

ECMWF Copernicus Procurement

Invitation to Tender



Copernicus Atmosphere Monitoring Service Volume II

Development of global greenhouse gas
aspects

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1 Introduction

Some of today's most important environmental concerns relate to the composition of the atmosphere. The increasing concentration of the greenhouse gases and the cooling effect of aerosol are prominent drivers of a changing climate, but the extent of their impact is often still uncertain.

At the Earth's surface, 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. Ozone distributions in the stratosphere influence the amount of ultraviolet radiation reaching the surface. Dust, sand, 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.

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.

The Service consolidates many years of preparatory research and development and delivers the following operational services:

- 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 surface flux inversions for CO₂, CH₄ and N₂O, 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 for the global and European domains and global emissions from wildfires and biomass burning

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

1.1 Definitions

Definitions specific for this ITT are defined below.

Global Service Provider: ECMWF is the provider of global products

Real-Time Global Products: the operational real-time analyses and forecasts from the global CAMS data assimilation and forecasting system, which is run by the Global Service Provider. These analyses

and forecasts are produced twice- daily and include 3-dimensional fields of aerosols, chemical species, and greenhouse gases with a temporal resolution of at least 6 hours.

Forecast-only Global Products: the outputs of a global CAMS forecasting system that is based on the system used to produce the Real-Time Global Products but without the assimilation of observations of atmospheric composition. The forecasts are produced at least daily and include 3-dimensional fields of aerosols, chemical species, and greenhouse gases with a temporal resolution of at least 6 hours.

Global Reanalysis Products: the outputs of a reanalysis from the global CAMS data assimilation and forecasting system, which is being run by the Global Service Provider. The reanalysis will cover the period from 2003 to 2017 and provide analyses and forecasts every 12 hours of 3-dimensional fields of aerosols, chemical species, and greenhouse gases with a temporal resolution of at least 6 hours.

2 Contract Summary

This ITT, entitled “Development of global greenhouse gas aspects”, is for providing support for and further development of the global production system of CAMS operated at ECMWF, which delivers 3D distributions of greenhouse gases (CO₂ and CH₄) in the troposphere and stratosphere through data assimilation and numerical modelling. The Successful Tenderer will be expected to deliver an improved representation of methane fluxes from natural wetlands for use in the CAMS global production system, implement the Farquhar photosynthesis model to allow future use of satellite observations of solar-induced chlorophyll fluorescence (SIF) to further optimize the land surface model used in the CAMS global production system, provide timely retrieval products from the GOSAT satellite, as well as deliver memoranda and reports. The Successful Tenderer will also provide expertise to the team working on the global production system at ECMWF regarding greenhouse-gas aspects. The ITT targets organisations with considerable experience in the field of modelling of greenhouse gases in the atmosphere and their sources and sinks.

3 Technical Specification

3.1 General Requirements

Modules for atmospheric greenhouse gases and related physical processes have been integrated in ECMWF’s Integrated Forecasting System (IFS), which forms the basis for the CAMS global data assimilation and forecasting system. The CAMS global data assimilation system is used to provide the Real-Time Global Products, the Forecast-only Global Products, and the Global Reanalysis Products. The extension of the IFS makes it possible (i) to use the detailed meteorological simulation of the IFS for the simulation of the atmospheric transport and removal processes of constituents (ii) to use the IFS data assimilation system to assimilate observations of atmospheric composition and (iii) to simulate feedback processes between atmospheric composition and weather. The IFS currently includes CO₂ and CH₄ as separate tracers. Although most surface fluxes for these two species are prescribed, the IFS is directly coupled to the CHTESSEL land surface model for the natural biosphere fluxes of CO₂ (see also: Agustí-Panareda et al. 2014, *Atmos. Chem. Phys.*, 14, 11959-11983, doi:10.5194/acp-14-11959-2014; Boussetta et al. 2013, *JGR*, doi: [10.1002/jgrd.50488](https://doi.org/10.1002/jgrd.50488)). A simple parameterisation for the oxidation of CH₄ is also part of the IFS.

