**Part B**

Proposal title:

Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring

Proposal acronym:

GAIA-CLIM

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Type of Action:

**Research and Innovation Action**

Call identifier:

H2020-EO-3-2014 Observation capacity mapping in the context of Atmospheric and Climate change monitoring

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List of beneficiaries:

|  |  |  |  |
| --- | --- | --- | --- |
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|  | Belgian Institute for Space Aeronomy | BIRA | Belgium |
|  | Consiglio Nazionale delle Ricerche | CNR | Italy |
|  | Met Office | MO | UK |
|  | BK Scientific GmbH | BKS | Germany |
|  | Koninklijk Nederlands Meteorologisch Instituut | KNMI | Netherlands |
|  | European Centre for Medium Range Weather Forecasts | ECMWF | International |
|  | Max-Planck Institute for Biogeochemistry | MPG | Germany |
|  | Ilmatieteen laitos | FMI | Finland |
|  | University of Bremen | UBremen | Germany |
|  | Tallinn University of Technology | TUT | Estonia |
|  | Global Climate Observing System | GCOS | International |
|  | National Physical Laboratory | NPL | UK |
|  | University of Bergamo | UniBergamo | Italy |
|  | EUMETSAT | EUMETSAT | International |
|  | National Oceanic and Atmospheric Administration | NOAA | USA |
|  | Helsingin yliopisto | UH | Finland |
|  | Lille University | USTL | France |
|  | Karlsruhe Institute of Technology | KIT | Germany |
|  | California Institute of Technology, Jet Propulsion Laboratory | NASA JPL / CALTECH | USA |

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# EXCELLENCE

## OBJECTIVES

The advent of the European Commission's Copernicus Programme marks the start of a new era in Earth Observation for Societal Benefit. The operational capability being implemented for Copernicus will deliver a step-change in the end-to-end chain that begins with observing our environment by satellite-based and in-situ-based instruments, and ends with providing end-user services to decision-makers and the general public. By bringing the full chain within one programme, Copernicus provides the co-ordinated framework to exploit scientific and technological innovation and to translate these into usable high-quality information tailored to diverse sectors of society.

Hence a critical component of the Copernicus framework is the provision of high-quality observational datasets from satellites. It follows that these need to be calibrated and validated to standards that enable them to be used with confidence for applications across a broad range of sectors. In turn, this requires ancillary datasets from in-situ and other sources that need to be of high-quality and sufficient quantity to robustly characterise sensor performance and radiative transfer modelling to provide confidence in the satellite data. For the purpose of validation, established practice from space agencies and other satellite dataset providers is to make substantial use of satellite-to-satellite intercomparisons combined with in-situ datasets and supplemented by datasets from operational numerical weather prediction and/or reanalyses (which blend observations with model forecasts taking into account the uncertainties in both). Few, if any, of these comparator measures constitute fully traceable estimates. The challenges to rigorous satellite data characterisation are therefore formidable because without traceability in the comparator measures there is ambiguity in any comparison.

The objective of the Consortium is to play a full role in supporting Copernicus by establishing prioritized needs for further observational capacity targeted at providing the required step-change in satellite calibration and validation capability. The principal aim is to lead to a step change of availability of, and ability to utilize, truly reference quality traceable measurements in support of satellite data characterisation. *It is only if robust uncertainty estimates are placed on the ground-based and sub-orbital data and used in the analysis that unambiguous interpretation of EO sensor performance can occur.* The magnitude of the challenge requires a co-ordinated approach to both establish the strategic approach and define specific campaigns. The Consortium has drawn together leading stakeholders from the relevant communities, who provide the necessary experience to fulfil the objectives. Specifically, the consortium has been chosen to bring together scientific, technical and leadership expertise in high-quality in-situ and sub-orbital observations, gap analyses, modelling, satellite operations and data assimilation, and in setting the priorities for the EO community at the European and global levels.

Robust EO instrument characterisation is about significantly more than simply where and when a given set of EO and ground-based / sub-orbital measurements is taken. It requires, in addition, quantified uncertainty estimation for the reference measurements and an understanding of additional uncertainties that accrue and increase the apparent discrepancy between measured data sets through mismatches in spatio-temporal sampling, given the complex spatial and temporal variability of the atmosphere, spanning spatial scales from sub-kilometer to synoptic scale and timescales from seconds to decades. It also needs user tools, which include statistical tools and the integrating capabilities afforded by data assimilation systems to enable users to access and work with the data in a ‘virtual observatory’ setting. Mapping of capabilities in a spatio-temporal sense will be undertaken by GAIA-CLIM for several of those atmospheric, land and oceanic ECVs, which are measured by EO instruments. Subsequent measurement mapping and the development of a range of tools will be undertaken with a focus on the atmosphere as a test case, in particular fundamental geophysical (temperature, humidity) and composition (long lived greenhouse gases, ozone and its precursors, aerosols) parameters of importance to environmental monitoring across a broad range of time and space scales. Comparisons and mapping to EO data will be undertaken at both level1b (radiance) and level2/3 (parameter) data levels. There is a particular focus upon the value of high quality reference / benchmark measurement capabilities to long-term sustained high-quality characterisation of space based EO sensor performance to maximise their value for climate applications. Tools and capabilities developed in this project with direct application to atmospheric ECVs defined by GCOS (among which a few are linked as well to e.g. air pollution and air traffic management) will be built in such a way as to be extendable in future to further atmospheric parameters and the terrestrial and oceanic domains.

Below, key objectives are outlined in terms of scientific progress, technological developments and outreach. The unique objective identifiers (Sn, Tn and On where n is numeric character) from these lists are then used in Section 3.1 to link each task in each Work Package (WP) back to one or more of these key project objectives.

Scientific objectives:

1. Define and document a tiered system of systems approach to EO measurements characterisation, based upon measurement properties, in order to categorize ground-based and sub-orbital measurement capabilities.
2. Map in geographical space, and in terms of temporal congruence with EO measurements current and known future ground-based and sub-orbital capabilities into the system of systems framework for several of those atmospheric, oceanic and terrestrial GCOS ECVs that are measured from space.
3. Provide quantified uncertainty estimates on atmospheric measurements for temperature, water vapour, carbon dioxide, methane, ozone and precursors (nitrogen dioxide, carbon monoxide, formaldehyde), and aerosols with a focus on provision of reference quality measurement uncertainties that are traceable to recognised measurement standards.
4. Understand and quantify the metrology of data comparisons, including additional uncertainties that result from measurement mismatches in both space-time and in terms of the measurement volume and interval, using a suite of multi-dimensional descriptions with explicit physics, statistical methods and data assimilation systems. Some metrology errors are irreducible; others can be reduced by optimisation of the measurement settings.
5. Integrate into data assimilation systems (global atmospheric models and reanalysis systems) the ability to utilize reference measurements so as to enable traceable characterisation of EO data.
6. Perform a Cal/Val gap analysis based upon geographical coverage, measurement capabilities / characterisation, user needs, technological impediments and opportunities, and national and international measurement strategies and governance.

Technological objectives:

These technological objectives, taken together, form the basis for a ‘virtual observatory’ that will allow users to undertake data analysis and visualization with the aim of making the use of ground based and sub-orbital reference measurements a routine and integral part of EO instrument characterisation.

1. Development of mapping tools to enable visualization of observing capabilities.
2. Development of software tools that are extendable to quantify comparison uncertainties associated with space-time differences in sampling and smoothing of atmospheric structures and variability.
3. Development of the ability to use reference quality measurements in a data assimilation framework to provide a robust data assimilation tie-points assuring traceability.
4. Development and population of match-up database of satellite measurements with reference measurements including measurement uncertainties and comparison uncertainties, and diagnostics from data assimilation systems.

User outreach objectives:

1. To demonstrate to a wide audience (including satellite agencies, industry, and applied scientists) how reference measurements can be used to underpin the calibration and validation of EO data.
2. Systematic consulting of the satellite and modelling end-user communities.
3. Stakeholder meetings and canvassing throughout the project lifetime.
4. Provision of software tools under a creative common licensing system.
5. Provision of a graphical interface mapping tool of observing capabilities.
6. Provision of collocation match up database and associated graphical user interface tools for reference quality observations for a number of atmospheric ECVs.
7. Presentations by consortium partners at international meetings and papers in the peer reviewed literature to promote partnership with the consortium.



## RELATION TO THE WORK PROGRAM

The proposal is in response to call EO-3-2014 ‘Observation capacity mapping in the context of Atmospheric and Climate change monitoring’. The use of ground-based and sub-orbital observations to characterize space based EO measurements is critically dependent upon adequate understanding of the comparator measurements and the effects of irreducible differences in match-ups due to measurement scales and sampling. Without such understanding the EO instrument characterisation problem becomes ill-posed in that any mismatch found cannot be attributed in an adequate manner either to the satellite measurement, the comparator measurements, or the method of comparison itself.

Error-free measurements of environmental parameters do not exist, so it is necessary to fully understand, to the extent possible, the measurement uncertainties. Fully *metrologically-traceable* measurement understanding, where an unbroken chain exists to community agreed measurement standards, is only possible for that restricted subset of the global observing system where such traceability is an objective of the network. Networks such as GRUAN, NDACC, GAW, TCCON, AERONET, and EARLINET and several European Infrastructures such as ACTRIS, ICOS, IAGOS and EUFAR, which also contribute to these global networks are examples. For these networks and similar measurement programs substantive expertise and measurement heritage exist to enable a thorough understanding of both the basic measurement and its subsequent processing to enable robust uncertainty quantification.

For measurements undertaken for most of the observing network legacy measurement standards, proprietary methods, black box software processing or necessary reductions in quality to meet cost requirements mean that only indicative uncertainties can be estimated. These remaining measurements and their uncertainties are useful for characterisation of spatial behaviour and short-term characterisation but by their nature do not greatly aid in long-term sustained EO instrument characterisation necessary to assure long-term climate applicability of EO measurements.

The proposed project will develop appropriate methods to map reference quality comparators onto EO measurements. It will document gaps in the current observing system and all aspects of measurement uncertainty mapping, and propose strategies to address these including recommendations regarding future funding of surface and sub-orbital observing capabilities to meet long term EO comparator needs. Finally, it will develop tools to aid end users through a ‘virtual observatory’.

