

Technical Annex for the budget implementation tasks linked to the provision of the Copernicus Atmosphere Monitoring Service (CAMS)

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1 Context

Some of today's most important environmental concerns relate to the composition of the atmosphere. Most prominent is the increasing concentration of the long-lived and reactive greenhouse gases. Climate warming and linked impacts such as sea-level rise and changes in rainfall distributions are offset to a degree by a cooling effect of aerosol concentrations, but the extent of the offset and the role played by aerosol-cloud interactions are key uncertainties in the driving of climate change. Other uncertainties relate to recent changes in the rate of growth of methane concentrations, the roles of different factors increasing tropospheric ozone concentrations, the quantification of land/atmosphere fluxes and the causes of changes in stratospheric water vapour and its associated radiative forcing.

There are also important effects of short-term variations in atmospheric composition. 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, again with impacts on human, animal and plant health. Dust, sand, smoke and volcanic aerosols affect the safe operation of transport systems. Aerosols also affect the availability of power from solar generation, the formation of clouds and rainfall, and the remote sensing by satellite of land, ocean and other atmospheric properties.

Accompanying these environmental concerns is a parallel set of needs for data and processed information. The Copernicus programme has been developed to meet these needs, aiming at supporting policymakers, business and citizens with enhanced environmental information. Economic studies have demonstrated a huge potential for job creation, innovation and growth. Copernicus will also address policy objectives, bringing an essential contribution to the 7th EU Environment Action Programme, which was recently agreed with the aim of "living well, within the limits of our planet". The information services provided will be freely and openly accessible to users.

Specifically the Copernicus Regulation reads:

"the atmosphere monitoring service, which shall provide information on air quality on a European scale, and of the chemical composition of the atmosphere on a global scale. It shall in particular provide information for air quality monitoring systems run at the local to national scales, and should contribute to the monitoring of atmospheric composition climate variables, including, where feasible, the interaction with forest canopies;"

It appears important to briefly outline how the past work on scientific and technological development was guided in order to ensure that users' needs are addressed and where possible anticipated by integrating the dialogue early in the process of definition of the work. Three important pillars which led to today's mature Copernicus Atmosphere Monitoring Service (CAMS) components were the consultation of users / potential users, the assessment of scientific and technical capabilities by experts and a series of precursor/pilot projects funded under the EU Framework Programme for Research and Development.

1.1 USER INTERACTION ACTIVITIES AND CONSULTATION OF EXTERNAL EXPERTS

The foundation stone for CAMS was laid in December 2006, with the organisation by the European Commission of the first “GMES Atmosphere Service workshop” in Brussels. The workshop was attended by over 100 participants from 22 European countries, several European Commission Directorates General (Environment, Joint Research Centre, Research, Enterprise and Industry), European agencies and organisations (ECMWF, EEA, ESA, EUMETSAT), as well as representatives of key projects funded through European Commission 6th Framework Programme and ESA GMES Service Element activities.

The workshop presentations and discussions focused on three main items:

- Users, objectives and requirements;
- Implementation issues;
- Conditions for sustainability.

The workshop was structured in three parallel sessions around different user communities: “Air Quality”, “Climate Change/Forcing” and “O3/UV/Renewable Energies”. These thematic divisions were established for practical reasons knowing that there are clear dependencies between the service components and their parameters have relevance to all three streams. To support discussions, an orientation document was circulated to the participants prior to the workshop. The main conclusions of the workshop and the finalised orientation paper are available¹.

On the basis of the workshop outcome the Commission conducted an extensive consultation of external experts in order to formulate recommendations related to the scope of the service, required observational in-situ and space infrastructure, the service architecture, and strategy towards implementing operational services. This Implementation Group (IG) based itself on 4 working groups (altogether around 50 experts) and met nine times between June 2007 and December 2009. The experts were tasked to federate the needs of potential users, i.e. to represent user interests. Similarly, member states were kept informed regularly on the progress of the IG’s discussions through the GMES advisory council.

The IG findings are summarized in a final report¹ containing the definition of a service scope with a detailed list of required data products in order to meet the underlying user needs together with a recommendation to initiate a future operational service.

Following the establishment of the GMES User Forum as part of the GMES operational governance, the pilot service for GMES Atmosphere monitoring together with the existing knowledge on user requirements were discussed, validated and supported by the GMES User Forum. This consultation has been based on a GMES preparatory user workshop (27/10/ 2011) followed by presentation and discussion of findings at a GMES User Forum (30/11/2011). The service scope by the IG in combination with the strategic

¹ See <http://www.copernicus.eu/pages-principales/library/implementation-groups/gmes-atmosphere-core-service/>

needs described in the workshop conclusions were acknowledged as base for the implementation of the operational CAMS.

The Commission presented for discussion at the 7th GMES User Forum on (20/02/2014) a document on the main technical and organisational aspects for the future operational Copernicus Atmosphere monitoring service. This document explicitly builds on the scientific and technological advances made during the past research and development integrated projects while at the same time acknowledges the concrete feedback from users regarding evolutions needed for the existing pilot service. The proposed transition from the pilot to operational service provision therefore foresees different phases as well as mechanism in order to ensure that the operational service remains open both to service evolution and participation. This document has been updated taking the views expressed by member-state delegates to the forum into account. The views provide high-level guidelines for the operational implementation of CAMS.

1.2 PRECURSOR R&D ACTIVITIES AND PILOT PROJECTS

As part of the building up phase of GMES/Copernicus, the findings from the IG have been used by the European Commission in order to define the scope of a call relative to establishing a pilot project for CAMS under RTD Framework Programme 7 (FP7).

As a result of the thorough FP7 selection process, a large European consortium led by ECMWF has been operating the MACC² project as a precursor of the GMES/Copernicus Atmosphere Monitoring Service. MACC started in June 2009 and ran until December 2011. It was followed by two other projects, MACC-II (November 2011 to July 2014) and finally MACC-III (August 2014 to March 2015) under FP7 and Horizon 2020, respectively, both led by ECMWF.

The main objectives of this series of three projects over more than five years have been:

- to continue the development of service value-adding chains, based on wider research finding and evolving technical capabilities and availability of satellite and in-situ observations;
- to deliver a growing range of services and products in pre-operational mode;
- to interact with users from both the public and private sectors in order to guide the developmental efforts as well as the technical interface to data and information;
- to interact more specifically with users from the policy sector at national and European levels in order to support evidence-based policy making;
- to develop outreach, training and communications activities in order to widen the audience and visibility of the pilot service.

In order to ensure that the activities serve the objectives set by the European Commission and the EU Member States, the entire life cycle of these projects has been based on the consultation of independent experts for the formulation of calls, the evaluation and selection of proposals, and the controlling during their implementation.

² MACC: Monitoring Atmospheric Composition and Climate

In order to guide the scientific and technological development with potential user needs the pilot projects included a strand of activities dedicated to the interaction with users. Thus, the pilot service for Atmosphere already iterated through the steps of gathering and analysing user requirements during its life cycle. The changing user requirements, together with the service specifications have been used to maintain a gap analysis accompanying and guiding the evolutions. The existing documentation of the pre-operational portfolio of products together with the expertise on involving users therefore provides already a good understanding of the way forward in the operations phase.

Besides user interaction activities within the pilot service, other projects have focussed on specific (potential) application areas in close cooperation with the related user categories. Examples are PROMOTE, PASODOBLE, ENDORSE, DorisNET, GRAAL, obsAIRve. Many of these projects included users in the consortium and/or concluded service level agreements (SLA) with user organisations to test and use the products. Relevant findings were continuously integrated into the pilot service.

1.3 SERVICE DOMAINS

CAMS will provide services which can be categorised into five “topical domains”, grouping data and/or information products according to their main application area. The domains are not mutually exclusive and some products can appear in different domains: domains can therefore be considered also as a “filtered” view on the products available in support of different application areas and constitute a convenient introduction to the entire portfolio. They are currently used in particular on the home page of the pilot service³. These domains are:

- Air quality and atmospheric composition: these products characterise the chemical composition of the atmosphere and provide information on greenhouse gases, reactive gases and aerosols. Products are provided at global scale for the entire atmosphere and at refined horizontal resolution over a regional domain covering the EU and neighbouring areas, including the European Environment Agency member states. The products include in particular the species relevant for EU and national legislation as well as international treaties.
- Climate forcings: several atmospheric constituents act as climate forcing agents, short or long-lived. Specialized products are provided to quantify the forcings on the Earth System, as well as information on sources and sinks of key observed greenhouse gases.
- Ozone layer and UV: information on constituents of particular importance for the stratospheric ozone layer is provided, as well as on ultraviolet radiation;
- Solar radiation: the domain covers radiation products of relevance in the context of solar energy;
- Emissions and surface fluxes: Natural and anthropogenic sources are key input data to the modelling of atmospheric composition. Besides usage for internal processing, the emission data sets are useful as self-contained product for the validation of independent emission reporting or other applications requiring emission information, especially from variable natural sources such as wildfires.

³ <http://atmosphere.copernicus.eu>

2 Functional description of the Copernicus Atmospheric Monitoring Service

An overarching principle for the design of the Service is to ensure consistency with the overall vision and development strategy of Copernicus. This implies strong requirements for coordination among different Copernicus Services to promote synergy and sharing of approaches and practices. In the case of the Atmosphere Monitoring Service, the service architecture elements flow naturally from the existing pilot service, which has dynamically evolved over the past years to fulfil the scope and users' requirements.

The functional architecture of the Service and data flow, and a summary of its main products, are presented in Figure 1. The green shaded central panels indicate the main areas of activity of the Service. The main data and information flows internal to the Service are illustrated by the green arrows while the orange arrows indicate the flow of data into the Service and the flow of products out to downstream-service providers and end users.

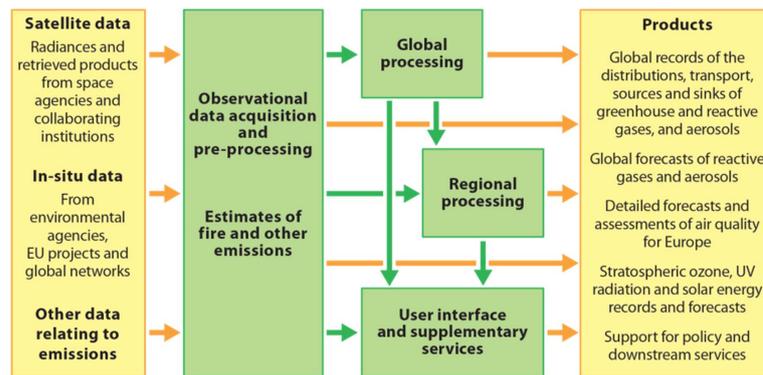


Figure 1: Architecture, data flow and products of CAMS

In the following, we discuss functional blocks which groups important areas of activities and aspects of important added value of the pilot service as it stands today and which should be given emphasis by the operational implementation in the future. Section 2.1 describes the body of tasks relative to the implementation of the budget and the technical management of the service. Section 2.2 describes the functional blocks which are specific for CAMS, while in Sections 2.3 and following activities of general nature within the Copernicus programme are described. This section does not intend to describe the solution or the architecture and consequently does not go into drawing dependencies and data flows, which are addressed in Section 3.

2.1 MANAGEMENT OF BUDGETARY AND TECHNICAL IMPLEMENTATION TASKS

The implementation of the CAMS will follow the “Indirect Management” mode in accordance with Article 58 of the Financial Regulation of the EU. The role of ECWMF

as Entrusted Entity will comprise overall management, technical management as well as engineering and development tasks.

Regarding overall management, the main foreseen responsibilities are in delivering the annual work programme plan and activity reporting. The Entrusted Entity will also procure service architecture elements and provide sound accounting, with internal control and external auditing as required by the EU Financial Regulation (see 3.1.1). Another significant element of activities will be maintaining close liaison with the European Commission and the main stakeholders of the Copernicus programme, including the other service operators, and in providing representation for the Service in European or international forums, such as the GEO.

The technical management of the CAMS will involve the co-ordination of all the engineering activities (see 3.1.2); this includes in particular the maintenance of a risk register and contingency planning regarding the critical risk areas. It will ensure liaison with related research developments, especially those funded under Horizon 2020. It will foresee and lead overall communication and outreach activities for the Service. A central responsibility will be to continuously collect and analyze feedback from the users in order to maintain requirements that meet their evolving needs. The Entrusted Entity will also contribute to training activities, which will largely be provided with the support of external partners/contractors. The Entrusted Entity will provide the first level of user support (see 3.3.6). This will be implemented by means of a help desk, with a level of service (e.g. hours, time guaranteed for a response) adjusted taking into consideration the user requirements. This help desk will benefit from being directly integrated in the existing ECMWF operational help desk, which is a very significant asset and expertise brought to the Copernicus Service. Lastly, the Entrusted Entity will maintain routine technical interaction with main observational input providers, ESA, EUMETSAT, and non-European space agencies for satellite data, EEA, WMO/GAW and the main relevant research infrastructures for in situ data (see 3.2).

2.2 OVERVIEW OF SERVICE ARCHITECTURE ELEMENTS

There are four main functional blocks of specific activities for CAMS appearing on Figure 1. The first one is relative to the acquisition and pre-processing of input data, primarily observations (from both satellite and in-situ instruments) but also ancillary data that are needed to estimate emissions of pollutants (see Section 2.2.1). The two next ones correspond to the two main modelling and value-adding chains, one focusing on the entire Earth (2.2.2) and the other focusing on a regional domain encompassing EU and neighbouring areas (2.2.3), which can be covered with a higher spatial resolution and support in particular further modelling activities for sub-regions at even finer scale as well as Air Quality monitoring and forecasting national activities. The last functional block is relative to applications processing and services and products that are built on top of the main global and EU/regional processing outputs.

2.2.1 Acquisition and pre-processing of input data

Observations are obviously at the heart of CAMS, as of all Copernicus Services. The data acquisition and pre-processing constitutes the direct interface to in-situ and space observational components.

CAMS has two sets of requirements regarding timeliness of observational data feed. CAMS components that operate on a routine daily basis need data available in near-real time (NRT), that is within a few hours after observation, so that they can be taken into account for initialization of the value-adding chains; the corresponding requirements on data quality control must be compatible with NRT and automated processing and are relatively relaxed. CAMS components that operate in delayed mode (delayed mode services, validation activities, re-analyses...) have less stringent timeliness requirements -typically availability within some weeks or a few months after observation, but the quality control must conversely be according to highest achievable standards.