The data assimilation of the IFS is based on the ECMWF 4-dimensional variational (4D-Var) formulation and assimilates a range of satellite observations of greenhouse gases in addition to the standard

meteorological observations (see also: Massart et al., Atmos. Chem. Phys., 14, 6139-6158, doi:10.5194/acp-14-6139-2014, 2014).

The central elements of this ITT are the further development of a parameterisation of wetland emissions for CHTESSEL, the implementation of the Farquhar photosynthesis model for future use of satellite observations of solar-induced chlorophyll fluorescence (SIF), and the provision of XCO₂ and XCH₄ retrieval products from the GOSAT satellite. Due to the operational, product-driven nature of CAMS, the Successful Tenderer shall ensure that the provided numerical code and developments are suitable for the time-critical, operational data assimilation and forecasting environment based on IFS, including its existing formulation of atmospheric transport and other meteorological processes.

3.2 Work package 4110 – Representation of CH₄ wetland surface fluxes

The IFS uses the Carbon-Hydrology Tiled ECMWF Scheme for Surface Exchanges over Land (CHTESSEL) land surface model to interactively model the Net Ecosystem Exchange of CO₂. CHTESSEL includes a representation of soil, vegetation, snow, mountains, and water bodies and the associated energy, water and carbon exchanges with the atmosphere. This includes a multi-layer soil scheme and a single-layer snow scheme representing thermodynamics and water transfer processes. A mixed-layer scheme for resolved and sub-grid water bodies has been recently added. Satellite-based land-use maps and monthly varying vegetation-soil descriptions (for Leaf Area Index and Albedo) specify ancillary conditions, while processes like evapotranspiration, snow and ice melting/sublimation, percolation and runoff are explicitly taken into account. The natural land carbon cycle is represented in its soil respiration, parameterised with a so-called Q10 scheme and modulated by a land-use dependent basal respiration, and a photosynthesis scheme known as A-gs that simulate the CO₂ assimilation by plants or gross primary production. The CO₂ residuals of assimilation and respiration processes compose the Net Ecosystem Exchange. The land surface model benefits from continuous benchmarking of its main prognostic variables and fluxes against in-situ and satellite remote sensing products and is used across all ECMWF forecasting applications (more information can be found in Chapter 8 of the IFS documentation at <https://www.ecmwf.int/file/267309/download?token=RV-BAg4d>).

While CHTESSEL is already providing the hydrological and CO₂-specific carbon cycle exchanges with the atmosphere, it does not include a model component for natural CH₄ fluxes. CH₄ fluxes in the IFS are currently prescribed either based on inventories or on optimized fluxes from flux inversions. In addition, a statistical model for wetland emissions has been developed to capture more of the temporal and spatial variability. However, the statistical model lacks a direct relationship with the underlying physical and biogeochemical processes and therefore does not easily allow further development of the CHTESSEL model in terms of both modelling and data assimilation aspects. The Successful Tenderer shall therefore develop a parameterisation for CH₄ fluxes from natural wetlands that can be included in the CHTESSEL model and is consistent with the modelling of the CO₂ respiration fluxes based on the simple Q10 empirical formulation as for instance described in Boussetta et al. (2013, JGR, doi: 10.1002/jgrd.50488) for CO₂ soil respiration, and Gedney et al. (2004, GRL, doi.org/10.1029/2004GL020919) or Bloom et al. (2017, GMD, doi.org/10.5194/gmd-10-2141-2017) for wetland CH₄ emissions. The scheme shall be parsimonious, favouring simple and sound parameterisation solutions with consideration for the number of predictors, to be chosen among and adapted to the ones already available in the IFS land surface model (e.g., soil moisture, soil temperature, snow variables, incoming radiative/water fluxes, and near-surface meteorology), and favouring maintaining the overall computational cost constrained with an increase of no more than twenty percent of the baseline CHTESSEL code.

The development should be implemented with incremental steps (e.g. using a climatological monthly wetland map before implementing the parameterisation of wetland cover). Such an eventual parameterisation shall be driven by meteorological input from IFS at temporal/spatial resolutions compatible with the operational NWP model, where possible, as well as suitable climatologies, where needed. In order to improve the spatial/temporal variability of the modelled CH₄ fluxes, the Successful Tenderer has the option of implementing a parameterisation for the wetland extend based on soil moisture and sub-grid scale topography (e.g. Gendey and Cox, 2003, JHM, 10.1175/1525-7541004).