The members of the consortium are uniquely positioned to ensure access to several high quality ground-based and sub-orbital global measurement networks and consortia, which is a requirement to enable global buy-in. The members of the consortium are also involved in international bodies and committees fostering the establishment and promotion of best practices in EO, in Cal/Val and in infrastructures in the framework of the GEOSS implementation and Copernicus services. To further assure that the tools developed in the project are widely disseminated and applied by the broadest range of users possible, significant support for stakeholder meetings and a highly international science advisory panel form an integral component of the project. Many of the tools that will be produced will be of applicability to a broad range of users interested in environmental monitoring applications of EO data across multiple space and time scales.

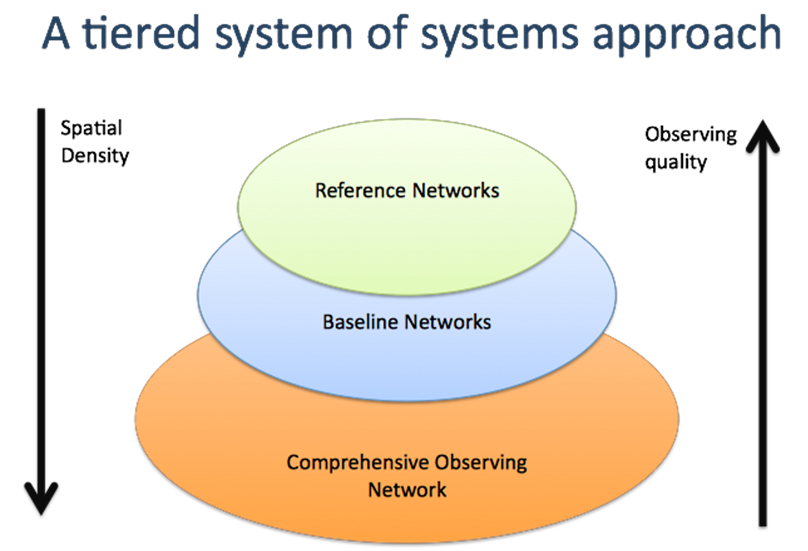
## CONCEPT AND APPROACH

### Overall Project Concept

The Global Climate Observing System (GCOS) and Group on Earth Observations (GEO) have defined a system of systems approach recognizing a desired hierarchy of measurement capabilities. Such an approach acknowledges that due to the cost and effort involved, the best measurements can only practically be made at a limited number of locations, but also that there is scientific value in all types of measurements for different purposes. To date, generally a three-tiered approach has been put forwards (e.g. [Seidel et al., 2009]; Figure 1):

* Reference (benchmark) networks constitute measurements of the highest quality attainable with robustly quantified uncertainties. GRUAN, NDACC, TCCON and ACTRIS amongst others are example networks / infrastructures that measure many of the atmospheric state and composition variables of interest to EO characterisation studies, including – but not limited to - ECVs. They generally consist of collections of remote sensing and in-situ observational capabilities that measure in a complementary and/or redundant manner. Aircraft measurements made by EUFAR partners amongst others (most notably NOAA and NASA aircraft) provide airborne measurements of similar quality but tend to be campaign-mode based.
* Baseline networks constitute long-term capabilities made in a sustained manner employing accepted best practices. An example is the GCOS Upper Air Network (GUAN). They are intended to characterize regional behaviour but lack robust uncertainty quantification and / or measurement redundancy capabilities.
* The remainder of the comprehensive observing system consists of measurements that provide rich spatial detail but by necessity are not of the highest quality or redundant and may, typically, have a shorter period of operation or answer to non-monitoring needs such as airport / aircraft operations or agricultural forecasting. The comprehensive observing system includes space-borne remote sensing capabilities but for the purposes of this call as these are explicitly the target data to be characterized a distinction is made between EO data and other aspects of the comprehensive network henceforth.

If fully resourced and managed in a coordinated manner a tiered system of systems set of capabilities would enable rigorous EO data characterisation for multiple posited applications. Reference quality measurements would enable robust quantification of the surface, column and profile characteristics in a sustained manner at a handful of sites. Baseline measurements would provide a sufficient ground-based network of measures of sufficiently high quality to characterise long-term geospatial stability. Finally, the comprehensive observing system would provide the necessary spatial detail to verify spatial details of satellite derived fields. These ‘standing’ capabilities could be regularly supplemented by campaign data consisting either of additional short-term measurement capabilities at existing sites, additional short-term high quality sites, aircraft measures or a mixture of all three. For example IASI was validated, in part, by a set of aircraft measurements collocated with high quality in-situ station measurements. The reality today is that aspects of such a system of systems approach exist, but it is incomplete, poorly coordinated at national, European and global scales, and the degree of completeness and maturity varies geographically and by variable of interest, such that the full value cannot be realized for EO measurement characterisation. This project aims to move us substantively towards such a more complete system.



**Figure 1**. Modified from Seidel et al., 2009 providing an indication of a tiered system of systems approach.

Geospatial mapping of in-situ and sub-orbital parameter measurement capabilities will be carried out for a range of atmospheric, terrestrial and oceanic Essential Climate Variables (ECVs) that are measured from space (Table 1). This mapping will include an analysis of the extent of temporal mismatch for those ground-based measures which do not operate in continuous mode such as balloon borne measures (which frequently are taken at nominally 00 and 12Z daily and are very rarely made more than 4 times daily) or FTS measurements (which require a clear line-of-sight to the sun).

|  |  |  |
| --- | --- | --- |
| **Atmospheric** | **Oceanic** | **Terrestrial** |
| **Temperature** | Sea Surface Temperature | Snow cover |
| **Water vapour** | Sea Surface Salinity | *Fraction Available Photosynthetic Absorption of Radiation* |
| **Carbon dioxide** |  | *Spectral albedo* |
| **Methane** |  | *Leaf Area Index* |
| **Ozone** |  |  |
| **Aerosols** |  |  |
| ***Carbon Monoxide*** |  |  |
| ***Formaldehyde*** |  |  |
| ***Nitrogen Dioxide*** |  |  |
| VOCs |  |  |
| Black and brown carbon |  |  |

**Table 1**. Those ECVs and additional variables for which capabilities will be classified in a system of systems approach and mapped in GAIA-CLIM. Bolded variables will, in addition, be further analysed in terms of measurement uncertainty mapping under WPs 2-5. The full list of GCOS ECVs is available at <https://www.wmo.int/pages/prog/gcos/index.php?name=EssentialClimateVariables>. Note that three atmosphere and three land variables in italics are considered under the QA4ECV project, which GAIA-CLIM will realize synergies with. The three atmosphere parameters that overlap will be considered in GAIA-CLIM only in so far as aspects not already covered under QA4ECV exist. For any areas of overlap GAIA-CLIM will make use of QA4ECV outcomes to avoid any redundancy of effort.

In depth measurement mapping which requires, in addition, an assessment of measurement uncertainty and measurement mismatch uncertainties will be limited to a subset of ECVs for which metrological understanding is mature and measurements are made under pre-existing global network governance structures as a proof of concept (bolded in Table 1). The methodologies demonstrated will serve as a model for additional atmospheric, oceanic and terrestrial ECVs and tools will be developed in such a manner as to be extendable to these.

The focus is on developing tools by which to effectively map high quality measurements with robust uncertainties onto satellite measures to enable unambiguous long-term EO instrument characterisation (Figure 2). Recourse will be made to metrological and statistical tools as well as data assimilation systems to enable this mapping. Open access user tools will be developed to enable match-up databases and visualizations. Numerous previous studies have highlighted the benefit of comparing reference measurements in the *observation space* of the satellite instrument (often, *top-of-atmosphere radiances*). There are good scientific reasons for this: the unique solution offered by a forward radiative transfer calculation gives a cleaner comparison of satellite and reference measurements and avoids the ambiguity that is inevitable in inverse calculations (retrievals). Hence although the project will characterise capabilities geographically by measured parameter / constituent subsequent work will consider the cal/val problem in both geophysical parameter and satellite observation (e.g. radiance) space. As such, tools are to be made available both in parameter (level2/3) and radiance (level1b) space, and taken as a whole will result in a ‘virtual observatory’ facility for end-users to be able to characterize EO data quality for a broad variety of application areas.

Overview_ImageGrouped.tif

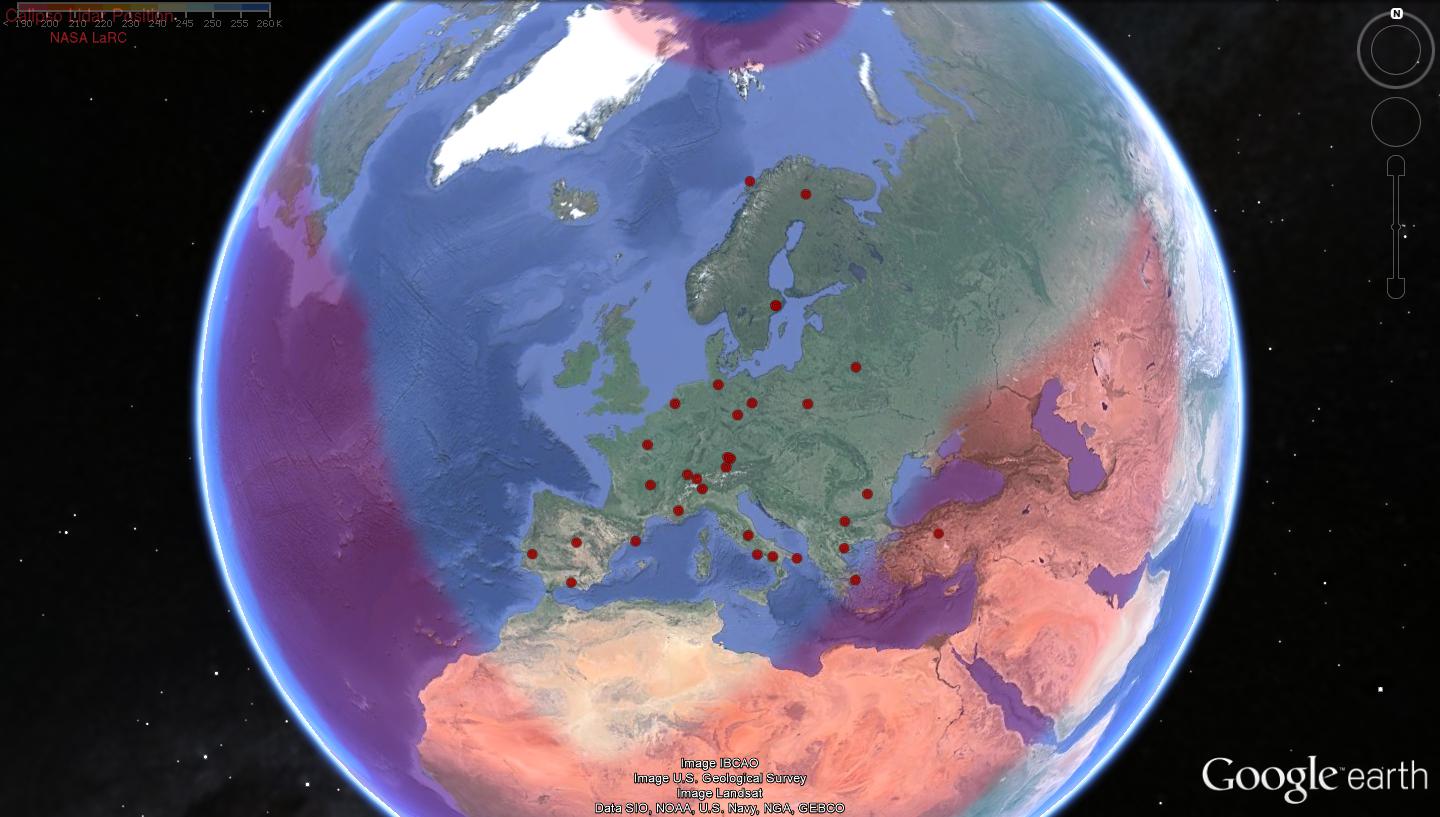
**Figure 2**. Pictogram representation of overall project scientific structure. See text in Sections 1 through 3.