Observations need to be acquired following different access modes, formats, and timing conditions (see 3.3.1 and 3.5.1). Traceable acquisition steps are needed to fill a well-defined data base serving simultaneously different processing tasks within the entire service. This includes pre-processing steps of reformatting in order to support a harmonized interface to different system components as well as quality checks and screening of usable data. The results are input data sets ready for further processing by the other service components.

The global observing system for atmospheric composition is less developed than for other application areas, such as numerical weather prediction (NWP). Besides, the Copernicus space infrastructure that will constitute the backbone of the service monitoring aspects, CAMS has a vital need to rely also on a number of satellite and in situ international research networks. Some activities are needed within CAMS to facilitate acquisition and pre-processing of this data, not only in delayed mode (which is the standard in general for such research data) but also for the NRT mode. Concerning satellite data, there is a need to support "ad hoc" NRT processing for some observations that are not routinely processed by the Copernicus Space infrastructure or more generally by international Space Agencies (see 3.8.3). It has proven effective in the pilot projects to support processing of Level 2 data for a number of products, which would not be otherwise available in NRT. It is proposed to pragmatically follow this approach during CAMS and be in position to procure ad hoc processing of data in areas where the global chemical observing system is otherwise sparse or data void. For in-situ atmospheric composition data, only a fraction of the data is operationally supported in Europe and elsewhere; these are mostly regulatory air quality surface observations. Like the pilot service, CAMS will rely on a number of research observation networks. CAMS would not support financially the acquisition of data itself, but only activities allowing their processing (quality control, format and dissemination aspects...) to meet operational requirements. It would utilize existing European and international infrastructures. These are well identified and are defined in Section 3.2 of this annex. The coordination aspects of arranging access to observation on a higher level potentially involving also other

Copernicus Services (such as agreements with providers) will be part of an overarching in-situ coordination activity, led by the European Environment Agency.

With the arrival of the dedicated Copernicus satellite missions (Sentinels) a significant positive impact on CAMS products is expected. The analysis of the impact on service quality and continuously advancing the usage of space based measurements remains important in regards of the considerable investments and in order to provide feedback for optimizing the observation infrastructure.

Apart from observations, emissions of atmospheric constituents at the surface and in altitude are an essential input to the production chains. In line with the two main production chains, emissions have to be estimated over the entire globe on the one hand and over the EU regional domain, on the other hand, at higher spatial resolution (see 3.8.1 and 3.8.2). Over the overlapping area (Europe), the consistency between the two emissions estimates, which are obtained independently have to be checked and remain consistent with the errors provided with the emissions. The estimation of emissions relies on a number of observation or assessed/reported ancillary data. When possible, NRT information, such as wildfire activities or road traffic, will be acquired in support of the daily production streams. Data available in delayed mode, such as sectorial statistical reporting will be used to regularly update the default/fixed emissions used to account for natural and human sources. Such update should in principle occur on a yearly timescale (in line with regulatory reporting in the EU on greenhouse gases and pollutants emissions). In the case of natural emissions, some processes will be modelled as a function of meteorological parameters (radiation, precipitation, surface temperature and soil wetness...) in order to be consistent with the models used to represent the atmosphere.

2.2.2 Global Processing

It is essential that the CAMS products are of highest quality internationally. Consultation with users has confirmed that quality and reliability of products is what makes Copernicus Services distinct from disparate services available from other sources. A consequence of this is that an appropriate level of developments must be maintained as part of CAMS, while tapping into wider research efforts that are supported in Europe by Horizon 2020 but also more widely national or international research findings. The final report of the IG has defined “tiers” of research and development: Tier-1 correspond to developments over a timescale of some months, requiring to work directly on the operational system and close to the operational configuration; this activity needs to be directly connected with developments on the physical/meteorological aspects of IFS and can only be done at ECMWF (see 3.3.3). Tier-2 activities correspond to development work that test and prepare evolutions, which are candidate for operational implementation. These activities will largely be outsourced to maximize uptake of research results and linkage with the relevant scientific communities. Tier-2 activities correspond to developmental objectives over timescales of one to two years and will investigate how potentially interesting developments (regarding identified user requirements) obtained elsewhere can apply in a context closer to CAMS operations; such activities are described with more details in Section 3.4. Tier-3 research aiming at riskier and longer undertakings is also essential for the medium to long term upgrade of

the system, but it will be supported by Horizon 2020 in particular and not by the operational Copernicus budget.

The global processing system based on IFS will be operated in two modes to deliver the products required by the users:

- daily/routine production for NRT analyses and forecasts with a system which will be regularly upgraded ;
- reanalysis production stream providing multi-annual consistent datasets with a frozen model/assimilation system; as it is common practice for the meteorological reanalysis done at ECMWF and in the future as part of C3S⁴, the chemical reanalysis will be continuously extended, so that the period covered extends up to the recent past weeks or months. The entire re-analysis will be reprocessed periodically every few years.

The monitoring of the different operational streams includes also the monitoring of the delivery and timeliness of expected outputs, according to the CAMS specifications based on CAMS user requirements. Activities designed to strengthen the resilience of the system to a range of operational issues will allow to maximise performance indicators in the expected range and to take stock fully of incidents and issues in order to improve continuously delivery and timeliness performance.

2.2.3 EU Regional Processing

The second main component of the production chain covers a regional domain covering EU as well as the EAA's member states. The geographical domain boundaries are: 25°W to 45°E and 30°N to 70°N. This domain is a result of extensive interaction with users during the pilot project phases and considered as an appropriate compromise allowing having an appropriate horizontal resolution. It is also based on the availability of observations and emission information at higher resolution than possible at the global scale. While this geographic domain will be kept for CAMS, solutions for user requirements that fall out of this domain will be provided based upon the global production chain.

The regional processing chain situates downstream of the global one, as it needs time-dependent boundary conditions information from it. From the start, providing an estimate of uncertainty with the regional products has been central to the thinking and development. This is a high-level requirement, given the policy implications of several of the products. The only tractable approach today to provide quantitative uncertainty on products is to have an ensemble approach, which is to use a collection of equivalently skilled system outputs to derive this information from the spread between them. Precursor activities inside and outside of the GMES/Copernicus umbrella have indicated that the most advantageous approach is to obtain this ensemble by considering different individual models of similar skill, as opposed to using several instances of a single model with different inputs or variations in the internal parameters. In addition, using a multi-

⁴ Copernicus Climate Change Service

model ensemble allows using the expertise distributed in Europe, which is strongly rooted at the national level to support national Air Quality regulatory activities. This distributed approach has proven successful in the pilot phases and will be continued in CAMS (see 3.5).

The multi-model regional processing system, similarly as the global one, will be operated in two modes to deliver the products required by the users:

- daily/routine production for NRT analyses and forecasts with a multi-model system which will be regularly upgraded;
- re-analysis production stream providing consistent annual datasets with a frozen model/assimilation system; this stream will support in particular policy applications, especially reporting duties.

As for the global processing system, Tier-1 and Tier-2 activities will be carried out as integral part of CAMS, while longer-term research will be relying on Horizon 2020 and national activities. Aspects covered by tier-2 R&D will comprise investigation of both potential improvements to the individual Air Quality assimilation and modeling systems and of ensemble processing technique that are used to derive the end-products and their uncertainty; such developments are described with more detail in Section 3.6.

Operational monitoring functions will be organised similarly as for the global system and will especially have to handle the distributed nature of the production chain. It is indeed expected that the different modelling systems contributing to the regional ensemble processing will be operated in different places in Europe. Data volumes and data transfer aspects will central to meet stringent user requirements in terms of delivery and timeliness. Best compromise will be made to meet these requirements by mitigating the horizontal resolution, the number of vertical levels and the number of individual species concentrated and provided to the users.

2.2.4 Supplementary services

Supplementary services are built on top of the main global and regional production systems. The list of such services that are delivered today in the pilot project and that will continue to be delivered under CAMS are the result of the interactions with users, as recalled in Section 1. An important aspect of these interactions was to determine how far these applications were generic enough for a range of users across Europe so that they don't fall in the category of "downstream" services, where opportunities for market developments must be maintained especially for "intermediate" users that can tailor the output of CAMS to meet the needs of their own clients.

There are four main categories of supplementary services:

- Products in support of policy users (see 3.7.1): these activities effectively add value upon "raw" data products in order to deliver information products in a form adapted to policy applications and more widely policy-relevant work. In particular, some of these products are in support of best-adapted short-term policy responses to air-pollution emergency situations (so called "green" forecast scenarios and source-

receptor calculations). Annual interim re-analyses, produced as part of the regional production, are interpreted (assessment report) and put in suitable form for facilitating uptake by national authorities in support of their annual reporting duties. Other “policy” products support longer-term policy objectives and the elaboration of international legislation and agreements.

- Solar and UV radiation products (see 3.7.2): a dedicated service line focuses on supporting the planning, monitoring, and efficiency improvements of solar energy production. It also provides quantitative information on UV irradiance for health and ecosystems downstream applications.
- Greenhouse gases surface fluxes inversions are an important component of CAMS, delivering estimates of global monthly surface fluxes of CO₂, methane (CH₄) and N₂O (see 3.7.3). These inversions are built on top of the re-analyses of these gases and they complement these. They allow monitoring the evolution in time of these fluxes, as a result of anthropogenic emissions and of the response of the Earth-System and, in particular, the vegetated surfaces.
- Climate forcings (see 3.7.4): while only aerosol direct and indirect effects were covered in the pilot projects phase, following requirements expressed by users, an extension is expected to cover also estimates of forcings from long-lived (CO₂, CH₄) and shorter-lived (stratospheric ozone, tropospheric ozone) agents.

2.3 QUALITY CONTROL AND ASSURANCE

Quality control and assurance is integral part of CAMS as of all Copernicus Services. Measures will be implemented by the Entrusted Entity in order to support documentation, evaluation and monitoring of all the aspects of the service. These activities are essential not only for the purpose of following up the implementation of CAMS by the delegating authority, but also for the benefit of users that can build their own quality management upon them.

2.3.1 Documentation

The Entrusted Entity will manage a repository for documentation, which will cover the description of the main production chains (regional, global and supplementary) and of their inputs, as well as of all the products in the CAMS portfolio. There is a direct heritage for such documentation from the pilot projects, with material online as well as in the form of deliverable reports. The Entrusted Entity will work together with its providers in order to maintain this documentation fully up-to-date and homogeneous. It will serve as a detailed reference for the users and it will also support quality check/quality control processes within the service.

For the main production chains, as well as for the products that are most widely used, the documentation will be provided in different forms that are suitable for readerships of different technical and/or scientific skills.

Concerning the products in the portfolio, standard data sheets will be maintained in order to provide a concise overview on the main metadata as well as technical details such as

delivery mechanism(s). The standard data sheets and their information contents are specified in Section 9.

2.3.2 CAMS validation activities

Validation of the products is integral part of the service (see Sections 3.3.4, 3.5.5, 3.8.4). In track from the pilot projects, these activities will have two main components: real-time and a posteriori.

On a daily basis, verification statistics between observations and analyses or forecasts will be computed automatically as part of the regional and global production chains. These statistics will be presented in the form of skill scores, available online and as part of periodic reports. Some care must be given in the interpretation of such scores, as they are affected by atmospheric variability, including for instance seasonal or weekly (emissions-related) variations. Some consideration must also be given to the representativeness of observations used in the calculations. Also, observations obtained in Near-Real-Time are often not yet fully validated. These important aspects must thus be covered in training sessions and material for users (see 3.9.6).

In addition, validation reports will be prepared on a quarterly basis. This delay of up to a few months allows including more observations than those available in Near-Real-Time and that can be incorporated in the automated production and verification processes. It allows also for going in some details into the performance of main production outputs for each quarter. The understanding and quantification of the skill of CAMS products requires indeed human expertise to assess likely causes for good or bad performance on specific episodes. Such quarterly validation reports have been produced for some years during the pilot phase, and a large fraction of the users are now accustomed to using information therein in addition to the verification skill scores produced routinely.

Given the particular importance of the Arctic (see 3.8.5) and Mediterranean (see 3.8.6) areas for Europe and the regional European climate, targeted validation efforts will be devoted to the two areas in order to assess the skill of CAMS outputs there, and to infer the significance of anthropogenic impacts in these sensitive regions.

2.3.3 Service performance analysis and reporting

The monitoring of CAMS service performance is essential. Consideration (34) of the introduction of Copernicus Regulation reads “The work of the entities to whom the Commission has delegated implementation tasks should also be measured against performance indicators. This would provide the European Parliament and the Council with an indication of the progress of the Copernicus operations and programme implementation.”

As detailed in Article 4 of the Copernicus Regulation, this reporting must include information on evolution of the portfolio and service specifications, as well as on the level of user uptake and satisfaction. It must also support and contribute to the assessment at the Copernicus programme level of the service contribution to jobs creation and economic benefit and growth in Europe. Finally, CAMS will provide

evidence of uptake of information and products for policy monitoring and development purposes at the European and national levels.

These activities will also enable the monitoring by the delegating authority of the execution of tasks by the entrusted delegated body. This monitoring will be carried out using Performance Indicators (PIs), that will follow both the performance of the delegated budgetary and technical implementation tasks on the one hand and of the service's products and outputs.

2.4 ARCHIVING

The strategy for archiving is guided by user needs and requirements. As a baseline, data products generated by CAMS should be available permanently. This default requirement comes from the requirement of traceability and reproducibility of results and findings.

However, overall budget considerations can necessitate that some of the data products are discarded after some time, if this could result in significant savings and should the European Commission agree to do so. For instance, this could be the case if some products are superseded by newer and better quality versions, while the need to have a capability for reproducing and trace-routing of issues has decreased to a minimal and acceptable level.

This requirement of availability of data implies the implementation of measures to mitigate the risk for data loss or destruction. Pragmatically ECMWF, as Entrusted Entity for the implementation of CAMS, will enforce a similar data protection policy as for its operational meteorological archive.

While products should be by default permanently preserved and accessible, user requirements and cost will guide the amount of data available immediately and with minimal latency. Costs will be mitigated by archiving older or less-accessed datasets on tape, involving thus a delay between ordering of data and their availability. Consideration of data volumes have also to be taken into consideration regarding the method for providing them to users. Requests for large data volume may thus be addressed better by means of exchange of physical archive media (tapes, hard disks...).