ECMWF will provide an off-line version of CHTESSEL that can be used for this model development together with support/training on performing the model simulations. The successful contractor will implement the parameterisation of the wetland emissions in the off-line version of the model and evaluate the parameterisations on a selection of in situ sites with meteorological forcing provided by ECMWF. The optimization and calibration of the parameters which cannot be modelled in CHTESSEL, such as the reference CH₄ heterotrophic respiration or scaling factors to constrain the budget, will be based on observations wherever available (e.g., CH₄ Eddy Covariance flux data), established model ensembles from Model Intercomparison Projects and information on the global budget provided by the Global Carbon Project (Saunois et al.(2016), doi: 10.5194/essd-8-697-2016). The development of the CH₄ wetland flux parameterisation shall be performed in coordination with ECMWF to assure consistency with other CHTESSEL developments. The parameterisation shall be benchmarked against the statistical wetland model, other model performances, inversion estimates and observations of CH₄ fluxes (where possible) and CH₄ atmospheric concentrations to ensure the natural variability is sufficiently accounted for. The Successful Tenderer shall also indicate if observations can be used to further constrain the CH₄ flux parameterisation. To optimize the collaborative aspects with the Global Service Provider related to this workpackage, the Successful Tenderer shall plan on-site visits at the ECMWF premises in Reading, United Kingdom. These on-site visits shall be arranged at least once per year and coordinated between the Successful Tenderer and ECMWF (cost to be included within the Tender to this ITT).

The tables below provide the deliverables and milestones for the work package. Tenderers shall complete Volume III C as part of their bid, which should include the deliverables and milestones already indicated in the tables below and will form a preliminary version. Volume III C will be used by the contractor to describe the complete list of deliverables, milestones and schedules for this 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.

WP4110 Deliverables			
#	Type	Title	Due
D1.y.z ¹ -YYYY	Report	Description of CH ₄ wetland parameterisation	M6
D1.y.z-YYY	Code	Provision of code and required input data sets	TBC
D1.y.z-YYYY	Report/ model-	Report on the calibration/validation of the parameterisation at given sites	TBC

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.

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WP4110 Milestones			
#	Title	Means of verification	Due
M1.y.z	Checkpoint installation and demo of baseline CHTESSEL	1-day review meeting and demo	M1-2
M1.y.z	Checkpoint installation and demo of the updated CHTESSEL	1-day review meeting and demo	
M1.y.z	Report/Journal publication	Report on the evaluation and benchmarking of CH ₄ fluxes from parameterisation (e.g. comparison with other CH ₄ wetland products)	

3.3 Work package 4120 – Implementation of the Farquhar photosynthesis model

The IFS currently uses satellite observations to constrain the atmospheric concentrations of CO₂ and CH₄ using its 4D-Var formulation. For this to work accurately a realistic short-term model forecast is needed. For CO₂, this forecast is dominated by the natural biosphere fluxes and it is therefore necessary to constrain the output of CHTESSEL as much as possible. Some of the hydrology-related variables (soil moisture, soil temperature and snow depth) can be constrained either through on-line assimilation of in-situ and satellite observations or through an off-line benchmarking. The CO₂ fluxes are currently benchmarked against FLUXNET (<http://fluxnet.ornl.gov>) observations. Because this does not sufficiently constrain the total budget, a bias correction is applied as part of the IFS model simulations. The use of satellite observations directly related to the CO₂ fluxes associated with the photosynthetic uptake like Solar-Induced Fluorescence (SIF) would help to constrain the biogenic fluxes, and in particular the disaggregation between the Gross Primary Production (GPP) and ecosystem respiration. However, the full assimilation of SIF satellite observations require the implementation of complex radiative transfer models that generally rely on the well-established Farquhar photosynthesis model (Farquhar et al. 1980). Currently the photosynthesis model in CHTESSEL is based on the Jacobs A-gs formulation (Boussetta et al., 2013, JGR, [doi:10.1002/jgrd.50488](https://doi.org/10.1002/jgrd.50488)) which pre-dates the Farquhar model (Farquhar et al., 1980, Planta, [doi:10.1007/BF00386231](https://doi.org/10.1007/BF00386231)). This ITT asks for the implementation of the Farquhar photosynthesis model in CHTESSEL. It will provide an additional photosynthesis formulation in the IFS that can open new avenues for the implementation of SIF radiative transfer models in the future and running different photosynthesis formulations in an ensemble of CO₂ simulations.