### Overall Approach and Methodology

#### Geographical capabilities mapping

The Global Climate Observing System (GCOS) has for over 20 years articulated the need to monitor ‘Essential Climate Variables’ which have been designated as those atmospheric, oceanic and terrestrial parameters and species necessary to understand global and regional climate changes [Bojinski et al., accepted]. Given their broad community acceptance it is proposed to consider a subset of atmospheric, oceanic and terrestrial ECVs (Table 1) that are either currently capable of being measured from space or envisaged in funded future missions. Climate monitoring requires establishment and archiving of accurate, long-term records of the ECVs. A sufficient global coverage of surface-based and sub-orbital measurements is required to fill in knowledge gaps and to ensure a full exploitation of satellite data over a global scale. A key first step is geographical mapping of existing and planned ground-based and sub-orbital observing capabilities in the context of a system of systems. The choice of system of systems framework will be documented, with preference given to using pre-existing classification schema. Capabilities will be assessed against a set of pre-determined criteria such as data completeness, data timeliness, measurement frequency, measurement archival, measurement quality, measurement understanding, measurement traceability, and funding sustainability that may help informed decision making by end-users and highlight gaps. These criteria would build off of e.g. work undertaken under the CORE-CLIMAX and QA4ECV projects to define in as objective a manner as possible key facets of the data maturity / suitability. The resulting recommended classifications and classification tools will be used as a basis for subsequent geographical measurement capability mapping.

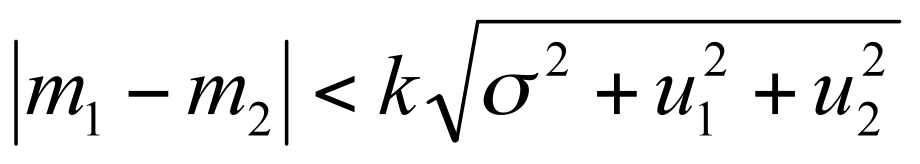
For each measurement type (e.g. reference, baseline, comprehensive) current capabilities shall be mapped and documented, among others in terms of geolocation, vertical range and atmospheric state, but also in terms of vertical and horizontal footprints and sampling of atmospheric variability and structures. As well as mapping where, for periodic measurements (such as balloon-borne measures), when they are taken will also be mapped in terms of EO orbits. Update information on satellite missions will be provided by the Committee on Earth Observation Satellites (CEOS) through the living CEOS EO Handbook directory maintained on the CEOS website (<http://ceos.org>), which contains information on instrumentation, target parameters and orbital configurations. Access to further details, particularly on future missions, will rely on well-established contacts with the CEOS Virtual Constellations, the CEOS Carbon Task Force and the CEOS GHG Task Force. Particular attention will be paid to current and planned Copernicus Sentinel missions, including the specifics of polar orbiting (Sentinel-5p and -5) and geostationary (Sentinel-4) missions.

**Figure 3**. Mock-up of potential mapping facility outputs. Here EARLINET - GRUAN lidar stations are shown within the composite FOV of the G-11, G12, MTSAT, FY2C, MET-7, MET-9 Satellite Imagery.

Based upon mapped and documented capabilities and understanding of intrinsic variability across a range of space and time scales gaps in our target subset of ECVs (Table 1) will be identified and prioritized according to objective criteria defined along with end users. Different variables will require different capabilities and, therefore, different criteria. For example, to characterize well-mixed LLGHGs while requiring numerous data points still requires fewer data points around the world than do ozone and water vapour in the upper troposphere, which are more spatio-temporally heterogeneous. This capability would also be assessed against the need to validate EO measures over multiple scene types (water, ice, various land surfaces), particularly for variables close to / at the surface where surface emissivity, albedo and orography complicates clean interpretation of returned radiances across broad swathes of the e-m spectrum. These analyses would constitute a key first component of an over-arching gap analysis. The problem will be tackled using both modelling experiments and geospatial statistical techniques, which are complementary and will assure confidence in the resulting findings and recommendations.

#### Formalization of the comparison of EO and ground based and sub-orbital reference data

To be useful for long-term characterisation of EO data, characterisation of the comparators is a necessary pre-requisite to avoid ambiguity in interpretation. Use of poorly understood comparators is as likely to inhibit as enable a characterisation of the long-term space-based sensor performance. For reference quality measurements robust and traceable uncertainty estimates are a necessary requirement [JGCM, 2008, Immler et al., 2010, WMO/BIPM, 2010]. Many near-surface composition measurements such as the Keeling curve for Carbon Dioxide already have such uncertainty estimates but columnar composition measurements and geophysical measurements often do not [Hartmann et al., 2013, Box 2.1]. Building off of the GUM [JGCM, 2008] and other literature, Immler et al [2010] outlined how to develop uncertainty quantification for GRUAN products and their comparison with other measures with a basic requirement of an unbroken measurement processing chain with all identified uncertainties reduced to the extent possible through modifications in measurement methodology, and then quantified. Mathematically:



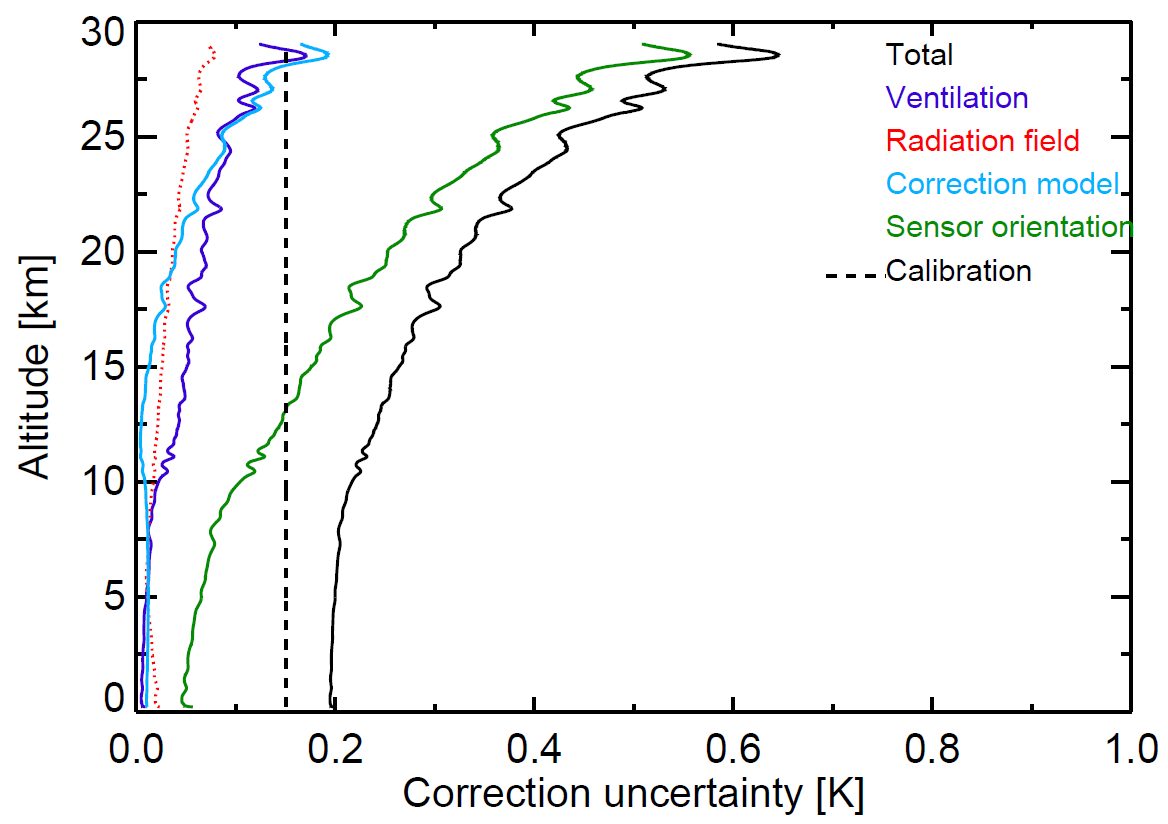
(eq. 1)

Where m1 and m2 are the best-estimate measurements from (in this project) the EO instrument and the comparator respectively, k is a coverage factor, σ is the uncertainty that results from mismatches in measurement time, measurement footprint and measurement volume, and u1 and u2 are the quantified uncertainties in the EO and comparator data. The two measures are deemed consistent within their recognised uncertainties if the coverage factor, k, is <2. To employ such an approach it is assumed that the desire is to ensure that EO data consistently performs within its specified design range, which can therefore be used as the value for u1, but remaining variables on the right hand side of equation 1 require explicit quantification.