2.5 PRODUCT DISSEMINATION

Product dissemination will make use of existing proven solutions as well as emerging technologies (e.g. WMO Information System -WIS-, web based services...). Important requirements are an unrestrictive user registration, effective product search and quick view, easy access to metadata including product descriptions, ability to visualize datasets, regional sub-setting, and data downloading in various formats including NetCDF.

Performance indicators in terms of responsiveness, speed, capacity, search effectiveness, ease of use etc. will be collected and routinely monitored across the system. Performance monitoring and evaluation will extend to all data providers contributing to the portfolio

of CAMS. Requirements on data availability, access speed and download capacity will vary depending on the criticality of specific datasets.

A central user management system for the CAMS portal will be developed, featuring single logons, definition of user groups with various levels of access rights and restrictions. User questions, complaints and suggestions will be handled by a traceable ticket system. Performance of the user management system and user satisfaction will be measured on the basis of surveys and questionnaires. A user support function will be established to deal with user queries interactively during European working hours. This function will include a help desk at the premises of the Entrusted Entity, complemented by user support at the data provider end.

ECMWF shall coordinate with the Commission in order to ensure the interoperability with the "copernicus.eu" overall federation of dissemination services (e.g. discovery, view, registration). The Commission will work in collaboration with ECMWF and other Copernicus Service entrusted entities to define the technical specifications for the federation of dissemination services. As long as the definition of the technical specifications of the federation of services is not provided to ECMWF, it is requested to use standardised interfaces for the dissemination services (INSPIRE and OGC compliant, such as offered by the WIS). The overall aim shall be to offer to Copernicus Users a common experience while accessing Copernicus data and information.

2.6 USER INTERACTION, TRAINING AND OUTREACH

User interaction activities are pivotal in a user-driven programme such as Copernicus in order to develop the number of users, to satisfy their current needs and help them optimize their use of the CAMS products, as well as to incrementally better address their aspirations (see 3.9). At the same time, exposing users with prototype/experimental products as they become available is also a good way to accompany them through significant technological evolutions. In the end, balance between evolution driven by the needs expressed by users and evolution driven by new ideas or products proposed by providers is essential for a healthy growth of the portfolio of products.

Besides spontaneous user feedback that will be acquired via user support / query line, meetings are essential to consult and discuss with users. Experience in the pilot phase has shown that short/focused events work actually better than long but less frequent discussion opportunities. Also, organizing such events across Europe is preferred over a solution to always organize meetings in the same places. Such considerations will guide the organization of such user events where products, their uptake and experience from existing users will feature. The "user board" regrouping representatives from the main user categories, which was established during the pilot phase, will be maintained during CAMS as it is a very effective way of following in time the dialogue between providers and users. These activities will feed a register of users' requirements, which will be then analysed and acted upon by CAMS.

An effective and traceable response to error reporting will be established, to assist in the usage of products, to train users on characteristics of products, and to analyse the

evolving users' requirements. The latter will provide the base for identifications of deficiencies or gaps in the products portfolio, as well as for continuous service improvement and evolution. The responsibility to approve and modify user requirements will remain with the Commission in interaction with the Copernicus Committee and User Forum.

In order to facilitate uptake by users and to support communication activities, CAMS should support short demonstrative projects of use cases for different application areas and in different parts of Europe. Examples of successful use of products are indeed very effective to trigger interest among potential new users. Besides demonstrating the usefulness, such activities should contribute also to capacity building among users.

Given the scientific and technical nature of CAMS products, significant efforts will be devoted to training using online material but also organising large or smaller-scale training events including hands-on sessions. This can cover explanation of the methodologies used in the service chain in order to assist in the correct understanding of product characteristics and guide to appropriate usage of products. Training in applications of product such as data formats, subsequent fine scale modelling, or other user specific post processing should also assist the service uptake.

Communication and outreach activities will strengthen during CAMS compared to the situation in the pilot phase, with most of the portfolio having reached scientific and technical maturity and operational status. These activities will be well articulated with overall communications for the Copernicus programme organised by the EC as well as with communication and outreach activities of the five other services. A communications strategy will be developed in the early stage of CAMS in order to set specific objectives and to monitor progress during its implementation.

2.7 SERVICE AND INFRASTRUCTURE EVOLUTION

Service and infrastructure continuous evolution is simply vital to avoid CAMS products to become obsolete or of lower quality than other similar products that may become available from other global actors.

Evolutions will be guided by different inputs:

- user evolving requirements;
- user feedback on the current service;
- emerging policy needs and more generally request from the EC;
- recommendations from experts;
- results from research projects allowing improvement of methods or system used;
- findings from the evaluation at EC level of annual activity reports provided by the Entrusted Entity;
- review around mid-term of the 2014-2020 period;
- ...

Under overall budgetary constraint, the Entrusted Entity will maintain a rolling multi-year strategy on service evolutions, taking full stock of the above-mentioned inputs (see “Service Evolution Strategy” document in Section 3.1.2). For evolutions that can have a substantial impact on the service, the Entrusted Entity will analyse the expected benefits, costs and impact on operations. On that base, it will propose specific changes and evolutions in the annual implementation plans (activities and budget), which will be evaluated by the delegating authority.

2.8 INTERFACES

The following interfaces to activities outside of Copernicus Atmosphere Monitoring Service need to be considered in the implementation:

2.8.1 Optimizing the exploitation of space infrastructure

With the arrival of dedicated Copernicus satellite mission (Sentinels) a significant positive impact on the quality of products from the Copernicus Atmosphere Monitoring Service is expected. The analysis of the impact on service quality and continuously advancing the usage of space based measurements remains important in order to justify the considerable investments and to provide feedback in order to optimize the observation infrastructure.

2.8.2 Interfacing to value-adding activities

The service provision down to products at a European level appears to be best balance between service provision at European level and national responsibilities and expertise as well as existing and potential new commercial value-adding activities. Nevertheless, the interfacing of value-adding applications and workflows by both public and private stakeholders is of technical nature. Therefore, strong emphasis on enabling the uptake through technical modifications and user interaction remains crucial.

2.8.3 Fitness-for-Purpose

The operational service provision is expected to result in increasing request for changes and extensions directly connected to the Copernicus Atmosphere monitoring as well as across different areas of activities within the entire Copernicus programme. The entity responsible for the operational service will have to manage a user interface as part of the operational service. However, a structured process providing independent advice regarding "Fitness-for-Purpose" in particular with respect to EU policy DGs and Member states is needed. This mechanism has to be capable of timely, independent, and sound analysis of questions and request regarding the quality and usefulness of the Copernicus Atmosphere monitoring service resulting in concrete recommendations regarding all aspects of the service chain.

3 Implementation of tasks

The execution of tasks will be based on a detailed implementation plan, prepared annually by the Entrusted Entity on the basis of this technical annex and of the work programme adopted by the European Commission in interaction with EU Member States representatives. Annual implementation plans will be approved by the Delegating Authority before entering into force. These 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.

This section of the Technical Annex reflects the essential tasks necessary for effective and efficient implementation of CAMS. It provides a framework for developing the annual implementation plans and for scoping the different service elements, both executed by the Entrusted Entity and procured externally. These tasks can be grouped in management (budget implementation and technical) and service elements.

Due to the high degree of technical and scientific complexity the coordination task of the Entrusted Entity requires a strong expertise in the field of satellite data processing, Earth system modelling, and maintenance of large-scale IT infrastructure. The objective of Delegation is to involve available technical expertise within the Entrusted Entity in the implementation of the budget. This implies that the delegated body will contribute to the detailed technical specification of the Service as well as developing proposals for its evolution. Besides, an overall technical management is required in order to coordinate the distributed externalized tasks of service provision. Such overall technical management tasks are foreseen for the Entrusted Entity. The default preference will be to procure externally the service elements. However, given the nature of some tasks, ECMWF will directly provide some of the service elements, as described precisely in the following. The fraction of activities provided by ECMWF is consistent with that of the pilot project phase and a decade of collaboration at European level and through a series of competitive Framework Programme calls.

Five main phases are foreseen for the implementation of CAMS over the period covered by the Copernicus Regulation. They are illustrated below. The pilot phase projects, which will deliver the pre-operational services with funding from the Framework Programmes, are also mentioned.

		2014				2015				2016				2017				2018				2019				2020				2021			
Q		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
CAMS Phases					Initiation				Ramp-up	Phase I								Phase II								Transition							
Pilot Phases		MACC-II (FP7)				MACC-III (HZ2020)																											

Initiation: This phase will start at the signature of the Delegation Agreement. It will comprise recruitments, preparation and launch of competitive procurement calls as well as the setting up of internal organisation within the Entrusted Entity. This phase will last around 5 months.

Ramp-up: This phase will enable progressive service delivery under full operational conditions. It will comprise two parallel elements. Firstly, pursuit and completion of the competitive procurements, as well as transition to operational configuration within the Entrusted Entity and the selected external providers. Second, ensure continued provision of services in the interim period after the current end of MACC-III (31st March 2015). There will be no interaction between the two aspects, pre-operational provision will ensure service continuity to the users, without affecting the parallel competitive selection process that will select and establish the set of providers for CAMS operations. These activities will establish administrative processes corresponding to the chosen. This phase will last around 5 months.

Phase-I: Services will be running in operational mode and system upgrades will be continuously brought in order to enhance quality and system performance, guided by user interactions. Towards the end of the phase, a review and analysis of user requirements will guide the definition and evolution towards Phase II. Phase I will run until the end of 2017 and last 28 months.

Phase-II: Changes from Phase-I will be implemented into the operational set-up. System upgrades will continue to be brought routinely in order to enhance quality and system performance, guided by user interactions. Towards the end of the phase, preparations for post-2020 Copernicus activities will take place. Phase II will run until the end of 2020 and last 36 months.

Transition: A transition phase for CAMS 2014-2020 is foreseen to run during 2021. Depending on the programmatic context, the associated work will be to organise closing down of activities or transition to subsequent phases of Copernicus. A provision allowing the equivalent of full service delivery for 6 months will be reserved in the budget.

3.1 MANAGEMENT TASKS (CAMS_1000)

The role of the Entrusted Entity will comprise overall management, technical management as well as engineering and development tasks.

Regarding overall management, the main foreseen responsibilities are in delivering the annual implementation plan and activity reporting. The Entrusted Entity will also procure service architecture elements and provide sound accounting, with internal control and external auditing as required by the EU Financial Regulation. Other significant elements of activities will be interfacing with the relevant expert groups and maintaining close liaison with the European Commission and the main stakeholders of the Copernicus programme, including the other service operators, and in providing representation for the Service in European or international forums, such as the GEO.

The governance of ECMWF is based upon its existing structures, with a sovereign Council supported by Committees and a Director General with delegated powers for all operational activities, supported by a team of Directors in charge of departments reflecting the main activities and functions. These structures are governed by the ECMWF Convention and protocol and supported by detailed Financial Regulations as well other supporting regulations and policies detailed on its website. CAMS will be operated as a Third Party Activity under a set of guidelines specified by Council for this activity. ECMWF regulations, policies and guidelines will all be reviewed and amended if necessary to ensure that the additional activities required by the operation of Copernicus services are fully covered by these rules. ECMWF's governance model, administrative functions and accounting processes have been subject to a pillar review carried out on behalf of the European Commission earlier in 2014 and are in the process of being amended in order to fulfill all the required conditions for being entrusted with the budgetary implementation tasks relative to CAMS.

A Copernicus department will be established at ECMWF, with the overall responsibility for the delivery of the Copernicus services. This Department will be headed up by a Director, who will be assisted by a person in charge of the overall management of CAMS. Activities performed by the Entrusted Entity will be provided by staff employed in the Copernicus Department, but also from other existing ECMWF Departments when appropriate, for instance when the activities funded by Copernicus do not constitute a critical mass. Co-ordination with ECMWF other departments (Administration, Computing, Forecasts and Research) will be managed through a Copernicus Services Board, on which will be chaired by the Director General and will include director level representation from all departments.

3.1.1 Expenditure management tasks (CAMS_1100)

The expenditure management tasks of the Entrusted Entity will be carried out using the existing infrastructure of ECMWF as augmented by additional and specialist resources needed to ensure the effective management of the budget delegated to it by the European Commission. These tasks will cover four main areas: finance and accounting; legal and procurement services; internal audit; ECMWF staff support services.

- Finance and accounting

ECMWF has recently implemented IPSAS reporting for financial accounting and currently also operates cash budgeting in parallel. It has upgraded its cost allocation model, to support the identification of direct and indirect costs for both the ECMWF's existing and the new Copernicus activities. This system will be operated alongside the ECMWF's existing accounting system (Navision) which will be replaced in 2015/16 with a new system to fully automate the generation of Copernicus reporting requirements. Additional staff will be recruited on a phased basis in 2014/15 to meet the demand for greater transaction volumes and reporting arising from Copernicus activities.

- Legal and procurement services

The high proportion the total Copernicus services budget to be provided by third-parties means that a significant level of procurements will need to be carried out and associated contracts put in place to ensure that an effective network of service providers can be established and within the appropriate legal framework. Although there will be an initial high-level of activity to establish the network, the need for ongoing re-tendering and to manage the budgetary uncertainty through framework agreements with frequent renewals, means that there will be a consistent need for both legal and procurement services throughout the life of the delegation agreement.

Additional specialist staff will be recruited to work alongside ECMWF's existing legal and procurement resources and it is likely that the duties of these staff will indicate a high proportion of their time will be dedicated to Copernicus activities. This will be supplemented by a variable proportion of the existing staff resources to ensure that Copernicus' needs can be met at peak times and, working together they can ensure that ECMWF's and the EU legal and procurement guidelines are fully adhered to.

- Internal audit

The new model of control recently implement by ECMWF will play an integral part in providing the assurance that effective financial and other controls are in place and operational. The internal audit team, which is a combination of internal and contracted resources, will provide an ongoing assessment of the control environment and of necessity will cover both Copernicus and non-Copernicus activities as part of its overall remit. They will liaise closely with external auditors and their output will contribute to the overall risk management profile of operations at ECMWF.

