenic and natural emissions that form an input to the IFS, to ensure appropriate use of these emissions in the chemical and aerosol schemes.

4.4 Access to ECMWF HPC and IFS code base

ECMWF will support the development work of this contract by providing access to the IFS code base, the High Performance Computing Facility (HPCF) and Data Handling System (DHS) to specific individuals for the duration of the contract. This will allow the successful Tenderer to carry out the required experimentation in both modelling and data assimilation mode for the technical testing and scientific evaluation of the results. The use of the HPC resources will be closely monitored by ECMWF to ensure they stay within the allocation for CAMS global development.

4.5 Communication

The successful Tenderer shall support ECMWF in its communication activities for the CAMS services, where they are related to the activities described in this ITT. Examples are contributions to the Copernicus State of the Climate report, CAMS web site news items, and CAMS brochures and flyers. All 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 written and graphic content and events. Agreed activity would also need to be evaluated and reported on, once complete, so that success measures and KPIs can be provided to the European Commission.

4.6 Support for user engagement and training activities

While user engagement and training activities are not part of the scope of this ITT, the Tenderer shall accommodate for eventual needs in providing technical and scientific expertise in support of these activities. The bidder shall specify in the bid 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 your mother tongue may be asked to be provided;

• Input to the URDB with user requirements (cf. template as provided during the negotiation process) as well sharing needs and aspirations as raised by potential new user communities;

An indicative maximum budget of 5,000.- EUR shall be allocated in the pricing table to accommodate for these needs. This shall be paid as a cost-reimbursement against a fixed fee rate/day. Details on the required activities and the budget shall be refined during the negotiation/contract preparation phase.

As part of the CAMS user interaction, user requirements are continually collected in a User Requirements Database (URDB) in a structured and traceable way. This URDB tracks all requirements emanating from a wide variety of user fora, surveys, user support and direct interactions between service providers and their users. The entries of the URDB are analysed on a regular basis in terms of user requirements per domain, importance and feasibility. This analysis constitutes the basis for distilling, filtering and translating user requirements into technical specifications for the Service and its evolution.

The successful Tenderer shall provide input to the User Requirements Database (URDB) regarding user requirements that are directly related to activities covered by this ITT. The successful Tenderer shall also support ECMWF and the contractor for User Interaction activities with the analysis of relevant user requirements in the URDB.

WP3560 Deliverables				
#	Туре	Title	Due	
D6.y.z-YYYY	Other	Input to CAMS URDB - YYYY	Checked by ECMWF annually in November	

The following deliverables are thus to be added to the WP3560 deliverable lists:

4.7 Data and IPR:

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

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

5 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 sub-sections.

5.1 Page Limits

As a guideline, it is required 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	2 (excluding Table 1 in Volume IIIB and CVs with a maximum
Deployed	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	6 (excluding Table 3, Table 5, Table 6 and Table 7 in Volume IIIB) +
Implementation	2 per each Work package description (Table 4 in Volume IIIB)
Pricing Table	No limitation

Table 1: Page limits

5.2 Specific additional instructions for the tenderer's response

The following is a guide to the minimum content required 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.

5.2.1 Executive Summary

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

5.2.2 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.

5.2.3 Quality of Resources to be Deployed

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

- A senior team member (Prime Investigator) with more than 5 years of experience in managing activities related to this ITT;
- At least two additional senior team members with more than 5 years of experience on 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. The successful Tenderer shall also appoint a Service Manager, which will be its primary contact for contractual delivery and performance aspects.

5.2.4 Technical Solution Proposed

The Tenderer is required to provide a short background to the proposed technical solution to demonstrate understanding of the solution proposed. This should include background of the Tenderer's understanding of the Copernicus Atmosphere Monitoring Service, the current state of monitoring and forecasting of global atmospheric composition, and modelling of reactive gases and

aerosol in the atmosphere. An exhaustive and detailed description of the proposed technical solution for all work packages described above, including any ramp-up or mobilization phase, shall be given

The Tenderer shall indicate in detail how they intend to develop the chemistry and aerosol schemes to ensure they continue to meet the international standards required. This shall take into account all the requested development activities.