For the remainder of the project, work will largely focus upon the use of reference tier measurements made under the auspices of existing networks and a subset of atmospheric ECVs (bolded in Table 1) for which metrological understanding of the measurements is most advanced. The rationale for choosing reference-quality observations is that these tend to be made at ‘super-sites’, which represent rich clusters of both instrumentation and measurement expertise. In particular at such locations each ECV tends to be measured redundantly. For example temperature profile information may be available from a radiosonde, a microwave radiometer and a Raman lidar. This redundancy provides an increased degree of verisimilitude in the data being used as the reference. Similar multi-measurement platform capabilities with similar maturity of understanding exist for the remaining ECVs, which form a focus of the project measurement mapping analyses.

#### Quantifying Uncertainty in comparator measurements (u2)

Currently reference quality measures consistent with Immler et al., 2010 exist solely for a subset of the measurements of interest such as some of the GRUAN radiosonde network (Figure 4, Table 2, top section). Many measurements in high quality global networks and European infrastructures come close and would require relatively little effort to ensure traceability and robust uncertainty estimation. Work will be required to extend the reference measurement quantification approach to additional types of instrumentation, to enable an expanded suite of long-term sustained reference data series that are robustly tied through an unbroken chain of traceability to SI or accepted standards. The project involves support for reference quality processing development for a subset of instruments of interest that cover the target atmospheric variables (Table 2 lower section). The tools developed and lessons learned will make extension to other instruments and variables in the future easier.

**Figure 4**. Example uncertainty quantification in a radiosonde temperature profile ascent using GRUAN processing procedures following Immler et al., 2010 [Ruud Dirksen, GRUAN lead Centre, pers. Comm., to shortly be submitted to AMTD]. The underlying profile is processed in a traceable manner to recognised SI standards.

Baseline measurement capabilities constitute existing long-term measurement networks. By their nature these measurements should be relatively well understood and may well have been quantified through numerous intercomparison campaigns such as periodic intercomparisons under the auspices of CIMO or similar bodies. Work will be undertaken to create realistic estimates of potential uncertainties in these measurements.

Remaining measurements from comprehensive networks would need to have best understanding uncertainty estimates appended. These may be manufacturer specifications, expert judgement or some other basis as deemed appropriate.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Instruments / programme | T | q | CO2 | CH4 | O3 | Aerosols | CO | HCHO | NO2 |
| Pre-existing / already in process on GAIA-CLIM timescales | | | | | | | | | |
| Radiosondes (RS92 and various others) |  |  |  |  |  |  |  |  |  |
| Frostpoint hygrometer sondes |  |  |  |  |  |  |  |  |  |
| Ozonesondes |  |  |  |  |  |  |  |  |  |
| QA4ECV project (various instruments) |  |  |  |  |  |  |  |  |  |
| Planned in GAIA-CLIM | | | | | | | | | |
| Lidars |  |  |  |  |  |  |  |  |  |
| Microwave radiometers |  |  |  |  |  |  |  |  |  |
| FTIR / FTS |  |  |  |  |  |  |  |  |  |
| UV/visible spectroscopy |  |  |  |  |  |  |  |  |  |
| MAX-DOAS/Pandora |  |  |  |  |  |  |  |  |  |
| GNSS-PW |  |  |  |  |  |  |  |  |  |

**Table 2**. Summary of pre-existing / funded for development reference quality data streams and those additional instrument types which will be developed under GAIA-CLIM. For each measurement type the GAIA-CLIM core target ECVs (Table 1) which are covered are highlighted. GNSS is commonly termed GPS.

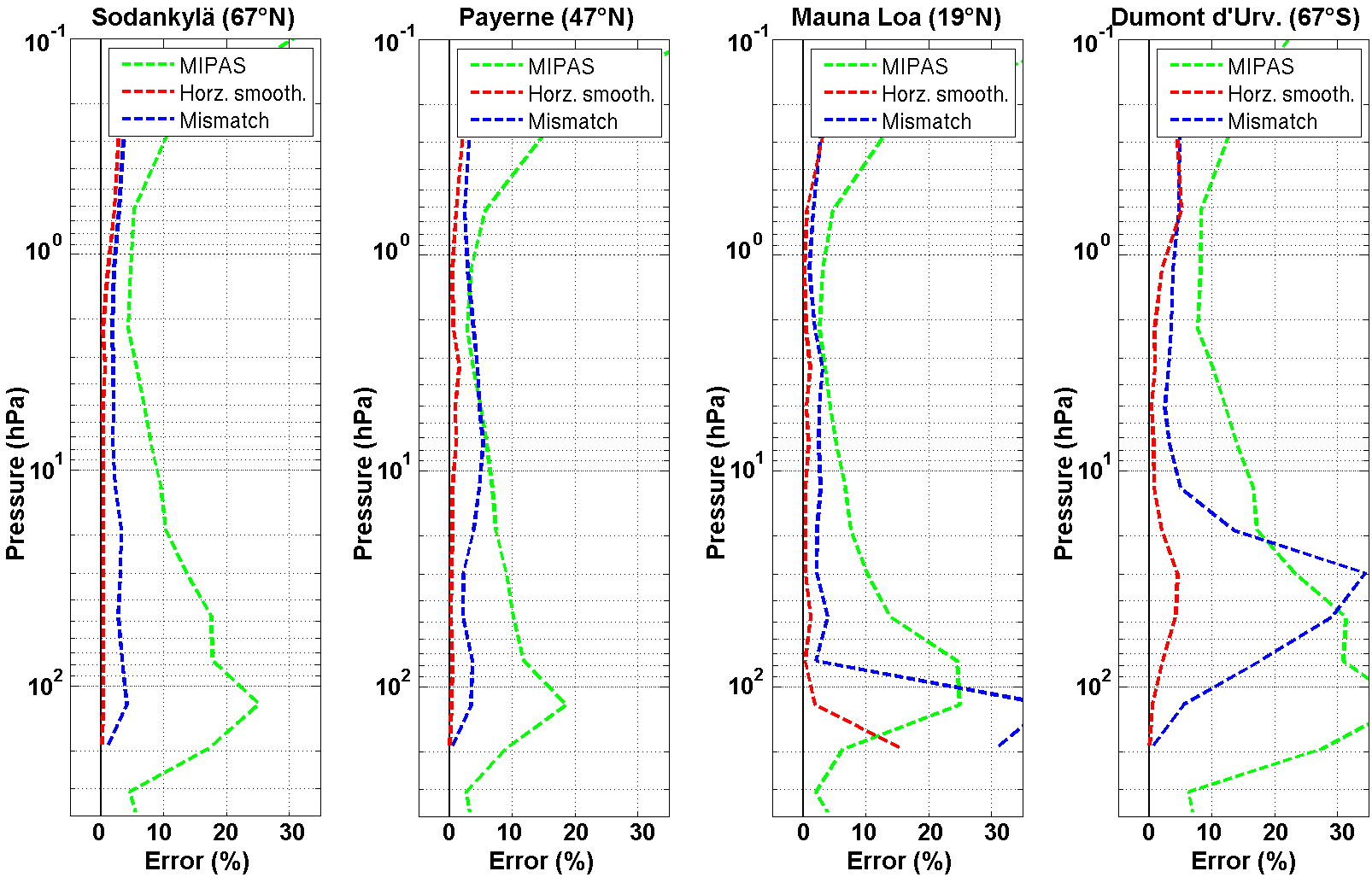
Quantifying uncertainties in the data comparison process arising from measurement mismatches (σ)

Even if we have completely quantified the uncertainty in individual measurements (u1 and u2) there almost inevitably exists a mismatch in measurement geolocation, measurement interval, measurement solar local time or some combination of these, and a mismatch in smoothing of the measured field (e.g. a balloon-borne sonde measures water vapour at about 100 m of vertical resolution and 20 m horizontal resolution while a nadir satellite measures the vertical column only, at horizontal resolution not better than kilometres up to hundreds of kilometres). As a result atmospheric gradients and variability will almost always interfere with any comparison between EO and reference data to produce additional comparison uncertainties (σ) due to:

* Differences in time of observation (including measurement time integral mismatch and diurnal cycle effects)
* Differences in horizontal geolocation, including such time-varying effects as drift of balloon borne measures
* Differences in vertical registration, especially in presence of altitude uncertainties/shifts
* Differences in vertical smoothing (need for vertical averaging kernels for both columnar and profile measures)
* Differences in horizontal smoothing (consider e.g. an in situ sonde with respect to a 300 km satellite horizontal resolution)
* Vicarious data issues such as cloud impacts if comparing to radiances in the IR spectrum.

Tools will be developed that enable these sampling (including collocation mismatch) and smoothing effects to be taken into account to enable a meaningful comparison to be undertaken. Uncertainties will be required both in native measurement space and to be appropriately propagated through the forward calculation to radiance space to enable ease of intercomparisons. To quantify comparison uncertainties, a dedicated tool built on the heritage of EU FP 6/7 projects GEOmon and NORS, already applied with success to the validation of Envisat and MetOp for the estimation of comparison uncertainties [e.g. Cortesi et al., 2007], will be further developed and used in this project: OSSSMOSE (Observing System of Systems Simulator for Multi-mission Synergies Exploration), which is a versatile simulator of global measurement systems for atmospheric composition developed at BIRA-IASB (e.g. [Lambert et al., 2012; Verhoelst et al., 2012]). This multi-purpose environment provides realistic simulations of the output of real and hypothetic global observing systems and of their comparison. It consists of various elements such as observation operators mapping in 2D/3D the real atmospheric information captured by a measurement, metadata on observations (including places and times of real measurements acquired by several ground-based networks and by different satellites), and a suite of 3D/4D atmospheric modelling databases on which observation operators can be applied. Compared to the few Observing System Simulation Experiments (OSSEs) already reported in the - usually meteorological - literature, the key innovation brought by OSSSMOSE is that for the first time the triple nature of the resulting data sets is addressed: the remote sensing nature of the measurements and their associated errors and smoothing properties, the orbital and/or network nature of the observing system and its associated sampling properties, and the atmospheric nature of the probed field with its temporal variability, cycles and spatial structures. In this project OSSSMOSE will be used to investigate and quantify the list of mismatch uncertainties bulleted above on the global scale and in the long term, for existing measurement systems and also for theoretical systems in support of later WPs.