- ECMWF staff support services

With a significant additional number of staff engaged at ECMWF for the implementation of CAMS, staff support services need to be scaled up accordingly. There are two main areas of staff support services: human resources and accommodation & general services. Human resources (HR) activities will be enhanced in order to support a significant uplift in recruitment activity in 2015 for CAMS. The fixed-term nature of the operational service period will require specific targeted recruitment and the existing ECMWF HR team will be consolidated to manage this activity as well as providing ongoing HR services to Copernicus Staff at ECMWF.

The additional staff requirements will necessitate the take on of additional accommodation to cater for both the additional Copernicus Staff at ECMWF as well as the higher level of visitors as well as conferences and meetings to be held within its premises. Options for increased on-site accommodation are being

examined, as well as nearby short-term office rental solutions in order to find the most adapted and cost effective solution for operating and delivering CAMS.

3.1.2 Technical management task (CAMS_1200)

The technical management of the Copernicus Atmosphere service will involve the co-ordination of all the engineering activities; this includes in particular the maintenance of a risk register and contingency planning regarding the critical risk areas.

Besides, the Entrusted Entity will constitute a service-level governance structure, the “CAMS Board” (CB), which will be set up to examine transverse issues regarding ongoing processes and activities, reporting as well as planning and service evolution. Key individuals, drawn from the leaders of the architecture elements procured externally, and the technical management provided by the Entrusted Entity will form the CB. It will meet typically on a monthly basis by teleconference, and in person a couple times per year. This board has a direct heritage from the project management boards that have been in existence during all the pilot phase. Though the relationship between ECMWF and its providers will be of a different nature during CAMS than during framework programme projects (joint partners in a consortium), it is expected that it will nevertheless help greatly in managing the interactions between the different service elements on a practical and routine basis.

Connecting actively with related (tier-3) research, especially funded under Horizon 2020, will be among the responsibilities of the technical management, in order to ensure that the latest findings are considered for the mid-term evolution of the service and that the quality of the products delivered by CAMS remain generally at the highest international level. This is especially important to support policy users, who need most accurate and up-to-date information on air quality trends and on climate forcings related to atmospheric composition changes.

ECMWF’s existing Communications team will co-ordinate the overall communications activities, working with third-party service providers to create platforms and channels to ensure timely and reliable dissemination of products and that users are fully informed and trained to make the most of the products. It will also co-ordinate the services’ presence at European and international relevant conferences, to develop publicity and educational/ training material, and to agree and monitor branding guidelines (see 3.9.7 and section 5).

A central responsibility will also be to continuously collect and analyse feedback from the users in order to maintain requirements that meet their evolving needs, as documented by mean of user interaction activities (see 3.9.4). The Entrusted Entity will also manage training activities, which will largely be provided with the support of external partners/contractors (see 3.9.6).

The Entrusted Entity will provide the first level of user support. This will be implemented by means of a help desk, with a level of service (e.g. hours, time guaranteed for a response) adjusted taking into consideration the user requirements (see 3.3.6).

The Entrusted Entity will be responsible to maintain the following technical baseline documentation:

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

User requirements will be collected in this database in a structured and traceable way, and links to entries in the Service Product Portfolio (see below) will be provided, when appropriate. The URDB, which will track all requirements emanating from a wide variety of user fora, surveys, and support panels, will be complemented by a Requirements Analysis Document (RAD) which will capture the stratification of User Requirements per domain, importance and feasibility. The RAD will constitute the basis for distilling, filtering and translating User Requirements into technical specifications for the Service. This document will therefore be formulated in a technical way such as geophysical parameter, temporal resolution and coverage, spatial resolution and coverage, data formats, time availability, expected quality, data format... The URDB and RAD will be maintained and continually updated by the Entrusted Entity assisted by the providers of CAMS_9400 (see 3.9.4), who will be in charge of user interaction activities.

Both documents will feed into the evolution of the Copernicus User Requirement Document (URD), which is maintained by the Commission with involvement of the Copernicus Committee and/or the Copernicus User Forum.

- Service Product Portfolio (SPP)

Both data and value-added products will be 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 (from the URD and the URDB), the routinely updated Requirement Analysis (from the RAD) and the existing service product portfolio, will be continually monitored and will feed into a Service Evolution Strategy (SES) document. This document will be produced on an annual basis and will provide, 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 will allow opening informed discussions on specific proposed service upgrades and extensions with the stakeholders.

3.2 SYSTEM ELEMENT : IN SITU DATA PROCESSING (CAMS_2000)

This architecture element aims at consolidating access of CAMS to a number of non-satellite observations streams that would not otherwise be entirely suitable for the service, either because of inappropriate timeliness of delivery or of non-existent or insufficient quality control at the time of dissemination. The use of data by the automated global and regional production streams, either for assimilation or verification in NRT, requires indeed a degree of preparation of the raw data as it is obtained from the measurement devices, as well as transmission of the resulting output within a few hours to the Entrusted Entity and/or some provider(s) of CAMS. These activities must be followed up in time so that the connection between CAMS and the international networks providing these important dataset remains healthy and effective.

The interaction with the EEA in its role of coordination for in situ data is not covered in this part, as it belongs to the technical management part (3.1.2). Links have already been established during the pilot project phase with the international data networks identified here. The nature of the tasks described in this session are purely of a technical (and sometimes scientific on aspect regarding quality control) nature.

3.2.1 Acquisition of ACTRIS data (CAMS_2100)

ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network, see <http://www.actris.net/>) is a European Project aiming at integrating European ground-based stations equipped with advanced atmospheric probing instrumentation for aerosols, clouds, and short-lived gas-phase species. ACTRIS will have the essential role to support building of new knowledge as well as policy issues on climate change, air quality, and long-range transport of pollutants. The ACTRIS network comprises both in-situ and remote-sensing (lidar) observing systems.

The Entrusted Entity will enter a direct negotiation with the coordinators of the ACTRIS infrastructure network (Dr. G. Pappalardo, CNR, Italy and Dr. P. Laj, CNRS, France) in order to define a work plan that will support steady uptake, preparation and automated quality control of ACTRIS data for CAMS. It is foreseen to set up a framework contract for the duration of CAMS and to define annually the detailed activities and tasks.

3.2.2 Acquisition of EEA/EIONET data (CAMS_2200)

EEA gathers observations from its Member States, building upon the EIONET partnership. The pilot projects for CAMS have been relying increasingly on data provided by the EEA in Near-Real-Time (NRT) as well as on quality-controlled data (Airbase) for re-analyses. The NRT data flow has been based on an earlier initiative from the EEA and EIONET “ozone web”, focusing especially on ozone observations. This system has been extended to cover more pollutants and, in particular, meet the needs of the atmosphere monitoring service. Experience over the recent year shows that, because of the distributed nature of the network, there is still some work to do to straighten and harmonise procedures. There are still discrepancies between the different country feeds (e.g. hours reported in local time or UTC, values integrated during a period of time

reported at the beginning or middle or end of the period...) and the support foreseen as part of CAMS will be devoted to resolving such technical issues and making sure that the automated procedures of CAMS can be entirely relying on the metadata provided with the data. Questions of data representativeness as well as instrument related issues (for PM in particular) will also be among the topics where CAMS will require some effort from the EEA and the EIONET.

The Entrusted Entity will enter a direct negotiation with the EEA in order to define a work plan that will support steady uptake, preparation and automated quality control of EEA/EIONET data for CAMS. It is foreseen to set up a framework contract for the duration of CAMS and to define annually the detailed activities and tasks.

3.2.3 Acquisition of EAN European Pollen Information (CAMS_2300)

One of the most significant recent evolutions in the pilot phase's portfolio has been to start development of a pollen forecast service. This came about during discussions with users, with the realisation that 25% of European citizens (on average) are sensitive to pollens and that a health service should thus include besides air quality information some information also on pollen. Natural particles can also be on occasions a noticeable fraction of total Particulate Matter.

EAN is a federation of privately owned networks across Europe monitoring pollen types and counts. Access to their data is essential to monitor the performance of the service, as well as to articulate communication on the forecasts for the next few days and communication on the observations. These networks are also often linked to medical doctor federations or to medical research units, which is a very important connection to investigate how pollen counts (what CAMS can forecast) relate to symptoms (what doctors observe from what patients tell them).

While such data on pollen cannot be in NRT, because of the central role played by operators in counting pollen grains and identifying the species, maintaining a close link between CAMS and EAN should help them direct effort towards more timely delivery of observations. Quality control of the observations is also a significant interest for CAMS.

The Entrusted Entity will enter a direct negotiation with the leaders of EAN at the Medical University of Vienna in order to define a work plan that will support steady uptake, preparation and quality control of EAN data for CAMS. It is foreseen to set up a framework contract for the duration of CAMS and to define annually the detailed activities and tasks.

3.2.4 Acquisition of GAW data (CAMS_2400)

GAW is the World Meteorological Organisation's programme on atmospheric composition observations, which is operated on a voluntary basis by countries worldwide. Its rationale is the need to understand and control the increasing influence of human activity on the global atmosphere. Among the grand challenges are:

- Stratospheric ozone depletion and the increase of ultraviolet (UV) radiation.

- Changes in the weather and climate related to human influence on atmospheric composition, particularly, greenhouse gases, ozone and aerosols.
- Risk reduction of air pollution on human health and issues involving long-range transport and deposition of air pollution.

The observation datasets acquired in the context of GAW are indisputably of great importance for CAMS, often providing the needed independent reference for assessing the products.

The Entrusted Entity will enter a direct negotiation with the secretariat of GAW in order to determine and define the needed actions to facilitate uptake of GAW data by CAMS, especially under Near-Real-Time conditions. It is foreseen to set up a framework contract for the duration of CAMS and to define annually the detailed activities and tasks.

3.2.5 Acquisition of IAGOS data (CAMS_2500)

IAGOS-ERI is one of the European Research Infrastructures selected on the ESFRI Roadmap 2006. It aims at establishing and operating a distributed infrastructure for long-term observations of atmospheric composition, aerosol and cloud particles on a global scale from a fleet of initially 10-20 long-range in-service aircraft of internationally operating airlines.

The data acquired by IAGOS is among the very few datasets that document the vertical distribution of key atmospheric compounds. These data are thus essential for validation purposes of CAMS products, as demonstrated during the pilot projects. IAGOS is developing capabilities for Near-Real-Time transmission of observations, following the well-proven methods used for meteorological data (AMDAR) acquisition and transmission from commercial aircraft.

The Entrusted Entity will enter a direct negotiation with IAGOS AISBL (International not for profit Association under Belgian Law) in order to define a work plan that will support steady preparation, transmission and quality control of IAGOS data for CAMS. It is foreseen to set up a framework contract for the duration of CAMS and to define annually the detailed activities and tasks.

3.2.6 Acquisition of ICOS data (CAMS_2600)

ICOS is also one of the European Research Infrastructures selected on the ESFRI roadmap. ICOS provides the long-term observations required to understand the present state and predict future behaviour of climate, the global carbon cycle and greenhouse gases emissions. Its mission statements are:

- to provide the long-term observations required to understand the present state and predict future behaviour of the global carbon cycle and greenhouse gas emissions;
- to monitor and assess the effectiveness of carbon sequestration and/or greenhouse gases emission reduction activities on global atmospheric composition levels, including attribution of sources and sinks by region and sector.

ICOS tracks carbon fluxes in Europe and adjacent regions by monitoring the ecosystems, the atmosphere and the oceans through integrated networks. These data are another essential input to CAMS work relating to greenhouse gases, including in particular the fluxes inversions (see 3.7.3).

The Entrusted Entity will enter a direct negotiation with the ICOS Head Office at the University of Helsinki in order to define a work plan that will support steady preparation, transmission and quality control of ICOS data for CAMS. It is foreseen to set up a framework contract for the duration of CAMS and to define annually the detailed activities and tasks.

3.2.7 Acquisition of NDACC data (CAMS_2700)

The international Network for the Detection of Atmospheric Composition Change (NDACC) is composed of more than 70 high-quality, remote-sensing research stations for observing and understanding the physical and chemical state of the stratosphere and upper troposphere and for assessing the impact of stratosphere changes on the underlying troposphere and on global climate.

While the NDACC remains committed to monitoring changes in the stratosphere with an emphasis on the long-term evolution of the ozone layer, its priorities have broadened considerably to encompass issues such as the detection of trends in overall atmospheric composition and understanding their impacts on the stratosphere and troposphere, and establishing links between climate change and atmospheric composition.

During the MACC-II pilot project, a companion project called NORS (Network of Remote Sensing Ground-Based Observations in support of the Copernicus Atmosphere Service) has been funded with its main goal to assess and improve the quality of the CAMS operational data products through the development and provision of customized high quality ground-based remote sensing data from NDACC.

The Entrusted Entity will enter a direct negotiation with the coordinator of NORS (Dr. M. De Mazière) in order to define a work plan that will support steady preparation, transmission and quality control of NDACC data for CAMS. It is foreseen to set up a framework contract for the duration of CAMS and to define annually the detailed activities and tasks.

3.2.8 Acquisition of in situ data from international networks (CAMS_2800)

As was the case in the pilot phase, CAMS will also rely on datasets from other international networks, among which in particular AERONET (solar radiation and Aerosol Optical Depths...) and TCCON (total columns of greenhouse gases).

A small amount of funding is foreseen in CAMS to facilitate collaboration with these networks, often managed in the US. This includes in particular travel & subsistence funds, allowing inviting the relevant experts in order to optimise usage of their data by CAMS. As opposed to the other contracts foreseen under CAMS_2000, these activities

will develop on an ad hoc basis and activities will be specified in the annual implementation plans presented by the Entrusted Entity.

3.3 SYSTEM ELEMENT : GLOBAL PRODUCTION (CAM5_3000)

The global production system and its outputs are the backbone of CAM5, delivering directly a significant fraction of the portfolio and serving a majority of the users as well as supporting the regional and supplementary services production chain. Ensuring its functioning under fully operational conditions is thus of utmost importance for CAM5 as a whole.

The approach for achieving this objective is to operate as close as possible to the way Numerical Weather Prediction (NWP) is operated at ECMWF and leading NWP centres in Europe and worldwide. NWP shares indeed many common aspects: input from in situ and Earth Observation, processing by complex numerical models on high-performance computers, time-critical delivery of outputs, and support to users in domains where life and property can be at stake. Given the three- to four- decade-long experience gained in this domain, it has been natural to follow methods and implementation practices while developing CAM5 in the pilot phase.