The Successful Tenderer shall implement the Farquhar photosynthesis model in the CHTESSEL model and calibrate/optimize the prescribed model parameters with independent FLUXNET data as in Boussetta et al. (2013). For this model assessment, ECMWF will provide an off-line version of CHTESSEL. The Protocol for the Analysis of Land Surface models (Best et al, 2015, JHM, 0.1175/JHM-D-14-0158.1) provides a list of 20 observational sites (listed in table1) that shall be simulated with the offline CHTESSEL for the Successful Tenderer to evaluate the energy and carbon fluxes outputs of the implemented parameterization. A benchmark of the Farquhar model and the A-gs model as integrated within CHTESSEL shall then be performed in conjunction with other similar state-of-the-art models. The implementation work in CHTESSEL shall be performed in collaboration with ECMWF to assure consistency with other CHTESSEL modelling work at ECMWF. To optimize the collaborative aspects with the Global Service Provider related to this workpackage, the Successful Tenderer shall plan on-site visits at the ECMWF premises in Reading, United Kingdom. These on-site visits shall be arranged

at least once per year and coordinated between the Successful Tenderer and ECMWF (cost to be included within the Tender to this ITT).

Table 1 PALS sites (Best et al., 2015)

Name	Code	Country	Lat	Lon	Plant functional type	Duration
Amplero	Am	Italy	41.90°N	13.61°E	Grassland	2003–06
Blodgett	Bl	United States	38.90°N	120.63°W	Evergreen needleleaf	2000–06
Bugac	Bu	Hungary	46.69°N	19.60°E	Grassland	2002–06
El Saler	El	Spain	39.35°N	0.32°W	Evergreen needleleaf	2003–06
El Saler 2	E2	Spain	39.28°N	0.32°W	Cropland	2005–06
Espirra	Es	Portugal	38.64°N	8.60°W	Evergreen broadleaf	2001–06
Fort Peck	FP	United States	48.31°N	105.10°W	Grassland	2000–06
Harvard	Ha	United States	42.54°N	72.17°W	Deciduous broadleaf	1994–2001
Hesse	He	France	48.67°N	7.06°E	Deciduous broadleaf	1999–2006
Howard	Ho	Australia	12.49°S	131.15°E	Woody savanna	2002–05
Howlandm	Hl	United States	45.20°N	68.74°W	Evergreen needleleaf	1996–2004
Hyttiala	Hy	Finland	61.85°N	24.29°E	Evergreen needleleaf	2001–04
Kruger	Kr	South Africa	25.02°S	31.50°E	Savanna	2002–03
Loobos	Lo	Netherlands	52.17°N	5.74°E	Evergreen needleleaf	1997–2006
Merbleue	Me	Canada	45.41°N	75.52°W	Permanent wetland	1999–2005
Mopane	Mo	Botswana	19.92°S	23.56°E	Woody savanna	1999–2001
Palang	Pa	Indonesia	2.35°N	111.04°E	Evergreen broadleaf	2002–03
Sylvania	Sy	United States	46.24°N	89.35°W	Mixed forest	2002–05
Tumbarumba	Tu	Australia	35.66°S	148.15°E	Evergreen broadleaf	2002–05
University of Michigan	UM	United States	45.56°N	84.71°W	Deciduous broadleaf	1999–2003

The tables below provide the deliverables and milestones for the work package. Tenderers shall complete Volume III C as part of their bid, which should include the deliverables and milestones already indicated in the tables below and will form a preliminary version. Volume III C will be used by the contractor to describe the complete list of deliverables, milestones and schedules for this 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.