The explicit description offered by OSSSMOSE of metrology will be complemented by statistical approaches, and traceability of the process to metrology standards will be assessed by NPL. The related collocation uncertainty may be characterised also using statistical modelling and functional data analysis. In particular the approach used by Fassò et al. [2013] for understanding radiosonde to radiosonde collocation mismatch, and the approach developed by Sofieva et al. [2014a] to assess sampling uncertainty of satellite ozone profile measurements, will be adapted and applied extensively to cover all different instruments in a systematic way, including different spatial averaging (for example radiosonde-lidar or radiosonde-EO comparison). Functional data can be defined at different spatial resolutions such as points, profiles or volumes. The typical outputs for each imperfectly co-located pair are a profile uncertainty decomposition for both measures and a total column uncertainty decomposition similar to Fassò et al. [2013]. We will consider the various types of mismatches, as they arise from the same resolution data, e.g. radiosondes vs displaced radiosondes or radiosondes vs lidars. Using the same statistical general modelling approach, we will also consider mismatches for different resolutions such as radiosondes to satellites or radiosondes to model outputs. Since model outputs usually refer to spatial and temporal averages, we will also consider different temporal resolutions.



**Figure 5**. Example of the total random error for Envisat MIPAS water vapour retrievals (in green), and how this error compares with estimates of the random component of comparison errors (e.g. between MIPAS and radiosondes) due to differences in horizontal smoothing (in red) and to horizontal collocation mismatch (in blue). From left to right: Sodankylä year-round (Finland, 67°N, 11°E), Payerne (Swiss Alps, 48°, 7°E) in October-December, Mauna Loa (Hawaii, 19°N, 155°W) in April-June, and Dumont d’Urville (Antarctica, 67°S, 140°E) in July-September 2003 (from [Lambert et al., 2012]).

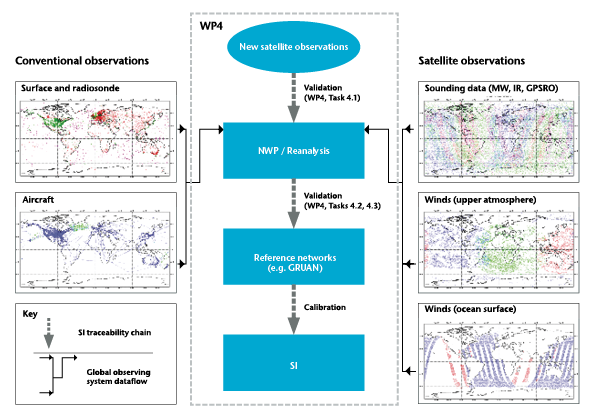
#### Use of data assimilation systems as integrators and comparators

Numerical weather prediction (NWP) models and reanalysis systems provide a natural framework for the consistent assessment of diverse observational datasets, and for a better understanding of the validation of EO data with reference data. Several NWP centres in Europe run operational global forecasting models. These models routinely ingest large volumes of observational data, both conventional and satellite data, to determine the initial conditions for forecasts. The data assimilation (DA) systems which produce these initial conditions (or analyses) are effective in combining observational data with model data to provide an optimal estimate of the 3-D global atmospheric state. The same DA systems are used to provide physically consistent estimates of atmospheric state over multi-decadal timescales by using state-of-the-art DA systems and forecast models to re-analyse historic observational data [Uppala et al. 2005, Dee and Uppala 2009, Poli et al. 2010, Dee et al. 2011].

NWP and reanalyses have been used to provide effective validation of temperature and humidity observations from meteorological satellites operated by US, European and Chinese agencies (see Bell et al [2008]; Geer et al [2009]; Lu et al [2011, 2014] and Bormann et al [2014]). The continuous coverage in space and time provided by the NWP and reanalysis fields coupled with their high accuracy in representing temperature and humidity make them very effective in characterising subtle biases and errors in satellite data. Such techniques have become recognised by space agencies as one primary method for the evaluation of new satellite sounding missions targeting atmospheric temperature and humidity. In turn, these studies have served to refine the specification of future operational satellite sensors for operational numerical weather prediction and climate monitoring.

Significant challenges remain, however, in developing the use of NWP and reanalysis systems for the calibration and validation of satellite EO data measuring, in the first instance, upper atmospheric temperature and humidity for which model knowledge is arguably most advanced. Estimating the absolute uncertainties associated with the NWP and reanalyses fields, and hence satellite data, remains problematic because neither model measures nor any of the input data are traceable to absolute or agreed standards. This has particular relevance in the problem of assessing long-term trends in climate variables. In the context of atmospheric state measurements the establishment of reference measurement networks offers a key part of the solution. Conceptually, a suite of complementary instruments, each providing traceable measurements, can be used to passively assess the performance of NWP and reanalysis systems, thereby providing a form of SI traceability to the NWP fields and, by extension, the satellite observations validated from them. This will be a key innovation to be developed, tested and assessed through GAIA-CLIM.

This project will develop, as a demonstrator of a general approach, the infrastructure required to ingest and monitor reference network data in global NWP and reanalysis models and produce near real-time statistics on the comparison. It will demonstrate the capability of such NWP and Reanalysis systems to assess measurements from key new meteorological satellites targeting atmospheric temperature and humidity. It will also define the measurement performance requirements for reference data sources for the validation of NWP and Reanalysis models and satellite observations. This approach is illustrated below in Figure 6.



**Figure 6**. Illustration of how an unbroken chain of comparisons, linking new satellite observations to the SI, will be achieved in GAIA-CLIM. By using the most mature component of the global observing system – the constellation of meteorological satellites measuring temperature, humidity and winds coupled with dense terrestrial and airborne observing networks - this project will show how data assimilation systems (NWP and reanalysis) can be used to validate new satellite observations. The project will also link these assimilation systems to the SI via designated reference networks, such as GRUAN. In the final stage of the project, it will be shown how this model can be extended to a much wider class of ECV’s - encompassing land surface, ocean-state and atmospheric composition variables.

#### Providing comparator collocation data and uncertainties in a usable manner through a ‘virtual observatory’

Comparator data for EO sensor validation and characterisation are only going to be broadly exploited if it is made sufficiently easy to access and analyse the data. A collocation database that consists of the various measurements and uncertainties alongside necessary metadata is therefore vital if ground-based and sub-orbital measures are to be utilized to their full potential in characterizing EO sensors. This database would provide spatio-temporal match-ups between EO measurements and the ground-based / sub-orbital measurements that meet certain space- and time-window criteria and observation feedback from the data assimilation process into NWP models and reanalysis. The comparator measurements would be retained in original data format, in geophysical space and in radiance space after conversion using radiative transfer models. Radiative transfer model comparisons in the IR (e.g. [Saunders et. al., 2007]) have shown that fast models such as the European RTTOV and the US CRTM are suitable to simulate instrument data. Both are used within the assimilation process for NWP models as well. To assure high quality for radiative transfer also line-by-line models can be used for comparison. For instruments measuring in the UV/VIS spectral range vector radiative transfer models need to be utilised

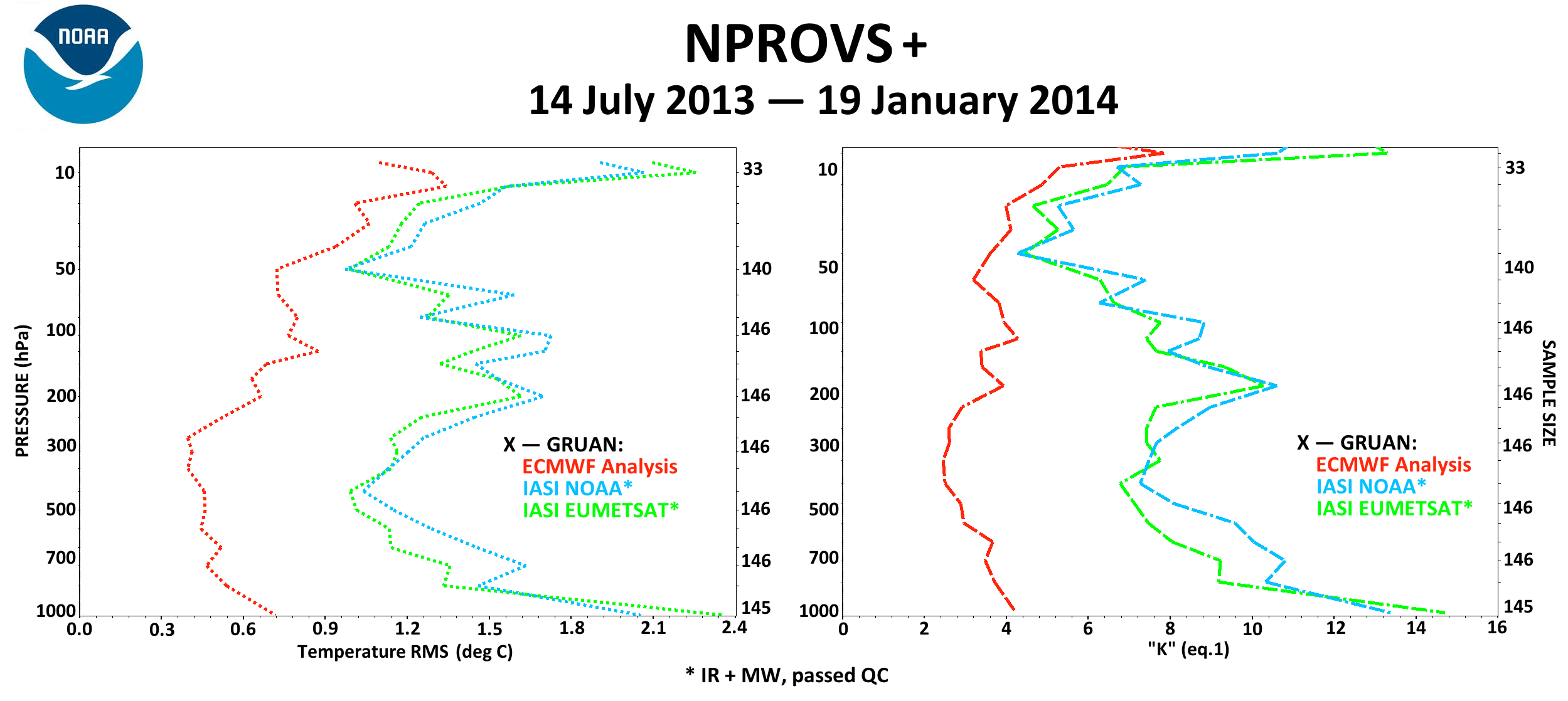
As a proof-of-concept, and because the measurements will have the highest impact on stability characterisation, a prototype will be built limited to a database of collocations to the reference quality measurements derived in preceding work. This collocation database and toolset effort will build upon:

* NOAA’s NPROVS system (<http://www.star.nesdis.noaa.gov/smcd/opdb/poes/NPROVS.php>) which already regularly collocates various radiosonde and NWP products with satellite measures and which is being extended to include GRUAN measurements and their uncertainties (Figure 7);
* The ICARE Multi-Sensor Data Visualization, Analysis and Extract Tools (<http://www.icare.univ-lille1.fr/browse/>) and (<http://www.icare.univ-lille1.fr/extract>) already collocates various satellite products (aerosol optical depth and ozone total column) with ground based network data such as AERONET and also MACC analysis data;
* The NORS platform ([nors-server.aeronomie.be](http://nors-server.aeronomie.be/)) which already automatically collocates and compares NDACC measurements with MACC analysis data, including full traceability and following QA4EO best practices;
* The ESA GECA tools for ingesting and collocating satellite measurements of atmospheric constituents concentrations with ground-based network measurements.
* Further progress with comparison metrology and representativeness of measurements foreseen in WP3.