The global production system developed at ECMWF in collaboration with the wide European partnership involved in the pilot projects has little (if not no) equivalent worldwide. The maintenance, continuous upgrade and operation of it cannot be distributed, as the different steps involved in the production are strongly inter-connected. For this reason, this architecture element will not be externally procured, but rather be provided by ECMWF as the Entrusted Entity. The capability for the Entrusted Entity to operate CAM5 in the same environment as its operational NWP production part of its core mandate allows significant economies of scale: building from scratch an infrastructure for CAM5 with the adequate performance level would have led to much higher overall costs.

3.3.1 Data acquisition and pre-processing (CAM5_3100)

This architecture element is to acquire data relevant for atmospheric composition from a range of providers, prominently from main European and international space agencies as well as from the providers identified in section 3.2.

These data will be acquired via different technical methods (EUMETCAST, ftp...) and be pre-processed and introduced into ECMWF's operational observations database. This will make them directly accessible to the global production system. Data acquired by ECMWF as part of the core NWP production will also be accessible to CAM5 within the same observations database.

The data acquired will be continuously monitored (with resulting statistics and plots accessible to users) and staff will maintain routine liaison with technical counterparts from the observations providers in order to feedback and to signal issues as they are detected. These interactions will aim at strengthening the resilience of the system to observations-related problems (timeliness, quality...).

This data acquisition architecture element will not only serve the global production of CAMS, but will also make data available to providers in charge of regional and supplementary services production as well as to providers working on validation (3.8.4 through 3.8.6) or other providers, as justified by the tasks within their responsibility.

3.3.2 Global production streams (CAMS_3200)

ECMWF will ensure the timely running of the different global production streams: NRT (routine and ad hoc configuration in support of events and field campaigns) and re-analyses. This will be operated in the same environment as for producing ECMWF's core Numerical Weather Prediction. This is a well-proven guarantee for a high-level of service delivery performance.

While daily operations will be conducted with a system that evolves in time (though model cycles), re-analyses spanning a decade (or more) will be run with a frozen well-validated system every few years. The precise planning for running re-analyses will be developed as part of annual implementation plans as they depend upon availability of new or better datasets as well as upon the significance of upgrades brought to the modelling or assimilation systems. It is expected that at least one entire reanalysis will be run during phase I.

3.3.3 Continuous global system upgrade (CAMS_3300)

This involves integration work but also running preparatory suites before handing over to operations for trial (E-suites). These tasks will make the link between the development activities described in section 3.4 and the operational activities, focussing in particular on the data assimilation aspects. One of the major goals is to avoid model performance regression at an early stage. This work element will have the responsibility to define the implementation objectives for the next model cycles taking into account the expected performance gains (vis-a-vis user requirements) as well as the technical capabilities available and the other constraints such as timeliness.

3.3.4 Routine monitoring and verification (CAM3_3400)

Outputs from the global production will be monitored to ensure the expected level of delivery performance, guided by the RAD document. In addition, outputs will be verified against available observations and verifications statistics will be provided online and in the form of periodic reports.

3.3.5 Bulk global data services (CAM3_3500)

Several data transmission mechanisms will be supported in order to best serve the different categories of users. Besides the two mechanisms already available during the pilot phase -archive (MARS) and ftp server-, a possibility for subscribing to receive “data frames” will be offered. Data frames will be dispatched daily as they are produced in push mode. This last delivery mechanism will thus be recommended for daily users of chemical boundary conditions who require stringent time-criticality. Many Numerical Weather Prediction operational applications indeed operate with such a mechanism, which is in turn very robust and thoroughly experimented.

A range of plots and quick-looks will form part of the production, both for daily streams and for re-analyses. These graphics will populate the CAM3 website. In the mid-term, on-demand plotting capabilities will be developed and will facilitate further the exploration of global products by users.

Access to the associated meteorological data will be facilitated as much as possible, by using existing data dissemination methods and following the applicable specific data policies.

Global production outputs will be archived at ECMWF. In addition, some of the added-value production will also be archived at ECMWF (when it is not possible or cost-efficient to do at the provider’s level), while this represents lesser volume amounts. A fraction of the archive comprising the most recent and used fraction of the above-mentioned data will be available online. Another fraction will be stored on off-line tape-based systems and accessible to users with some latency, in general of a few hours and up to one day. For cost mitigation reasons, it is anticipated that not all the data produced by the global system and value-added services will be permanently archived. Should this be necessary and expected to allow noticeable cost reductions, some products could be kept only for a period of time and then be discarded. ECMWF will include in annual implementation plans proposals for discard of data, for consideration and decision by the European Commission.

3.3.6 Help desk / operational support (CAM3_3600)

A help desk with a tracking system of users’ queries and their resolution will be operated by the Entrusted Entity. Very much as it is the case in the pilot phase, a single support email/contact will be provided to users in order to respond to their questions and requests in a timely manner. A tracking system (Jira) will be operated to keep track of all requests and their processing, so that statistics can be made available as part of reporting.

At present, it is foreseen that a 24/7 support will be available for solving production computing related issues in order to inform users in case of operational problems or delays, while other questions will be addressed during European office hours and within a pre-defined maximum response time (performance target). Complex questions requiring specialised support, as for instance on scientific aspects, will be organised by the Entrusted Entity by maintaining a list of available contacts from its staff, those of its providers as well as from external experts (see 3.9.1).

The global user support will also communicate pro-actively on planned significant changes to the global production. Changes to this chains necessitating changes at the user's side will be announced at least one month in advance together with associated sample outputs (if appropriate).

3.4 SYSTEM ELEMENT : GLOBAL SYSTEM DEVELOPMENT (CAMS_4000)

The system used for CAMS global service production (CAMS_3000) is based upon ECMWF's Integrated Forecasting System (IFS). As part of precursor/pilot projects' activities, an in-line representation of atmospheric composition has been enabled in the IFS covering greenhouse gases, reactive gases as well as aerosols. The resulting system, now known as C-IFS (Composition-enabled IFS), has little equivalent worldwide and is a good example of how resources and expertise distributed across Europe could be harnessed together to set up a system otherwise beyond reach of single institutes or even single countries. Besides, C-IFS benefits directly from three decades of (and permanently on-going) research and developments on the Numerical Weather Prediction modelling and data assimilation infrastructure, and can effectively make use of observations from close to one hundred different satellite and in-situ observing systems.

The purpose of this developmental service element of CAMS is to empower the continuous upgrade of C-IFS, taking stock of the latest research developments (in the countries, in Europe and worldwide) and investigating the potential of introducing them in the CAMS global production chain by conducting tests and experiments in a context close to the operational one.

Most of this work will be conducted outside of ECMWF, as it has been the case in previous phases, with providers expected to bring topical expertise in the three atmospheric composition fields (CAMS_4100, _4200 and _4300). ECMWF will have itself a role in these tier-2 R&D activities, working in particular on transverse aspects (CAMS_4400) that support the basic modelling and assimilation infrastructure and contributing also with its own expertise to the activities.

3.4.1 Greenhouse gases aspects (CAMS_4100)

The target species for CAMS are the main long-lived observed greenhouse gases CO₂, CH₄ and N₂O. Though, in principle, representation of other greenhouse gases could be considered and introduced in the system, such evolution will rely on user requirements as well as on the observations available -for validation and/or assimilation.

A few among the main developmental areas are mentioned here, while the list of topics

cannot be exhaustive and will evolve in time as research results become available. One of the main R&D areas in this field is to account for surface sources and sinks of compounds, with emphasis is put on the interface with the vegetated surfaces and soils. The representation of this interface benefits from being fully interactive with meteorological conditions (radiation, precipitation, surface temperature and humidity, soil wetness...). The work will particularly be on the magnitude, distribution and variability of source and sink terms, which are the main responsible factor for biases in the end products. There will be a link with flux inversion activities (CAMS_7300), which provide a possibility to apply correction factors as well as to guide investigation into the main problem areas. Besides fluxes, concentrations of main long-lived gases in the lower atmosphere are determined by the dispersive properties within the Planetary Boundary Layer (PBL). Progress in the physical understanding and modelling of the PBL (and of mixing therein) is thus an important aspect to be covered. Last, characterising background error covariances is a crucial challenge for data assimilation - an area, which will gain in importance with future satellite missions that target CO₂ in particular, such as OCO2 or CarbonSat -if selected by ESA as part of the Earth Explorer programme.

There will be a competitive procurement for these activities, aiming at a coordinated group among leading active European research actors in the field of data assimilation and modelling of greenhouse gases in the atmosphere. Proven technical capabilities to work with advanced modelling tool such as ECMWF's numerical system will be also among the selection criteria.

3.4.2 Reactive gases aspects (CAMS_4200)

Reactive chemistry in the atmosphere is a fundamental process that affects atmospheric composition at large and regional/global distributions of gases (including methane, which is influenced by oxidants) and aerosols (via nucleation & condensation processes). The processes are accounted for in numerical models using so-called "chemical schemes" that represent explicitly or implicitly (in the case of Volatile Organic Compounds) the chemical and photochemical reactions active in the troposphere and stratosphere. C-IFS benefits today of three different options for this (chemical schemes from the MOZART, TM5 and MOCAGE chemistry-transport models) and such variety will be maintained in order to maintain on top fast-paced developments occurring as a result of research activities (measurements in the laboratory, spectroscopy, formation of secondary organic aerosol...). The increasing availability of computing resources is also an opportunity to make the representation of chemical species and reactions more explicit and closer to the observed reality. Data assimilation of observations of species that are short-lived is a particular challenge, as is simultaneous assimilation of observations of different species that are chemically related. There is still important work needed to bring theoretical ideas to a level that is affordable in an operational context (when timeliness matters, for forecasts in particular) and tractable on contemporary high-performance computing.

There will be a competitive procurement for these activities, aiming at a coordinated group among leading active European research actors in the field of data assimilation and

modelling of reactive gases in the atmosphere. Proven technical capabilities to work with advanced modelling tool such as ECMWF's numerical system will be also among the selection criteria.

3.4.3 Aerosol aspects (CAM5_4300)

C-IFS supports today two options for representing aerosol types, size distributions and mixing state. One is based on a size-bins approach and the other on a modal approach. Both approaches are indeed used in the scientific community as they present complementary advantages. As for reactive chemistry, the upgrade of CAM5 will rely on maintaining options for a comprehensive representation of aerosol and related processes that reflect the current scientific understanding while remaining computationally tractable. Aerosol being multi-faceted, as size, type and well as mixing state or shape affecting radiative properties, there are specific challenges in using observations from remote-sensing. The increasing availability of ground-based and satellite lidar is a very important development for the coming few years and CAM5_4300 activities must support inclusion of them in the operational production. Specific attention will be paid to the assimilation of Sentinel-3 Aerosol Optical Depth observations over sea and land.

There will be a competitive procurement for these activities, aiming at leading active European research actors in the field of data assimilation and modelling of aerosols in the atmosphere. Proven technical capabilities to work with advanced modelling tool such as ECMWF's numerical system will be also among the selection criteria.

3.4.4 Fire emissions (CAM5_4400)

In many areas, air quality is dominated by smoke during wildfire episodes. Globally, biomass burning is a significant source for various aerosols and reactive and greenhouse gases: For example, fires are the dominant source of organic matter, which is the dominant aerosol in terms of average aerosol optical depth. Fire emissions also contribute approximately 40% of the carbon monoxide emissions and the carbon emission rate of open vegetation burning amounts to about 25% of the corresponding rate due to fossil fuel consumption, globally. Since biomass burning is highly variable on all timescales from hours to decades an accurate representation of smoke in the atmosphere requires fire emission input data that is derived from observations of the actual fires.

The primary objective of these activities is to support the continuous evolution of the global fire emission service that produces accurate emission estimates from biomass burning for use in the global and regional CAM5 production systems (see 3.2.2). Additionally, retrospective fire emissions must be provided for use in reanalyses. Besides serving the purposes of the regional and global production streams, the outputs will also be delivered as products for users.

The focus of these development activities will be on improving the system with respect to accuracy, operational stability and usability. The NRT service is based on fire radiative power (FRP) observation from LEO and GEO satellites. Tasks will aim at incorporating additional FRP observations, including from Sentinel-3 when it will

become available (expected in Q1 2016). The incremental addition of FRP observations from further satellites will improve the accuracy of the emission estimates, enable better temporal resolution, and safeguard against a failure of one of the currently used satellite instruments. Conversion and emission factors will be calibrated, according in particular to the validation results (see 3.8.4) and to feedback from users.

The providers will commit to ensure that the service level requirements are met whenever scientifically and technically possible. They will collaborate with the wider scientific community as well as with related activities of the European Commission, such as the fire risk forecasting of JRC regarding in particular enabling short-term fire forecasting (in line with the forecast horizon of the global and regional production streams). Other opportunities for synergies will be sought by liaison with relevant research in particular funded under Horizon 2020. The providers will support the Entrusted Entity with defining the input satellite data products requirements for liaison with ESA, EUMETSAT, NASA/NOAA and other international agencies operating instruments relevant for this application.

There will be a competitive procurement for these activities, aiming at a coordinated group among leading active European research actors in the field of data assimilation and modelling of fire emissions. Proven technical capabilities will be also among the selection criteria.

3.4.5 Integration/transverse aspects (CAMS_4500)

This body of activities includes developments on transverse aspects of the global modelling system, especially work on coupling aspects between reactive gases, aerosols and methane as well as on representing the interactions between composition and radiation. Development work will be also devoted to the improvement of the model basic infrastructure such as data structure and modelling grids, transport and mass conservation issues and to augmenting the variational data assimilation system to handle the variety of atmospheric composition observations used by CAMS.

Data assimilation developments will specifically form part of these activities, as it is very difficult (if not impossible) to outsource significant work on such aspects. This is in particular because of the needed connection to the very large observations database (weather and composition) handled at ECMWF. The development team at ECMWF will both investigate methodological aspects and will also devote specific efforts for the assimilation (and preparation) of future Sentinels data, especially Sentinel-3, -5p and, towards the end of the period, Sentinel-4.

These activities will be carried out at ECMWF because of the specific technical expertise needed and close interaction with the wider development activities of the IFS. They will comprise also the contribution of ECMWF's staff to the developments described above (CAMS_4100, _4200, _4300). They will aim also at preparing activities "Continuous global system upgrade" (CAS_3300) by making external and internal contributions are suitably formulated for facilitating their integration in new candidate model cycles (e-suites).