WP4120 Deliverables			
#	Type	Title	Due
D2.y.z-YYYY	Report	Description of parameterisation and required datasets	M3
D2.y.z-YYYY	Code	Provision of the parameterisation code and required input data	TBC
D2.y.z-YYYY	Report/ model- output	Report on the calibration/validation of the parameterisation at given sites	TBC

WP4120 Milestones			
#	Title	Means of verification	Due
M2.y.z	Checkpoint installation and demo of updates in CHTESSEL	1-day review meeting and demo	
M2.y.z	Report/Journal publication	Report on the evaluation and benchmarking of parameterisation for the CO ₂ , water and energy fluxes	

3.4 Work package 4130 – Provision of satellite retrieval data from GOSAT

The CAMS data assimilation system for greenhouse gases currently uses observations of CO₂ and CH₄ from the TANSO instrument on board of the Japanese GOSAT satellite for its production of daily analyses, which form the initial conditions for the daily forecasts. GOSAT is a research satellite and data are generally not available via the established operational data acquisition channels. Also, retrieval algorithms are still rapidly developing to achieve the required high accuracy for greenhouse-gas observations. In order to ensure the continuity of the service provision, this ITT asks for Level-2 retrievals of CO₂ and CH₄ from TANSO delivered within 1 day of the availability of Level-1 radiance data from the Space Agencies (JAXA, NIES, ESA, or EUMETSAT). The Successful Tenderer shall provide column-averaged dry air mole fraction (XCO₂ and XCH₄) values with associated retrieval uncertainties, averaging kernels and the a priori information used in the retrieval for each individual satellite footprint. The quality of the retrieval values shall be competitive with international standards, such as are for instance available from the European Space Agency Climate Change Initiative (ESA-CCI; <http://www.esa-ghg-cci.org>). This quality shall be assessed against independent observations, such as are for instance available from the Total Carbon Column Observing Network (TCCON), and documented in annual reports. In case the GOSAT instrument fails during the duration of the contract based on this ITT and Level-1 data are not available anymore, ECMWF shall discuss with the Successful Tenderer alternative tasks for the remainder of the contract.

The tables below provide the deliverables and milestones for the work package. Tenderers shall complete Volume III C as part of their bid, which should include the deliverables and milestones already indicated in the tables below and will form a preliminary version. Volume III C will be used by the contractor to describe the complete list of deliverables, milestones and schedules for this 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.

WP4130 Deliverables			
#	Type	Title	Due
D3.y.z-YYYY	Data	XCO ₂ retrievals from GOSAT-TANSO	Daily
D3.y.z-YYYY	Data	XCH ₄ retrievals from GOSAT-TANSO	Daily
D3.y.z-YYYY	Report	Status report of XCO ₂ retrievals including validation against TCCON	Annually
D3.y.z-YYYY	Report	Status report of XCO ₂ retrievals including validation against TCCON	Annually

WP4130 Milestones			
#	Title	Means of verification	Due
M3.y.z			

3.5 Work package 4140 – User support and documentation of service

The objective of this work package is to provide specialised 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 CAMS Service Desk is used for

ticketing user requests and distributing these requests to specialists as needed. Dedicated staff at ECMWF provide basic support in the form of self-help facilities (FAQs, knowledge bases, tutorials etc.) as well as individualised support on technical queries related to the CDS, 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 expected 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 CAMS Service Desk facility, as well as contributions to FAQs, user guides and knowledge bases.

As part of the bid, Tenderers shall describe the level of user support service on CAMS Service Desk tickets, they can provide.

Tenderers shall also address development of user guides. Documentation of the CAMS services is an integral part of the service provision. The technical and scientific specification of each service shall be documented in reports that will be available to users through the CAMS web site. The successful Tenderer shall therefore produce documentation reports describing in detail the methodologies and products it delivers for this ITT.

The tables below provide the deliverables and milestones for the work package. Tenderers shall complete Volume III C as part of their bid, which should include the deliverables and milestones already indicated in the tables below and will form a preliminary version. Volume III C will be used by the contractor to describe the complete list of deliverables, milestones and schedules for this 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.