The project is analysing and reusing elements of these tools and will create further extensions to incorporate information from the modelling analyses described in the preceding sub-section and the geographical capability mapping tool arising from the geospatial capability mapping work package. The design of the Virtual Observatory will benefit from requirements gathered by the above mentioned initiatives, requirements gathered by the GAIA-CLIM project and experiences in the use of the existing tools.

Efforts will include a graphical display and analytical interface that meets various customer requirements ranging from basic quality assurance confirming the integrity of the collocated observations (ground, satellite and model) to a broader landscape of scientific/statistical analysis of respective observations and performance characteristics. The interface would accommodate user interactivity ranging from raw data table inspection to individual graphically displayed profiles to ensemble statistical and scientific analysis for selected sites, satellites and measures. In particular the availability of download functions for standardised reports as pdf files as available from the NORS server and collocation data in widely used formats such as NetCDF employing the CF convention shall efficiently support the use of the analyses / results and alleviate burdens of data analysis for users. Preliminary capability to do this exists within systems such as the Environmental Data and Graphical Evaluation (EDGE) analytical interface developed in conjunction with the NPROVS. Leveraging against such capability will facilitate the timely emergence of a robust quality assurance and analytical facility (tool) planned with sustainability in mind serving the project during development phases and long after project completion.

The Virtual Observatory shall become accessible for invited users after two thirds of the project, which allows the structured collection of feedback on its functionality. The feedback will be used to develop a roadmap how the developed tools can be further improved and sustained within European services such as the Copernicus Atmospheric and Climate Change Services.

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**Figure 7**. Example screencap of output from EDGE interface showing comparison between level 2 products performance for respective IASI soundings provided by NOAA and EUMETSAT (EU) from MetOP-A, ECMWF analysis field and GRUAN radiosondes in both RMS units (LHS) and in coverage factor “K” (eq 1, RHS). The curves are derived from common samples of each for satellite soundings which passed internal qc and were retrieved using combined IR+MW sensor data. The common sample size of 146 in troposphere is reduced from over 1800 prior to subsampling based on the qc indicator and sensor combination. This reduction in yield was a factor of 3+ greater for IASI from EU versus from NOAA and is among the many characteristics that must be considered in overall product comparisons. Furthermore, in computing “K”, both the σ and u1 terms (eq 1) were set to zero so the comparison is pessimistic. Work will be undertaken in the present project to bring in realistic values for these terms for use in such comparisons as well as to extend the facility to enable comparable comparisons in the satellite sensor level “1b” radiance space.

#### Capability gaps meta-analysis and final recommendations

As a final set of outcomes this project will provide both a meta-gap analysis and a set of prioritized recommendations as to how to improve our ability to characterise EO observations from surface and sub-orbital measurement platforms. The meta-gap analysis would summarize the gaps identified in the component work units and will provide forward-looking recommendations and priorities based upon the totality of the evidence produced during the project lifetime including feedback gathered throughout the project from targeted external users. Specifically it would address:

* Gaps in geographical coverage and their impacts arising from the geographical mapping exercise
* Gaps in knowledge of measurement properties and uncertainties for both specific instrument types and on an ECV basis.
* Gaps in understanding of the impact of measurement mismatches arising from inadequacies in knowledge of how to deal with measurement mismatch issues.
* Open issues regarding how to use dynamical model and data assimilation techniques as integrators
* Issues that remain in enabling easy use of reference quality measures as cal/val tools.
* Gaps between user needs and current observational and analysis capabilities
* Consideration to the somewhat fractured nature of observing systems. Over recent decades numerous networks have been implemented by various national and international partnerships. The result is a somewhat fractured observing system with many networks consisting of complementary but non-overlapping aims, protocols, and contributing stations.

The gaps analysis and impacts assessment will be a living document, version pointed at various points during the GAIA-CLIM project duration. It will form the basis for the production of a set of prioritized recommendations, which will be developed in the final year. Significant and sustained consultation both within the consortium and the broader community will be undertaken to provide a scientific and usage-based prioritization of identified gaps and resulting recommendations as part of this exercise.

## AMBITION

### Advances Beyond the State-of-the-Art

To date satellite validations utilizing ground-based and sub-orbital measurements as a reference have not taken systematically full account of uncertainty in the comparator measurements. Furthermore, few of them have given appropriate care to metrological understanding and knowledge of the impact of measurement mismatches. Over the past decade significant efforts have been made by groups and networks such as: GRUAN, NDACC, TCCON, EARLINET and AERONET; related Research/Archival Infrastructures such as ACTRIS; and projects such as GEOmon, CEOS-ICAL, and NORS, to improve our understanding of the fundamental measurement uncertainties and traceability. In the framework of ENVISAT validation, GEOmon, the ISSI WG on H2O and NORS, a few pioneering studies of spatial representativeness and advanced validation methodologies have also shown evidence of the quantitative impact of multi-dimensional measurement mismatches. Mapping tools of e.g. satellite data coverage do exist, like the CEOS Visualization Environment (COVE), but they remain limited to a simple ensemble of metadata (the ground footprints of past and current missions) and they are decoupled from any existing mapping tool for ground-based networks.

The time is therefore right to holistically reassess how we can map in a measurement sense the ground-based and sub-orbital comparators to EO measurements to make a more useful and realisable characterisation of the EO sensor performance on a sustained basis. The GAIA-CLIM project represents substantive advances beyond the state of the art in our ability to map ground-based and sub-orbital measurements onto EO data and correctly and unambiguously interpret the ensuing comparisons. In short the GAIA-CLIM project will represent substantive advances beyond the state of the art in the following:

* Mapping and visualizing existing capability based upon objective assessment criteria by ECV, by measurement fundamental characteristics, and by degree of typical measurement temporal mismatch.
* Understanding of the impacts of spatial capabilities gaps upon our ability to characterise EO sensor performance on a sustained basis.
* Substantively extending the range of ground-based and sub-orbital instrument types for which fully traceable measurement estimates with resulting robustly quantified uncertainties can be produced.
* Improving our ability to quantify the impacts of measurement mismatches between EO instruments with typical dwell times of at most seconds and footprints of several kilometers to several hundred kilometers, and ground-based and sub-orbital measures.
* Advancing the ability of NWP and reanalyses to use reference quality measurements to improve absolute calibration of the model fields and to act as a transfer standard from such high quality measures towards global scale EO measurements characterisation.
* Providing a ‘virtual observatory’ that allows a user to interrogate and visualize a database containing collocations of EO data with reference quality comparator data. This facility shall include: measurement uncertainties, measurement mismatch uncertainties, data from data assimilation schemes in NWP and reanalyses. It shall also contain all necessary metadata required to fully interpret the comparison.

Innovative Potential

The use of a robust mapping framework that assures metrological traceability for EO characterisation, taken together with proposed on-board calibration units, and satellite-to-satellite inter-calibrations such as GSICS, would open up new opportunities for their usage for a variety of applications, in particular long-term environmental monitoring of ECVs. Through a multi-point data characterisation system with a robust ground-based / sub-orbital segment long-term continuity of EO measures can be assured to maximize the return on the considerable investment that has been made in developing and maintaining present and future EO capabilities. Use of the tools developed within this project would demonstrably increase the ability to accurately characterize EO sensor performance. More accurately characterized EO data would open up many opportunities for their improved usage across a broad range of application areas.

The virtual observatory facility arising from GAIA-CLIM can act as effectively ‘an insurance of last resort’ for EO capabilities. Space is a complex environment within which to operate high precision, high quality remote sensing instrumentation. The possibility for either mechanical issues or effects of space weather / debris is ever present (and the latter is increasing in time, especially in the polar orbiter altitude range as more and more assets are launched into that orbit) such that it is likely a matter of when and not if some subset of instrumentation eventually fails, as attested to by historical operations of e.g. the MSU series around the time of the TOVS-9 satellite [Mears et al., 2011]. When there is either a funded capability gap for measuring a given ECV or if an instrument fails on orbit traceable ground-based and sub-orbital data series could be used to bridge appropriately any gap before a replacement payload is launched, whilst also accelerating its operational acceptance after launch. This ‘insurance of last resort’ would help to assure the long-term climate record for ECVs with minimal ambiguity arising. Without the developments envisaged under GAIA-CLIM the potential impact of such failures on climate data records of ECVs will be substantially greater.

By bringing together many of the principal global high quality measurement networks and capabilities alongside important European Research Infrastructures GAIA-CLIM will substantially help to improve cohesion of these efforts. The mapping exercises under WP1 will help highlight potential capability synergies and their scientific value. Instrument streams developed for the instruments developed under WP2 may reasonably be expected to be deployed across several networks / locations, significantly aiding intercomparability. Improved metrological understanding of the issues arising from mismatch may serve to optimize observing strategies. The virtual observatory facility will serve to increase visibility and value of all the high quality reference observations networks and make clear their synergies and value. The project will also enable a sharing of best practices and a better understanding of areas of mutual concern and benefit. Through working together on the problem of EO sensor characterisation from ground-based and in-situ measures desired rationalisation of existing capabilities to optimize their value along with informed strategic future capabilities development can be expected to accrue. Recommendations arising from WP6 as a result of the GAIA-CLIM work will provide a further road-map to achieve subsequent steps in this direction.