3.5 SYSTEM ELEMENT : REGIONAL PRODUCTION (CAM5_5000)

This system element corresponds to the production chain that will deliver high-resolution CAM5 products over the defined European regional domain (see 2.2.3). As in the pilot phase, this chain will be composed of a homogeneous ensemble of models producing analyses, forecasts and re-analyses and their verification. As these activities constitute the core of the operational regional production, this architecture element will be procured “en bloc” in order to facilitate organisation by the provider that will be chosen of the distributed streams. This provider will be required to have considerable operational experience and of data exchanges. The individual models must be operated by the European teams that are also their main developers; this criterion has proven a very effective solution in the past to allow for model changes whenever issues were found as part of validation activities or had been reported by users.

3.5.1 Supplementary data acquisition and pre-processing (CAM5_5100)

The providers in charge of this element will primarily acquire observational data from ECMWF (see 3.3.1), but they will also acquire supplementary data over Europe directly from the data owners. This will be the case in particular for data channelled via the EEA as well as for some other in-situ data providers (see 3.2).

Data will be pre-processed (format, filtering of erroneous values...) and their representativeness will be assessed (flagging). Given the stringent user requirement to have reliable estimates of the skill of regional products as well as the fact that data coverage is relatively dense in Europe, a selection of sub-datasets will be made in order to flag some of the data for being assimilated, while other data will not be assimilated but will be used as independent data for verification purposes.

3.5.2 Regional production streams -individual systems (CAM5_5200)

Between five and ten individual models will be run in parallel in order to deliver the three different production streams of the regional production:

- on a daily basis, hourly analyses and forecasts up to +96h;
- with a delay of a few weeks (in order to maximise the number of available observations), interim re-analyses will be produced daily with systems frozen in their configuration of January 1st every year;
- with a delay of up to two years (due to the delay in getting fully validated data from EIONET Member States), re-analyses with frozen systems and only updated every few years.

All the assimilation and forecast systems must be already mature and well validated. All models will need to use the meteorological forcings from ECMWF’s operational high-resolution run, the chemical boundary conditions for gases and aerosols provided by CAM5 global production, and finally the CAM5 regional and fire emissions.

3.5.3 Regional production streams -ensemble (CAM5_5300)

The different individual model products will be centrally concentrated and processed in order to deliver ensemble products and the related uncertainty information. This will be done under strict operational conditions in order to guarantee a high-level of service delivery and timeliness -the ensemble products being the major/front-end of the regional production chain.

3.5.4 Continuous regional system upgrade (CAM5_5400)

A significant part of the work of the different providers will be to implement and test in their own models' environment the recommended developments, which will have been experimented under CAM5_6100 (see 3.6.1) and CAM5_6200 (see 3.6.2). As far as possible, this will be done by importing directly code routines (for e.g. observation operators...) but some re-coding will be also necessary, for instance for introducing new reactions or changing reaction kinetics... The fact that the providers of the regional production are the main developers of the system they operate for CAM5 is absolutely essential so that the teams can modify their system fairly easily in order to continuously upgrade and improve them. As was the case in the pilot phase, such activities provide also an opportunity for sharing European expertise on modelling and assimilation for operational air quality applications.

3.5.5 Routine monitoring and verification (CAM5_5500)

The performance targets for service delivery and for skill scores will be guided considering using the user requirements (RAD document, see 3.1.2). The providers in charge of regional production will deliver routine skill score statistics, using the well-established set of skill scores used during the pilot phase. As for corresponding activities for the global production (3.3.4), these statistics will be made available online as well as within periodic reporting documentation.

3.5.6 Bulk regional data services (CAM5_5600)

Similar data transmission mechanisms as for the global production (see 3.3.5) will be provided for the regional products. It is expected that the user experience must be very similar, if not identical, as one expects to have users of both regional and global (for instance in the middle to upper troposphere and above) products.

A range of plots and quick-looks will form part of the production, both for daily streams and for re-analyses (including interim). These graphics will populate the CAM5 website. In the mid-term, on-demand plotting capabilities will be developed and will facilitate further the exploration of regional products by users.

Access to the associated meteorological data will be facilitated as much as possible, by using existing data dissemination methods and following the applicable specific data policies.

Regional production outputs will be archived at the provider in charge of central regional production. A fraction of the archive comprising the most recent and used fraction of the above-mentioned data will be available online. Another fraction will be stored on off-line tape-based systems and accessible to users with some latency, in general of a few hours and up to one day. For cost mitigation reasons, it is anticipated that not all the data produced by the regional systems will be permanently archived. Should this be necessary and expected to allow noticeable cost reductions, some products could be kept only for a period of time and then be discarded. The provider, together by the management of CAMS within the Entrusted Entity will include in annual implementation plans proposals for discard of data, for consideration and decision by the European Commission.

3.5.7 User support for regional services (CAMS_5700)

The provider of the regional production will offer support for the regional products. In order to offer a single entry point for users' queries and requests, all requests will be received first by the global/main user support of the Entrusted Entity (see 3.3.6).

User queries that have no time-critical dimension and that the main user support can't handle directly will be channelled to the regional user support, which will then take over and address during European office hours and week days only. The regional user support will also communicate pro-actively on planned significant changes to the regional production chains. Changes to this chains necessitating changes at the user's side will be announced at least one month in advance together with associated sample outputs (if appropriate).

Regarding operational time-critical production, the provider in charge will operate 24/7 support for informing pro-actively the central help desk of CAMS as well as registered operational users and for answering queries from users that have a time-critical dimension. This will cover essentially information on the health and status of the regional production service and on measures adopted in case of temporary operational issues (incoming observational data, computing or network problems...).

3.6 SYSTEM ELEMENT : REGIONAL SYSTEM DEVELOPMENT (CAMS_6000)

Modelling and data assimilation is an active research area at the national and international level. Given the potential for applications relevant to society (health, ecosystems...), it is expected that Horizon 2020 will fund several project in this field. While such research cannot be directly part of CAMS, similarly as for the global system, tier-2 R&D activities will aim at testing and recommending the way forward for implementation in the individual modelling and assimilation systems as well as for ensemble processing and methods. This work will not necessarily be done with all the individual systems contributing to the regional production, but will make the findings and results available in a suitable form (routines...) for integration in these systems. Providers selected for these activities will liaise routinely with the teams in charge of the continuous upgrade of the regional system (see 3.5), and they should provide routines and scripts in the same environment as the regional models or system so that they may be applied with limited supplementary development efforts.

3.6.1 Regional air quality modelling aspects (CAM5_6100)

Maintaining the individual air quality modelling systems used for regional production at the best international level will require R&D to investigate closely their behaviour and performance and identify how this can be improved, working in support of (and together with) the teams in charge of developing and operating each of the operational systems (CAM5_5000).

Besides, latest international findings on the representation of key processes will be compiled and made available to regional operational teams. This will cover in particular (non-exhaustive list):

- homogeneous and heterogeneous chemical reactions, including reaction rates updates from latest laboratory and field campaign measurements;
- representation of aerosol formation and transformation processes;
- representation of dry deposition processes;
- mixing and transport within the Planetary Boundary Layer.

Tier-2 developments as part of CAM5_6100 will have to keep in scope that their implementation must be compatible with the stringent timeliness requirements for the individual regional production streams. This could require work in the area of code optimisation, scalability and portability onto new computing processors such as Graphical Processing Units or accelerators.

There will be a competitive procurement for these activities, aiming at leading active European research actors in the field of air quality model development and forecasting. Documented expertise in these areas at the international level (e.g. scientific peer-reviewed publications) as well as experience with operational activities will be among the selection criteria.

3.6.2 Regional air quality data assimilation aspects (CAM5_6200)

Data assimilation is also an area where R&D is needed before elements can be tested and implemented in the operational production system. CAM5_6200 activities should cover in particular elements that are jointly needed by all the systems, such as observation operators, approaches to best estimate background error co-variances or statistical tests, which are needed to monitor the performance and health of the data assimilation process.

Pioneering activities with new datasets that are considered for inclusion into operational data feeds will also be part of these activities. The objectives will be to test these new datasets before resources from the operational production teams are mobilised on the implementation in the different systems, effectively minimising the trial-and-error phase and facilitating a fast and efficient process.

Part of these activities will also be devoted specifically to the preparation of Sentinel 4 (as well as of MTG/IRS), in particular using Observing System Simulation Experiments.

Geostationary observations sensitive to lower atmosphere concentrations of key pollutants (NO₂, aerosol, CO and -to a limited extent only- ozone...) will constitute a game-changer for European Air Quality monitoring and forecasting due to the high space and time resolution they will offer. The challenges of accommodating and making the most of the very large data volumes constituted by the observations themselves and the associated metadata (such as averaging kernels) require indeed significant R&D activities. These have to start some years before launch, in order to ensure readiness for uptake of the data as early as possible after the instrument has been declared operational.

There will be a competitive procurement for these activities, aiming at leading active European research actors in the field of air quality / atmospheric composition data assimilation. Documented expertise in this area at the international level (e.g. scientific peer-reviewed publications) as well as experience with operational activities will be among the selection criteria.

3.6.3 Ensemble processing aspects (CAM5_6300)

A number of methods are available to derive ensemble products from the population of individual models' outputs. Some have been explored already during the pilot projects phase, but additional R&D is needed to make the most of the multi-model ensemble for the benefit of users.

Besides, these activities will explore the feasibility of Model Output Statistics post-processing methods to provide accurate forecasts in places where past time series of observations are available. A wealth of approaches are available for this: testing the most promising ones and demonstrating the potential value of adding MOS as part of the central post-processing of the ensemble will be among the objectives.

There will be a competitive procurement for these activities, aiming at leading active European research actors in the field of ensemble methods and statistical adaptation of model outputs. Documented expertise in these areas at the international level (e.g. scientific peer-reviewed publications) as well as experience in integrating new methodologies within an operational processing chain will be among the selection criteria.

3.7 SYSTEM ELEMENT : SUPPLEMENTARY SERVICES PRODUCTION (CAM5_7000)

Supplementary services are services built on top of the main global and regional production chains and providing significant added-value for the benefit of large categories of users. At variance with "downstream applications", the supplementary services are delivered consistently and homogeneously across the defined European domain or over the entire globe. They range in four categories: products in support of policy users (3.7.1), solar radiation products (3.7.2), greenhouse gases inversions (3.7.3) and climate forcings. As for all products in the CAM5 portfolio, these supplementary products will be quality checked and evaluated rigorously.

3.7.1 Products in support of policy users (CAMS_7100)

The activities within the precursor projects including close interaction with policy users (at European, national and local/city level) has led to the development of a range of “policy” products as part of the CAMS portfolio. These products are:

- interim assessment reports based on the interim re-analyses and material in support of reporting at the national level on air quality and threshold exceedances;
- assessment reports based on the reanalyses performed with validated data, to serve as a reference on the status of air quality in Europe;
- “green scenarios” that offer alternative forecasts with reduced level of anthropogenic emission, which allow assessing the effectiveness of possible mitigation measures to reduce forecasted pollution episodes;
- emissions reduction scenarios in support of future policy developments in order to assess the effectiveness of candidate measures in terms of impact upon key Air Quality indicators;
- source-receptor calculations, which allow to track the origin of the pollutants and the different contributions;
- an automated aerosol “whistle-blower” system which flags area in the world where aerosol concentrations are exceptional and may deserve attention. The system currently covers aerosol at the global scale and it is expected that such automated system would be extended to other variables and to the European domain.

The provider for these products will be selected by means of a competitive procurement, aiming at a consortium of actors with relevant experience and with a track record of supporting environmental policies in topical areas related to CAMS at the regional, national or international levels.

3.7.2 Solar radiation products (CAMS_7200)

The major goal of this element is to provide and evaluate continuously the CAMS service lines related to solar radiation. This includes global UV irradiance monitoring and forecasts, as well as global (clear sky) and multi-continental⁵ (taking into account clouds) solar irradiance databases. Time series based on an on-request access to long-term data sets and several days NRT information will be available to users, targeting particularly solar energy applications.

A high-quality system of global UV irradiance monitoring constitutes a valuable tool to provide global coverage for UV impact studies. It is equally important to have UV forecasting capabilities to produce global UV spectral irradiances for supporting health-related applications as well as applications for agriculture and ecosystems.

⁵ Europe, Africa, the Middle East and Asia as defined by the METEOSAT field of view

With regard to renewable energies, the service will meet the needs of European and national policy development and the requirements of (commercial) downstream services (e.g. planning, monitoring, efficiency improvements, integration into energy supply grids), such as those having been implemented by the ENDORSE (Energy Downstream Services, FP7) project.

Efforts will be devoted to the maintenance and continuous upgrade of processing chains with automatic error diagnostics, extending the radiation's time series service temporal coverage, testing and applying regular QC/validation procedures, intensified dealing with users, defining standards in collaboration with users how to communicate uncertainty information to users. Assessing the impact of information provided by CAMS global production (ozone, aerosol...) onto the quality of solar radiation products will be a specific area of investigation.

The provider(s) will have to demonstrate expertise in the field as well as a proven track record of delivering operational quality-controlled solar energy services.

3.7.3 Greenhouse gases fluxes inversions (CAM5_7300)

Natural and anthropogenic surface fluxes of greenhouse gases are key drivers of the Earth's climate evolution and their monitoring is essential, as reflected by user requests already in the FP projects phase. Ground-based and now satellite remote-sensing observations give a handle to quantifying these. The data provided so far by the pilot projects leading to CAMS have delivered time-series of CH₄, CO₂ and N₂O surface flux fields of high quality. Such information has been used in particular as part of the Fifth Assessment Report of the IPCC.

Activities CAMS-7300 will primarily aim at extending the time-series, while maintaining their quality at the highest international standard. Periodically, reprocessing of the whole period will be conducted in order to reflect possible improvements in spatial resolution as well as in modelling and data assimilation techniques used for the inversions. The documentation of associated errors and comparison with independent observations as well as with main competing international products will also form part of the activities.

3.7.4 Climate forcings (CAMS_7400)

Atmospheric composition changes are drivers of the changes in the Earth Climate. The effect of radiatively active atmospheric gases and particles are quantified through so-called “climate forcings”, which aim at quantifying the effect brought by anthropogenic emissions/activities on the energy budget of the Earth system. Climate forcings are both short-lived and long-lived, depending on the atmospheric residence time of the corresponding species.