WP4140 Deliverables			
#	Type	Title	Due
D4.y.z-YYYY	Other	Specialised user support via the CAMS Service Desk (Respond to user support queries requiring expertise specific to the global aerosol aspects developed)	Continuous
D4.y.z-v1	Other	Specialised User Support - Period 1	At Payment milestone 1
D4.y.z-v1	Other	Specialised User Support - Period 2	At Payment milestone 2
D4.y.z-YYYY	Report	Documentation of global greenhouse gas developments	Annually
...			

WP4140 Milestones			
#	Title	Means of verification	Due
M4.y.z	Link with CAMS User Support team established; service desk set-up completed	Specialised Service Desk up and running	Month 2
...			

3.6 Work package 4100 – 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:
 - ECMWF will organise annual CAMS General Assemblies within EU member states. The successful Tenderer is expected 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 should propose additional project internal meetings (kick-off meeting, annual face-to-face 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.
- Personal data management (name, ID and contact details of prime contractor's data controller in line with Clause 2.8).

The tables below provide the deliverables and milestones for the work package. Tenderers shall complete Volume III C as part of their bid, which should include the deliverables and milestones already indicated in the tables below and will form a preliminary version. Volume III C will be used by the contractor to describe the complete list of deliverables, milestones and schedules for this 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.

WP4100 Deliverables				
#	Responsible	Nature	Title	Due
D0.y.z-YYYYQQ	Tenderer	Report	Quarterly Implementation Report QQ YYYY <i>QQ YYYY being the previous quarter</i>	Quarterly on 15/01, 15/04, 15/07 and 15/10
D0.y.z-YYYY	Tenderer	Report	Annual Implementation Report YYYY <i>YYYY being the Year n-1</i>	Annually on 28/02
D0.y.z	Tenderer	Report	Final report, including letter from auditor specific to CAMS contract YYYY <i>YYYY being the last year of the contract</i>	60 days after end of contract
D0.y.z-YYYY	Tenderer	Report	Draft Implementation plan YYYY <i>YYYY being the Year n+1</i>	Annually on 28/02

D0.y.z-YYYY	Tenderer	Report	Finalised Implementation plan YYYY <i>YYYY being the Year n+1</i>	Annually on 31/10
D0.y.z-YYYY	Tenderer	Other	Copy of prime contractor's general financial statements and audit report YYYY <i>YYYY being the Year n-1</i>	Annually
D0.y.z-YYYY	Tenderer	Other	Letter auditor's opinion specific to CAMS most recent Annual Implementation Report YYYY <i>YYYY being the Year n-1</i>	Annually
D0.y.z	Tenderer	Other	Updated KPIs (list, targets...) after review with ECMWF	One year after start of contract

WP4300 Milestones				
#	Responsible	Title	Means of verification	Due
M0.y.z	Tenderer	CAMS General Assembly	Participation to the meeting	Annually
M0.y.z	Tenderer	Monthly teleconference meetings with ECMWF	Participation to meeting	Monthly
M0.y.z	Tenderer	Progress review meetings with ECMWF / Payment milestones	Minutes of meeting	~ Every 6 months
M0.y.z	Tenderer	Kick-Off meeting	Minutes of meeting	Month 1
M0.y.z	Tenderer	Internal face to face project meetings	Minutes of meeting	Annually
M0.y.z	Tenderer	Internal project monthly teleconferences	Meetings happened	Monthly

4 General Requirements

4.1 Implementation schedule

The Framework Agreement will run from 1 April 2019 to 31 December 2021. The Tenderer shall provide a detailed implementation plan of proposed activities for the period until 30 June 2021. However, note that by Q4 2019 the level and duration of activities for the full year of 2021 will be communicated by ECMWF to the successful Tenderer based on the Copernicus programme review by the European Commission.

Adjustments to the proposed implementation plan can be made on an annual basis depending on needs for service evolution, changed user requirements, or other requirements as agreed between the European Commission and ECMWF.

4.2 Deliverables and milestones

Deliverables should be consistent with the technical requirements specified in section 3.