The tools used and the lessons learnt about measurement properties and procedures will be shared with broader aspects of the Global Observing System through e.g. the WIGOS and GCOS structures and the relevant CEOS bodies: WG on Calibration and Validation (WGCV), Virtual Constellations (VCs), and WG on Climate (WGClimate). Such interactions with WIGOS, GCOS and CEOS bodies constitute proven mechanisms to establish best practices in measurement, cal/val and data management, and to reach an international consensus on the global strategies proposed. By sharing tools and lessons with global actors, other ground-based and sub-orbital measurement capabilities will be improved either in their accuracy or their uncertainty characterisation. As an example, lessons learnt about radiosonde best practices and uncertainties in the framework of GRUAN are beginning to be propagated both to the baseline GUAN network and the broader GOS sonde networks and lead to the design by manufacturers of new, improved, instruments and renewed efforts by manufacturers to improve fundamental measurement property understanding (Section 2.1).

# IMPACT

## EXPECTED IMPACTS

### Impacts and Innovations

The GAIA-CLIM project will undertake for the first time in a comprehensive and systematic manner mapping of in-situ and sub-orbital measurements onto EO observations. A key first step is defining and mapping geospatial measurement capabilities. Above and beyond this, mapping includes measurement traceability of the comparators and understanding of the effects of measurement mismatches, enabling an unambiguous interpretation of the resulting comparisons. A variety of tools will be developed including statistical approaches and data assimilation techniques to aid interpretation.

Usage of GAIA-CLIM project outcomes will be assured through the development of a ‘virtual observatory’ visualization and analysis facility, finding collocations of comparator measurements with EO data, and providing a wealth of both data and metadata. The virtual observatory facility will make it substantially easier for users to discover and use appropriately ground-based and sub-orbital data to characterise EO sensor performance than has been the case to date. Because the data have been so hard to find and because users have not been assured of their basic quality they have rarely been used for example to aid the creation of climate data records from satellites. By providing the envisaged virtual observatory in future it can be expected that greater use of the high quality ground-based and sub-orbital data to this critical problem will accrue. However, the virtual observatory will be available without restriction with the intention that it be used by a broad sector of users including those interested in more near real-time activities such as forecasting and monitoring of air pollution events.

Improved characterisation of EO sensor performance and improved traceability to fundamental measurement standards would improve substantially their utility for a broad range of applications and hence their scientific and economic value. For example, greater absolute accuracy of EO data and improved radiative transfer modelling will lead to improvements of the ability to use EO data in weather forecasting and in real-time environmental monitoring as well as for long-term climate change monitoring. Commensurate with the vision of climate services from WMO or the European Copernicus Atmospheric and Climate Change Services the knowledge and understanding gained through GAIA-CLIM will benefit weather forecasting, air pollution monitoring, air traffic management and myriad other users as well as climate research and applications. As such these benefits will directly feed through into the GFCS priority sectors: agriculture and food security, water, health and disaster risk reduction.

Based upon a combination of the GAIA-CLIM project outcomes and strong and sustained user interaction through surveys and a series of stakeholder workshops a comprehensive gap analysis will be undertaken, which will identify and prioritize gaps in our observing capabilities, providing knowledge of the measurements and the ability to quantify and control for the effects of measurement mismatches. Potential pathways to address the identified gaps will be identified and prioritized on both a scientific and user-requirement basis. The final key project outcomes are a gap analysis and impacts document and a recommendations document. These will be delivered to the commission and key stakeholders such as the Copernicus Atmospheric and Climate Change Services. To this end, the consortium members include key representatives from ground-based and aircraft measurement networks as well as members of numerous GCOS, GEO, CEOS and WMO working groups and expert teams concerned with both present and future measurement capabilities. In addition the MO involvement will assure appropriate interactions with the ESA Climate Modelling User Group. Through these roles they will appropriately distribute and champion GAIA-CLIM outcomes and recommendations. This is key to assuring global buy-in on the outcomes from the data providers.

A further measurable impact would the number of stations, facilities and networks that request to participate in the ‘virtual observatory’ as well as in the data processing or to join those high quality observing networks / infrastructures participating in GAIA-CLIM as a result of the project activities. This will lead to improved capabilities regionally and globally and help to engender a truly system of systems observational network design. GAIA-CLIM participants and activities will strongly encourage such capacity building through both the provision of capabilities that will arise through the five scientific work packages and more general advocacy activities.

Research is to be undertaken within GAIA-CLIM to improve observational traceability for a number of broadly used methods of observation. Within the WIGOS program (to which GRUAN is a pilot project and hence GAIA-CLIM participants already have a strong working relationship), and a system of systems structure, it would be expected to eventually transfer many of the scientifically valuable procedures and innovations undertaken in this project in reference-quality networks to more operational baseline and comprehensive network operations leading to improvements in their data quality and understanding. Experience with reference networks to date is that such innovation trickledown is effective. For example, work by GRUAN on the Vaisala RS-92 and Modem radiosondes has spurred innovation not just at these manufacturers, but with a number of other manufacturers to improve both measurements and transparency. Insights from Modem radiosondes are shortly to be propagated across all sites running Modem radiosondes and will lead to a step change in their quality and hence their value to NWP and climate applications. Improved observational capabilities and improved observational understanding inevitably lead to better science and more informed usage of the data.

Finally, the novel approach to comprehensive, traceable, EO Cal/Val demonstrated in GAIA-CLIM for two mature observing systems (atmospheric state and composition) will pioneer an approach which is of wider applicability to a broader class of ECVs. The well-developed meteorological satellite observing system, coupled with rapidly evolving reference network capacity and global data assimilation systems has already served as the model for global composition monitoring. In GAIA-CLIM these elements will be brought together in a coherent way to provide robust uncertainty estimation for the relevant ECVs. By extension, it will be shown how similar approaches can be applied to analogous networks targeting land surface and ocean state variables. This component of the project will draw upon the expertise brought to the GAIA-CLIM consortium by several partners engaged in providing world-leading operational services (EUMETSAT, ECMWF, MO, KNMI, FMI) and world-leading metrology (NPL) covering a wider range of ECVs. These findings will be disseminated to the relevant communities through various outreach activities planned in the project, including international workshops, documentation and web-based media.

### Barriers and Obstacles

Historical precedence shows the largest barrier to developing and implementing robust ground-based and sub-orbital EO cal/val tools to be the highly fractured landscape of both funding and governance mechanisms for these measurements. Often these are in conflict with one another politically, economically, or scientifically. Working towards a streamlined and more coherent set of regional and global governance and funding support mechanisms for ground-based and sub-orbital measurements explicitly is out of scope and covered by forthcoming Research Infrastructure calls. That said, clearly the tools and analyses produced within the project, along with the involvement of so many of the senior members of a number of high quality measurement networks / infrastructures should be conducive to helping achieve such an aim.

As well as being a barrier to uptake of outcomes the fractured support and network architecture is also a potential obstacle to achieving GAIA-CLIM’s objectives. Stations and networks will need to actively engage with GAIA-CLIM and share necessary data and metadata for the project’s objectives to be met. Recognizing this as the likely limiting obstacle to any successful project in this thematic area, the GAIA-CLIM consortium was built from the bottom-up by a partnership between GRUAN, NDACC and TCCON and the many European Infrastructures which contribute to / interact with them. In doing so the consortium has been built with the aim of providing GAIA-CLIM access not just to the best observations in the European domain but also globally to meet the requirements called for in the call for proposals.

As noted in the H2020 call text, any effective project outcome requires global buy-in. Here through: the dedicated WP on Impacts, Outreach and dissemination (WP6); the nature of the consortium members and their roles in regional and global governance structures (Section 3.3); and the composition of the scientific advisory panel (Section 3.2), stringent efforts will be made to build in such buy-in as part of the project process throughout the GAIA-CLIM project.

For reference quality measurements it is a basic necessity to have both agreed standards and transparent processing. In very many cases currently one or other or both of these are missing. For example an instrument manufacturer may provide a black box processing package. Experience has shown many manufacturers are willing to allow either access to such software and / or the raw digital counts so that reference quality measurements can be made following appropriate dialogue and assurances. But some manufacturers may not be willing to do so. In such cases, should they arise, efforts will be required to come up with solutions that are still scientifically acceptable. Several consortium members have good working relations with manufacturers, which will be leveraged.

Appropriate propagation and use of measurement uncertainties in different application areas is a scientific usage barrier. Specifically the uncertainties may be correlated vertically, spatially or temporally such that for example a user interested in use of reference-quality data to infer something about instantaneous EO measurement values needs to utilize the uncertainties in a distinct manner from a user interested in ascertaining potential for long-term EO sensor drift. Work in the virtual observatory domain will aim to help address this issue making it easier for users to appropriately apply the measurement uncertainties to their problem of interest.

## MEASURES TO MAXIMISE IMPACT

### Dissemination and Exploitation of Results

A core facet of GAIA-CLIM is the ‘virtual observatory’ of cal/val tools, which will constitute the primary means by which users will be able to access, visualize and utilize the outputs of the project. This work will be led by EUMETSAT and collaborate with existing European and international programs with synergistic aims. Significant efforts will be made to build an interface that is easy to use and which makes data discovery, visualization and analysis easy. The virtual observatory work will look to build upon and extend a number of existing facilities which already undertake subsets of the desired functionality such as NORS, ICARE and NPROVS. The virtual observatory workpackage includes a specific task dedicated to documenting the steps required to transition this facility from a research to an operations framework.

Additionally, the GAIA-CLIM project contains a work package dedicated to impacts, outreach and dissemination which includes tasks to maintain a living gaps assessment and impacts document and to produce a set of final recommendations. This work package includes a broad user survey and three external users meetings enabling strong and sustained input from the user community to steer GAIA-CLIM development and build and sustain stakeholder engagement throughout the projects lifetime.