In the series of pilot projects, work has been devoted to the estimation of aerosol direct and indirect forcings, based on the atmospheric composition reanalysis. These quantitative estimates have been cited and used in the last IPCC⁶ assessment report, bringing a significant contribution by considerably reducing on one of the most significant uncertainties on in our current understanding. Besides supporting continuous provision and qualitative improvements of aerosol forcings products, CAMS will support developments in support of the provision of forcings from other atmospheric compounds: main greenhouse gases, stratospheric ozone, and tropospheric ozone.

In addition, sensitivity studies will be performed with respect to known uncertainties of critical parameters that influence climate forcings.

Estimates of the aerosol direct and indirect radiative forcings will be provided every six months for the preceding six months, as it has been the case in the pilot projects. As maturity develops within CAMS, the other radiative forcings will be provided to users.

3.8 SYSTEM ELEMENT: VALIDATION AND SUPPORT TO PRODUCTION (CAMS_8000)

This service element delivers validation results for the global and regional production chains in the form of reports updated quarterly (3.8.4 to 3.8.6). These reports require significant expertise and use reference observations that are available up to a few weeks after time. They complement the statistical skill indicators that are computed as part of the global (3.3.4) and regional chains (3.5.5) and go into some details into the analysis of events of specific relevance (large-scale pollution, dust outbreaks, large wildfires...).

The other activities in this service element deliver products that are simultaneously important inputs for the service chains and also part of the CAMS portfolio and available to users. These include global and European regional gridded surface emissions at the appropriate horizontal resolution, as well as retrievals of satellite data which would not be otherwise available in time for being taken into account in the production while they constitute a significant addition to the observations already routinely acquired.

⁶ Intergovernmental Panel on Climate Change

3.8.1 Global anthropogenic emissions (CAMS_8100)

Emissions are an essential input to the main production components of CAMS. Besides being a key ingredient to the service chain, they are also an important product in their own right.

The goal of these activities is to provide distribution of anthropogenic and biogenic surface emissions in direct support of CAMS global production chain. The target horizontal resolution will be of the order of 50 km, in line with the target resolution of global analyses and forecasts. A model for temporal variations monthly, weekly and hourly scales will be provided together with the annual totals for main gas and aerosol emitted species and for main activity sector. Natural emissions will also be provided either in the form of fixed (pre-calculated) values or of an emission model with meteorological and surface parameters as an input. Extrapolations to provide estimates for the current year based on recent trends will be provided. The global emissions dataset will cover the entire period of the re-analyses that will be carried out during CAMS (CAMS_3200).

The emissions data developed within the pilot projects will be evaluated through detailed comparisons with all other datasets publicly available. The providers will have to ensure that the products are fit-for-purpose and satisfy the common understanding in the international community. International collaboration on emissions will be strongly encouraged to insure that the dataset produced as part of CAMS is of highest international standard, liaising in particular with future modelling exercises of the IPCC.

While methods to derive emissions will be (essentially) bottom-up, there will be also work aiming at utilising the results of inverse modelling for the optimization of the emissions of key observed primary gases and aerosol. Emission increments will be gathered and analysed, and the robustness of the results will be assessed. The optimized spatial distributions will be compared to those provided by inventories, and they will contribute to the assessment of the quality of the CAMS global emissions dataset. The consistency with the regional emissions of CAMS will also be an area of work and investigation.

3.8.2 Regional anthropogenic emissions (CAMS_8200)

Emissions of gases and particles for air quality purposes requires finer horizontal resolution as well as realistic profiles for temporal variations for the main activity sectors (traffic, industry, energy production, agriculture...). This architecture element will provide gridded emission data at a resolution of 0.1° or finer over the domain (25°W to 45°E; 30°N to 70°N). This dataset will comprise emissions data for the key gas phase and aerosol compounds. A minimum of 8 pollutants must be included: NO_x, SO₂, NMVOC (including the split into individual species for each country), NH₃, PM₁₀, PM_{2.5}, CO and CH₄. In order to allow for sensitivity studies and policy supplementary services such as “green scenarios”, these emissions must be stratified into headline activity sectors defined in the Standardized Nomenclature for Air Pollutants (SNAP).

The period covered by the emissions will be initially 2003-2009 and subsequent years will be added at the pace of one additional year every year, as reporting and ancillary

activities data become available. Besides the yearly totals, the providers will deliver monthly, weekly and hourly temporal profiles (depending on pollutant, country and activity sectors) so that hourly gridded emissions can be easily derived.

Natural emissions will also be provided at a matching spatial resolution, either in the form of fixed /pre-calculated values or of an emission model with meteorological and surface parameters as an input.

Continuous development activities will aim at keeping methodologies at the best international level, focusing especially on areas (former Eastern European countries) and activity sectors (shipping) where uncertainties on current estimates are thought to be largest. Developments towards estimation of recent emissions based upon proxies will also be an important focus of development activities, in order to provide up-to-date emissions information for modeling activities. Last, there will be investigations of the possibility of providing emissions forecast for some sectors, taking into account meteorological conditions, traffic or other activities related data.

3.8.3 Ad hoc satellite data processing (CAMS_8300)

These activities will be supported in the framework of CAMS on an ad hoc basis and for certain products, which are not available from EUMETSAT (including O3M-SAF), ESA (CCI...) or national space agencies. Funding for processing data in NRT will be provided for parameters that are not well covered otherwise or from research instruments that have significantly better sensitivity than existing/available products.

3.8.4 Global and regional a posteriori validation (CAMS_8400)

Every product in the CAMS portfolio needs to be accompanied by validation information, which is essential for users. This implies an automated production of verification/validation data and plots, and updates of validation reports with fixed, 3-monthly, intervals in order to ensure routine documentation of the quality of the services. Due to the central role of validation in the service as a whole, this architecture element is in interaction with all the other elements and will stimulate CAMS-wide common methods and practices facilitating the validation work. Validation work will be externally procured and it is expected that the validation and assessment work will be independent from the development and production work. Organised in that way, service validation activities have proven effective and useful to users during the pilot projects.

The main outputs of the activities are a series of 3-monthly validation reports for the near-real-time global products. The report primarily documents the performance of the daily operational analyses and forecasts of reactive gases and aerosols. In parallel to the main operational suite (so called "o-suite") a few alternative model versions/configurations are run daily, and the performance of the o-suite analysis is also compared to these other model configurations. Apart from these core validation reports, validation activities will also provide a set of plots and quality monitoring statistics, which will be integrated in the CAMS website and will be easily accessible together with the products from the CAMS catalogue. Such information might not be available immediately because of the availability of observations, but they will be refreshed daily lagging behind present by a few days up to a couple weeks.

Validation activities also play an important role in the global o-suite update procedure, which will occur between one and two or three times per year. Before replacing the o-suite, a new system setup is tested in parallel, the so-called “e-suite”. At the end of the e-suite test period, the providers of validation will produce an e-suite evaluation report. Based on this report the decision can eventually be made to replace the o-suite by the Entrusted Entity and following discussions with the CAMS board (see 3.1), as appropriate. Validation activities will similarly assist the Entrusted Entity in charge of running reanalysis by evaluating outputs from preliminary tests carried out with the intended datasets and the chosen assimilation and model configuration. In both case, this is intended at minimising the risk for skill degradation when the Near-Real-Time or reanalysis production systems are upgraded. While changes have in general mixed effects on all the outputs and parameters, it will be checked that the evolution is at least overall neutral.

Validation efforts will also be directed towards the evaluation and documentation of the CAMS re-analyses, using especially independent observations. As it had been the case for the evaluation of previous atmospheric composition reanalyses performed during the pre-operational phase, this will take the form of comprehensive reports, targeted at providing users or potential users of the re-analysis products with an overview of its main strengths and weaknesses. These reports will be made available on the CAMS website and be delivered in conjunction with the release of the re-analysis datasets.

Besides the main focus on global product validation, there will also be activities to validate regional products above the surface using profile observations (sondes, aircraft and ground-based remote-sensing). This will complement the characterisation of multi-model skill performed routinely with surface observations (3.5.5) and is especially of value for users who intend to use the CAMS regional outputs as boundary conditions for higher resolution applications over countries or large conurbations.

The providers of validation activities will reserve some resources for the development of new skill scores and scoring methods which are relevant for users, the introduction of new validation datasets and the analysis of significant events affecting atmospheric composition.

3.8.5 Validation over the Arctic area (CAM5_8500)

Specific validation activities will be devoted to the evaluation the quality of CAM5 products as well as to the estimation of the environmental impacts of changing atmospheric composition in the sensitive Arctic area. The work will cover reanalysis datasets, as well as daily analyses and forecasts.

3.8.6 Validation over the Mediterranean area (CAM5_8600)

Specific validation activities will be devoted to the evaluation the quality of CAM5 products as well as to the estimation of the environmental impacts of changing atmospheric composition in the Mediterranean area. The work will cover reanalysis datasets, as well as daily analyses and forecasts.

3.9 SYSTEM ELEMENT : USER INTERACTION, TRAINING AND COMMUNICATIONS (CAMS_9000)

This architecture element will take care of the interfaces between CAMS and its users. Specialised user support activities will follow up on user requests that go beyond the scope of what the basic user support can handle directly. Specialised global and regional data services will be offered in order to facilitate discovery and access to CAMS data for certain categories of users requiring advanced plotting and/or data extraction tools. Interactions with users (events, update of key user requirements and feedback documentation...) will be managed externally, giving a degree of independence and of transparency to these very important activities for CAMS.

Last, training and communication will be organised by the Entrusted Entity, which will procure external support as needed for the organisation of events or of outreach campaigns, for the preparation of glossy material as well as for procuring professional support whenever needed. Management at the Entrusted Entity level will allow a very close connection with CAMS management.

3.9.1 Specialised user support (CAMS_9100)

Such request may range from scientific questions to small developments to solve technical issues or to facilitate the use of products. Sometimes, the answer may thus require significant work. CAMS management will channel requests where appropriate and will procure best adapted answer/solution. Likely, this will be done using the current providers (add-on to the contract) for the sake of response time, but competitive procurements will be considered if the amount of work and budget is

3.9.2 Specialised global data services (CAMS_9200)

Bulk data services will be delivered as part of the global production (see 3.3.5). These data services are best adapted for frequently returning users, users that have timeliness requirements or users who require to access large volumes of data. Though several delivery mechanisms are offered, this data access mode requires a minimal technical environment as well as, possibly, some training.

First time users, users that want to explore datasets or users lacking the adequate technical environment need simple tools to visualise and extract pieces of data. In the pilot phase, prototype OGC WCS/WMS tools have been developed to serve such categories of users.

Online data visualisation and post-treatment tools adapted for CAMS global outputs will be offered, with an emphasis put on ease-of-use on the user end. It is expected that only a sub-set of the global production will be accessible this way (e.g. most widely used datasets and requests by users) and with no stringent timeliness requirement. Time-critical delivery of data will be handled by bulk data services as part of the global (3.3.5) and regional (3.5.6) production chains.

Developments in the area of offering associated cloud-computing capabilities will be explored. Use of these would not be funded by CAMS centrally but by the users who could prefer to use such solutions, rather than their own in-house computing capabilities.

3.9.3 Specialised regional data services (CAMS_9300)

Similar services as those offered for global data products will be offered for regional products covering the area domain (25°W to 45°E; 30°N to 70°N). Best technical solutions might be somewhat different for handling global or limited-area datasets, so a separate procurement call will be issued for regional data services. However, some degree of consistency between the specialized global and regional data services will be ensured, for the benefit of user experience.

3.9.4 User interaction activities (CAMS_9400)

These activities will manage the relationship between CAMS and its users, with as overarching goal to ensure the best possible use of the products by the users and to their full satisfaction. In more detail the objectives are to:

- facilitate understanding of the requirements of users with a focus on operational user needs, and other Copernicus services and translate these user requirements into specifications for the core service lines and the supporting upstream processing, product delivery and web facilities;
- organise user feedback loops (via online forms, during project meetings and at the project level via a User Advisory Board);
- coordinate all specific Service Level Agreements (SLAs) and maintain standardized SLA template(s) for the different types of CAMS products and users.

This will be achieved by gathering and analysis of user requirements and of user feedback and response to service evaluation campaigns (via e.g. questionnaires). The user interaction tasks will continue seamlessly from the pilot phase. Users can provide valuable feedback on the service via two routes: by directly interacting with it as part of the interaction activities described here and via the national representation to the Copernicus User Forum, which monitors overall progress and “fitness-for-purpose” of the Services. Such parallel users’ feedback structure appears appropriate to represent interests of both activity areas, on the one hand, and of national strategies on the other hand. The CAMS user board established during the pilot phase in order to represent the key applications areas and categories of users will be instrumental in facilitating this.

The providers of user interaction activities will coordinate the integrated user feedback and the Service Level Agreements signed between the service and users who have specific requirements, beyond the general service provided as a baseline. They will maintain the User Requirements Database (URD) and work together with the Entrusted Entity (see 3.1.2) to update the Requirement Analysis Document (RAD). All user requests will be tracked in the URD in order to provide full traceability of the original user expression; actions taken as a result (introduction in the RAD under a new or an already existing item, quick fix or addition on the CAMS website...) will also be listed in the URD.

3.9.5 Use cases (CAMS_9500)

Illustrative and exemplary “use cases” are very effective element to support training and communication activities. They can also be an incentive to develop CAMS products usage for new “downstream” applications with potential for development or in European areas where CAMS products are less used, in particular Eastern and Southern Europe.

The Entrusted Entity will organise regularly competitive calls for short projects (12-18 months duration) aiming at demonstrating use cases. These calls will be defined in the annual implementation plans.

3.9.6 Training activities (CAMS_9600)

As part of the pilot projects, training activities have been organised in support of the continuous uptake of the atmosphere monitoring services. Based upon this experience, it seems appropriate to organise three different streams of training activities:

- on-line material in the form of Questions & Answers, videos and other elements such as illustrative “use cases” (see 3.9.5) facilitating the understanding of products detailed scientific and technical documentation
- Summer schools organised on a bi-annual basis. A first summer school was organised during the MACC-II project in June 2013. Training was provided for around 60 participants (selected from around one hundred candidates) and feedback was in general very good, recommending holding future similar events.
- smaller-scale and shorter events organised across Europe, in order to facilitate participation of potentially interested users at minimal cost for them (limited time and travel). This will be based on the format of the events organised by the “Copernicus user awareness and uptake” FP7 project, with a duration of one to two days including general presentation as well as “hands-on”/practical sessions. These events will be used as a tool to strengthen the user base in countries and areas of Europe where user uptake is less well established.