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). The total of these allocated resources shall amount to the entire requested budget.

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

4.3 Acquisition of necessary data and observations

ECMWF shall provide an off-line version of the CHTESSEL model for the development of the CH₄ wetland flux parameterisation and the implementation of the Farquhar photosynthesis model. ECMWF shall also provide the required input data for CHTESSEL that is needed for the work described in this ITT.

4.4 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.

4.5 User requirements

As part of CAMS, the database and three documents described below will be maintained. 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 CAMS_94 (User Interaction) with the analysis of relevant user requirements in the URDB. Finally, in case the successful Tenderer provides service elements that are listed in the Service Product Portfolio (SPP), the successful Tenderer shall provide input on product lines and their metadata to ECMWF to ensure the SPP is up-to-date.

User Requirements Database (URDB) and Requirement Analysis Document (RAD)

User requirements are collected in this database in a structured and traceable way, and links to entries in the Service Product Portfolio (see below) are provided, when appropriate. The URDB, which tracks all requirements emanating from a wide variety of user fora, surveys, and support panels, is complemented by a Requirements Analysis Document (RAD) which captures the stratification of user requirements per domain, importance and feasibility. The RAD constitutes the basis for distilling, filtering and translating user requirements into technical specifications for the Service. The URDB and RAD are maintained and continually updated by ECMWF and its contractor for CAMS_94 (User Interaction).

Service Product Portfolio (SPP)

Both data and value-added products are presented in this document in a structured way, providing key technical aspects, when appropriate, such as geophysical parameter, temporal resolution and coverage, spatial resolution and coverage, data formats, time availability, expected quality, data format together with a direct link to detailed information on methodology and quality monitoring for each specific product or services.

Service Evolution Strategy (SES)

The appropriateness of the list of emerging and existing user requirements, the routinely updated Requirement Analysis Document and the existing Service Product Portfolio, are continually monitored by ECMWF and feed into a Service Evolution Strategy (SES) document. The SES document is produced on an annual basis and provides, in addition to the annual implementation plan focussing on year n+1 service Deliverables, a proposed longer term (typically 4 years) perspective for forthcoming service upgrades and extensions, the expected benefits and costs, together with recommendations for potential research needs outside Copernicus operations. This document allows informed discussions to be opened on specific proposed service upgrades and extensions with the stakeholders.

The following deliverables are thus to be added to the WP4300 and WP4350 deliverable lists:

WP4100 Deliverables			
#	Type	Title	Due
D0.y.z-YYYY	Report	Input to CAMS SPP - YYYY	Annually in September
...			

WP4140 Deliverables			
#	Type	Title	Due
D4.y.z-YYYY	Other	Input to CAMS URDB - YYYY	Checked by ECMWF annually in December
...			

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 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.

<i>Section</i>	<i>Page Limit</i>
<i>Executive Summary</i>	2
<i>Track Record</i>	2 (for general) and 2 (per entity)
<i>Quality of resources to be Deployed</i>	2 (excluding Table 1 in Volume IIIB and CVs with a maximum length of 2 pages each)
<i>Technical Solution Proposed</i>	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)
<i>Management and Implementation</i>	6 (excluding Table 3, Table 5, Table 6 and Table 7 in Volume IIIB) + 2 per each Work package description (Table 4 in Volume IIIB)
<i>Pricing Table</i>	No limitation

Table 2: Page limits

5.2 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.

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 expected 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, and the current state of monitoring and forecasting of global greenhouse gases 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 its development plan for the proposed CH₄ wetland flux representation in the IFS, as part of CHTESSEL developments, and the implementation of the Farquhar photosynthesis parameterisation in CHTESSEL. For the GOSAT satellite data provision, the Tenderer shall indicate its proposal for providing the Level-2 CO₂ and CH₄ products, including the acquisition of Level-1 data, the proposed retrieval algorithm and its required input, and the expected data provision (e.g., data format, timeliness). Finally, for the model implementation aspects, the Tenderer shall indicate its proposal for required input data sets and observations/products to be used in the optimization of model parameters and final evaluation of the model performance.