The Entrusted Entity will oversee the organisation of these three components, procuring external support whenever possible and appropriate. Experts from the providers of services will in particular be invited to give lectures or deliver training sessions, providing first-hand insight into the products, their generation and some of their possible uses. Feedback from users/participants of these trainings will be used as guidance for continuous improvement.

3.9.7 Communications (CAMS_9600)

The Entrusted Entity will procure a number of services and activities to implement the communication strategy for the service itself and as a contribution to wider Copernicus communication effort. This strategy is briefly outlined in section 5. Some specialist staff will be recruited to work alongside ECMWF’s existing Communications team with a significant proportion of their time dedicated to Copernicus activities. This proportion of their remuneration as well as the cost of specific bought-in services will be directly chargeable to Copernicus as well as a Communications service charge, calculated on the basis of time spent by Communications staff on these activities.

The nature of the procured services and items in support of communication activities will be diverse. Whenever possible, these will be competitively procured. A non-exhaustive list is:

- organisation of events in Europe;
- production of glossy material and goodies in support of communication activities;
- the elaboration and filming of videos;
- the preparation of articles about the service from media experts;
- interviews and surveys;
- support to communication strategy by specialised companies.

Detailed planning of expenses will be made annually, as part of the detailed implementation plans.

4 Indicative Cost Breakdown

[commercial-in-confidence]

5 Communication

5.1 PLANNING AND MAIN COMMUNICATION MEANS

An overall communication plan for the Copernicus programme is developed and maintained by the Commission. The plan will identify communication activities to be implemented on programme level, including some key messages, the intended target audiences, as well as communication channels and means.

The Entrusted Entity will be asked to support the activities identified in this plan as far as the entrusted tasks are concerned in close coordination with the Commission.

Taking the Copernicus Communication Plan into account the Entrusted Entity will during the first year of the operational service implementation draw up a Communication plan for activities to be implemented on service level. This plan will be coordinated and agreed with the Commission. A revision and update of the communication plan is foreseen on annual basis.

This plan will identify in particular major events, where participation of the Copernicus programme would be advised and specific preparation (booth, video, printed matter, other material) would be needed.

Any further communication by the Entrusted Entity on the delegated tasks is welcome but should be coherent with the overall Communication strategy and acknowledge the Copernicus programme and the European Union funding.

5.1.1 Website

The CAMS website will be integrated with the Copernicus portal, as "atmosphere.copernicus.eu", where the current pilot service MACC-III website can already be reached. The Common visual identity will be respected. The web site will comprise as a minimum:

- general information on CAMS;
- the complete technical reference documentation, product portfolio, data sheets, product specifications;
- OGC-compliant catalogue on the products;
- daily plots and quick-looks for the main products lines and, in the mid-term, on-demand plotting tools;

- access to the products for authenticated users according to access rules per user category for each individual product. Authentication shall support (in the mid-term) single logon across the Copernicus programme in the mid-term.

Coordination with the Commission and/or its contractors responsible for the Copernicus portal / web site will be done as appropriate.

5.1.2 Printed matter

The Entrusted Entity shall draw up and provide brochures, flyers and data sheets on the CAMS and its products. These should follow the Copernicus visual identity and should be approved by the Commission before going to print.

5.1.3 Conferences and workshops

Further, outreach activities on service level will be carried out specifically to the related scientific and professional communities.

5.2 STRATEGY AND OBJECTIVES

Building upon the corresponding activities during the pilot projects phase, a fully developed communications strategy for CAMS will be formulated by the Entrusted Entity for the start of phase I and it will be updated annually. This section outlines the approach that will be followed. This communications strategy will aim to signal a direction of travel leading from the Service's mission to its vision.

CAMS's mission is to monitor and analyse the composition of the atmosphere in near-real-time as well as retrospectively to provide daily forecasts of global atmospheric composition and European air quality to policy makers, businesses and citizens at large.

The vision is that of a society where citizens and businesses are equipped with reliable and timely information on atmospheric composition, allowing them to make informed societal decision, including on health and energy.

The overall aim of CAMS is to be the authoritative source for atmospheric composition information at European level and beyond. Its key messages are:

- CAMS is part of Copernicus, the European Union (EU) flagship programme on monitoring and observing the Earth;
- CAMS is monitoring the Earth atmosphere's changing composition using satellite and in-situ observations;
- CAMS is a collective effort funded by the European Union to help EU citizens to live well within the limits of our planet;
- Air quality awareness can save health and life;

- CAMS promotes and delivers a society where citizens (EU and beyond) can protect themselves through free access to timely and reliable information on atmospheric composition.

Correspondingly, the first communications objectives will be to:

- build upon the successful image established during the pilot phase in order to develop and enhance the profile of the Atmospheric Composition Service, and the overall Copernicus Services programme;
- be and be seen as a collaborative effort;
- ensure smooth flow of information to users and other stakeholders to support business continuity over the transitional period.
- create platforms and channels to ensure timely and reliable dissemination of products;
- further-develop the users base of the pilot phase;
- ensure users are fully informed and trained to make the most of CAMS' products.

The strategic approach for CAMS will sit within and be developed in collaboration with Copernicus overall communications strategy, in liaison with wider communication activities of the European Commission, with the European Environment Agency (as several topics covered by CAMS will support the agency in fulfilling its mandate) as well as with national ministries and relevant national agencies in the EU. An important round of initial consultation will allow defining the articulation between the different communications strategies as well as how responsibilities and activities will be shared. Throughout the period, such liaison will be maintained to keep in sync and agree evolutions.

Among the first steps will be also to consolidate the definition of the primary and secondary audiences for CAMS, again based upon the experience gained during the pilot phase. The initial strategic approach will approach focussing on making the service visible to its primary audiences in the first instance, and potentially / partially to its secondary audience. This will be achieved by ensuring *inter alia*:

- continued presence at European and international relevant conferences, allowing CAMS to be seen by and engage with its stakeholders;
- to work with EC/DG-ENTR and the other five Copernicus Services to develop joint material, so CAMS can be understood as a standalone programme, but also and very importantly within its bigger context;
- to work to agree branding guidelines involving and guarantying visibility of Copernicus and CAMS logo as and where appropriate;
- to create educational / media material with the areas covered by atmospheric composition and its impacts on society at large. This experience has been done at a very limited dimension in the pilot project phase and has proven disproportionally successful; in this instance, and as a first step, we would recommend the development of a series of material matching different audience

types, which could start with: video footage; monthly 'round-up', highlighting key figures of news items of the week; fact-sheets and success stories.

6 Monitoring Provisions

The objectives and principles supporting monitoring provisions are described in section 2.3.3. Reporting duties of the Entrusted Entity will comprise information on service performance, including the management tasks.

ECMWF will operate performance monitoring activities to support the follow-up of the programme by the European Parliament and Council. The definition of PIs will be based on the experience acquired by ECMWF during the pilot phase, as coordinating entity for the projects. While there is a need for some indicators to be followed consistently in time in order to track progress over the years, the set of indicators is expected to evolve slightly in time, following feedback and insight gained from user interaction activities and from the different review and advisory processes established by the delegating authority.

In practice, the implementation plan of each year will specify the set of performance indicators that will be monitored over the next year and will be reported in the account of activities. For the procured service elements, the contracts will include timely provision of PIs to the Entrusted Entity, who will compile them for reporting.

Here, first suggestions of categories of PIs for the performance of service provision are mentioned:

- statistical comparison with observed quantities;
- Technical quality of service as measured by timeliness, number of interruptions, response time for troubleshooting;
- uptake of products by users as measured by number of users, number of views via web portal, number of downloads of products or volume downloaded;
- user satisfaction, as measured periodically for instance by means of user surveys.

Indicators will also be defined in for the implementation of budgetary tasks, including the completion of procurement processes and, subsequently, the running of contracts.

7 Reporting Provisions

A set of reporting guidelines together with templates will be agreed between the EC and ECMWF in line with the reporting provision of Article 21 in the Delegation Agreement with the objective to optimally organize the reporting work during the duration of the agreement.

8 Procurement Provisions

[commercial-in-confidence]

9 Product Portfolio

Discovering, exploring and accessing quickly and easily to products, metadata and related information is essential for the continuous uptake of CAMS products by users.

One of the significant developments in the pilot phase, compared to precursor research and development precursor projects has been to develop a “catalogue”, as a central tool for the atmosphere service webpage. This catalogue is available at <http://atmosphere.copernicus.eu/catalogue> and receives good feedback from the users. It offers a capability to browse the entire portfolio, with search tools based upon selection of criteria or text input. Once a product is selected, a window appears and provides key characteristics on the product as well as links to plots, data and verification/validation and background information. The interface links actually with a number of servers distributed in Europe, which host the datasets which are not produced by ECMWF.

The Entrusted Entity will maintain this catalogue access but will also pay attention to and contribute to new developments foreseen as part of the early stages of the Climate Change Service (catalogue and broker system). In the end, it is foreseen that the search, discover and access/order tools that will be developed will be used by both services. This will facilitate the experience of users of products from different Copernicus Services.

A key element to the catalogue as it is operated today is to maintain a unique reference specifications and metadata database for all the data and information products in the portfolio. This reference database is used for search in the catalogue, for producing documentations on the products (specification documents...) and for enabling interoperability via e.g. the WMO Information System. This ensures that all information related to the products remain in sync, whatever the access method. This method has proven useful indeed to avoid conflicting or obsolete information in the documentation relative to the products. The Entrusted Entity will maintain this database on-line, up-to-date and permanently accessible.

The products in the CAMS portfolio will be delivered by the entrusted entities and its providers and will reside on a number of servers distributed. In general, data will be stored where they are produced:

- products from the global production streams will be accessible at ECMWF
- products from the regional production streams will be accessible at the provider in charge of generating ensemble products

The storage of other products, including in particular value-added ones, will be discussed between the Entrusted Entity and their providers by finding the most adapted (regarding

ease of access and use for users) and cost-effective solution.

A complete list with metadata describing the nature of the data products has been compiled by the existing pilot service and distributed to the GMES User Forum in February 2014⁷. The description within this Technical Annex concentrates on defining a perimeter for the service activities and the following list thus only lists below the main service lines. This is to allow flexibility in order to enable response to user request without the necessity to amend this technical annex which forms part of the legal base. Details will therefore be specified in service specification document, which will be maintained on the basis of the above-mentioned reference database. The main product lines in the CAMS portfolio are listed in the next table.

Updates	Coverage	Products
Daily	Global	Analyses for aerosol and gases
Daily	Global	Forecasts for aerosol and gases
Daily	Global	Forecasts of UV radiation
Daily	Global	Biomass burning emissions
Daily	Global	Aerosol automated alerts
Daily	Europe	Multi-model air quality analyses
Daily	Europe	Multi-model air quality forecasts
Daily	Europe	Forecasts of “green scenarios” (emissions mitigation) for air quality
Seasonal	Europe	Multi-model pollen forecasts
Annual	Europe	Multi-model air quality re-analyses
Annual	Europe	Air quality assessment reports
Multi-annual	Global	Re-analyses for aerosol and gases
Multi-annual	Global	Monthly surface fluxes for CO ₂ , CH ₄ and N ₂ O
Multi-annual	Global	Direct and indirect forcings from aerosol
Multi-annual	Global	Biomass burning emissions
Multi-annual	Global	Surface clear-sky solar irradiation
Multi-annual	Global	Anthropogenic emissions
Multi-annual	Europe	Anthropogenic emissions
Multi-annual	Meteosat disk	Surface solar irradiation
On demand	Europe	Source-receptor calculations for air quality
Ad hoc	Global	Satellite retrievals (data produced with CAMS funding)

A standard product-level specification document will be available for all the CAMS data or information (assessment reports...) products. Such documents will be automatically generated from the reference product specifications and metadata archive.

In track with the product specification document available as part of the pilot project (e.g. MACC-II, deliverable D153.4), the relevant main information about each product will be gathered on a short standard “data sheet”. This product data sheet will be available next to each product in the catalogue and will summarize the key technical aspects. It should also enable to quickly identify documentation for users requiring deeper understanding of the used methodology as well as to the relevant results from quality monitoring. Since a single product might be required to be provided by different access types or characteristics, the data sheet could include a list of delivery mechanisms.

⁷ UF-GMES-2014: Title: "Copernicus Atmosphere Monitoring: Technical aspects of operational implementation"

The following table describes a minimal set of attributes that will be used to populate the data sheets. The presentation of the data sheet will be specified by the Entrusted Entity at the beginning of Phase I. Evolutions to this presentation or to the attributes included will be brought as part of annual reporting and planning by the Entrusted Entity, based on the requirements and feedback from the users or from the delegating entity.

Attribute	Comment
Product name	As listed in the catalogue/portfolio
Product family	One or more among: "Air quality and atmospheric composition"; "Climate forcings"; "Ozone layer and UV"; "Solar radiation"; "Emissions and surface fluxes"
Description	Short descriptive text (5 lines maximum), including type of processing (analysis, forecast, re-analysis...).
Status	One among: "In development"; "Experimental"; "Pre-operational"; "Operational".
Parameters or Species	List of geophysical or chemical parameters
Geographical coverage	"Global" or latitudes/longitudes defining a limited area
Horizontal coordinate	°, km, spectral...
Horizontal resolution	Numerical value
Vertical coverage	Text or list of values
Vertical coordinate	Hybrid sigma-P, altitude, column... (more than one possible)
Temporal coverage	Length of available product archive
Time resolution	Time steps of series within product
Update frequency	Frequency of production of product (daily...)
Documentation	Link(s) to background information on product, methodology...
Quality	Link(s) to information of product quality (on-line statistics, reports...)
<i>List of delivery mechanisms</i>	
Delivery mechanism (#)	Dissemination channel/method: ftp (push/pull), WCS/WMS...
Formats available (#)	Technical name: GRIB2, NetCDF, KML, ASCII, PDF...
Dissemination time (#)	Time when product is available relative to update frequency
Availability target (#)	Annual mean percentage of dissemination of product in time