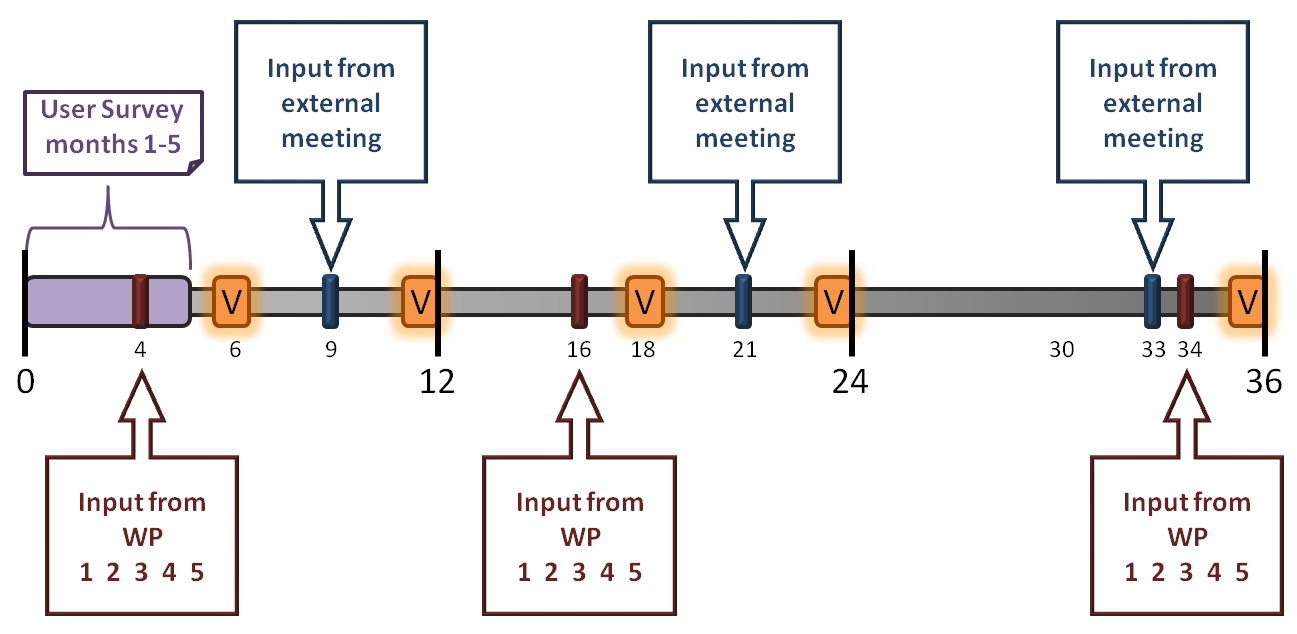
Furthermore, all remaining work packages include some aspects of dissemination and exploitation of the results through provision of reports and peer reviewed papers. Numerous routes to dissemination of project progress will be exploited, viz. participation at international conferences, publication of results, a project website, and data sharing.

GAIA-CLIM shall participate in the *Pilot on Open Research Data*. Knowledge generated during the project will be shared openly. Any milestones, deliverables or technical documents produced will, following appropriate internal-to-project review procedures involving at least an expert and a management based review, be published online and made discoverable. Peer-reviewed publications will by policy be to journals that are either open access or allow the authors to pay for the articles to be made open access.

The project is not envisaged to directly collect primary data (make measurements for the sole purpose of the project). Rather it will provide added value to existing measurements taken by both consortium members under separate funding support and third party institutions participating in various national and international measurement programs. It is likely that some data providers will solely allow delayed mode usage in which case these data will only be used by the project as and when they become openly available. Hence the project will only deal with both EO and in-situ / sub-orbital data which are available for academic use without restriction to simplify issues over dissemination of added value products derived by the project. These added value products will be made available immediately they are produced and without restriction with converters to convert to at least two different formats that are in broad use within the recognised primary stakeholder communities e.g. CF-compliant netcdf. The data will be made available along with visualisation tools through the ‘virtual observatory’ facility, which will aid data discovery and data usage for calibration and validation of level 1 and level 2/3 EO observations.

### Communication Activities

User engagement and outreach is a key facet of GAIA-CLIM, reflected in the dedicated outreach work package which aims to facilitate a two-way conversation between consortium members and the broader user and stakeholder communities on a sustained basis (Figure 8). The project includes sufficient travel and subsistence funding to enable three significant meetings of users and stakeholders to engage the broader expert user community. It also includes a task dedicated to a broader survey of user requirements, which will be carried out at project inception. This survey and the first meeting, both of which shall also occur within the first year, will ensure that consortium members have an adequate understanding of the broader community’s needs and ideas from the outset. Following these inputs and early inputs from the underlying WPs KNMI will lead the development of a living Gap Assessment and Impacts Document (GAID) which will form a focal point for subsequent user and consortium input. This document will be made publicly available and advertised. Appropriate feedback mechanisms such as blog discussions or an email address will be maintained to allow third party input to be captured between versions of the document. Several further revisions to the GAID will occur, reflecting an iterative evolution of understanding and progress and be guided by two further iterations from the underlying WPs and external stakeholders meetings respectively. These inputs are offset from one another in time such that there will be a total of five versions of the document. This document will form a basis for the development of recommendations and their prioritisation, which will be undertaken in the final year. This recommendations and priorities document will be a key focus of the final external users meeting. This will ensure that GAIA-CLIM recommendations are well aligned with users priorities and also their provenance is well understood by the community at large.



**Figure 8**. Pictoral summary of the program of activities that will inform the production of the Gap Assessments and Impacts Document (GAID). This document is a living document, which will form the basis for the final set of recommendations arising from the GAIA-CLIM project. Internal project inputs are denoted in red and consist of project internal milestones of gaps in the context of the respective WP arising from WPs 1 through 5. External user input will be solicited through a combination of a survey and a series of external participant meetings held throughout the project (blue). This ensures that the process will be iterative and fully account for both internal to project and external to project viewpoints and developments and assure buy-in to project outcomes. Subsequent to the various inputs version pointing of the living GAID will occur (denoted by V).

The key final outputs to users will be the virtual observatory facility, the GAID document and the recommendations and priorities document. As well as delivering these key documents and capabilities to the Commission and Copernicus services, GAIA-CLIM participants will ensure that they are appropriately communicated to the large number of national, European and global activities in which they participate including research infrastructures, measurement networks and strategic global observation governance groupings (Section 3.3 and Section 4.1). Efforts will be made to reach out to and encourage use by near real time data users / non-climatic applications such as pollution monitoring, air traffic management and weather forecasting.

For more project process related matters, the project will have a dedicated website maintained by the project coordinator’s institution and make use of blogs and other social media tools to enable appropriate communications of progress and results alongside interactions with users. In the interests of openness and transparency all aspects of the project will be summarized and communicated without prejudice wherever possible through the project website. Examples are minutes of any management meetings or recommendations arising from meetings of the scientific advisory panel. Obvious exceptions where issues over IPR, financial or personal information or other exceptions exist will not be communicated. These are envisaged to be very few in number. The project will undertake standard reporting of progress to the Commission sponsors.

# IMPLEMENTATION

## WORK PLAN – Work Packages, Deliverables and Milestones

### Work Plan Structure

The project consists of seven distinct work packages (Fig 8). The work packages follow the structure outlined broadly in Section 1. Work packages and associated remits are as follows[[1]](#footnote-1):

1. Geographical capabilities mapping
   1. Defining measurement levels and associated characteristics
   2. Geographic mapping on an ECV basis
   3. Provision of mapping visualization as component of ‘virtual observatory’
   4. Analysis of the impacts of spatial gaps in observing capabilities on EO characterisation
2. Measurement uncertainty quantification
   1. Defining reference measurement protocols and uncertainties for key instruments
   2. Quantifying defensible uncertainty estimates for non-reference quality measurements
   3. Ensuring best practices in measurement uncertainty quantification
3. Comparison error budget closure – Quantifying metrology related uncertainties of data comparisons
   1. Creation and application of tools to quantify measurement mismatch effects and associated uncertainties
   2. Provision of resulting tools and estimates as component of the ‘virtual observatory’
4. Assessment of reference data in global assimilation systems and characterisation of key satellite datasets
   1. Assessment of several new satellite missions using data assimilation of reference quality measurements targeting temperature and humidity.
   2. Develop infrastructure to deliver near real time data dissemination for reference data
   3. Develop a software infrastructure for near real time monitoring and evaluation of reference data
   4. Develop a general methodology for using reference data for the characterisation of EO data
5. Creation and population of a ‘virtual observatory’
   1. Creation of collocation database between EO measures and reference quality measurements
   2. Preparation of data to enable comparisons including relevant uncertainty information and metadata
   3. Creation of data interrogation and visualization tools building upon existing European and global infrastructure capabilities
   4. Planning for transition of ‘virtual observatory’ from research to operational status
6. Impact, outreach and dissemination
   1. User consultation through surveys and a series of user workshops
   2. Overarching gap analysis and prioritization of recommendations
7. Management and coordination
   1. Project management, coordination and oversight
   2. Reporting
   3. Upkeep of project website and other general communications activities
   4. Ensuring congruence with Pilot on Open Research Data

Because of the distinct nature of the work packages they will all start at project inception. Dependencies within and between individual work packages mean that not all aspects of a given work package will start immediately. Where critical dependencies exist they are documented within the work package descriptions, as well as constituting overall project milestones in the case of input to the GAID and to the virtual observatory facility (Table 3.2a).

**Figure 9**. Work package and process diagram.

### Gantt Chart (D=deliverable)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No. | Task | 2015 | | | | 2016 | | | | 2017 | | | |
| I | II | III | IV | I | II | III | IV | I | II | III | IV |
| **WP1** | **Geographical Capabilities Mapping** |  | D |  |  |  | D |  |  |  |  |  | D |
| T1.1 | Define system of system approach |  |  | D |  |  |  |  |  |  |  |  |  |
| T1.2 | Mapping geographical capabilities |  |  |  |  |  | DD |  |  |  |  |  |  |
| T1.3 | 3D tool design for online visualisation |  |  |  |  |  |  |  | D |  |  |  |  |
| T1.4 | Statistical assessment of gaps |  |  |  |  |  |  |  |  |  |  |  | D |
| T1.5 | Model-based assessment of gaps |  | D |  |  |  | D |  |  |  |  |  | D |
| **WP2** | **Measurement Uncertainty Quantified** |  | D |  |  |  | D |  |  |  |  |  | D |
| T2.1 | Develop reference capabilities |  |  |  |  |  |  | D | D |  |  |  |  |
| T2.2 | Quantification of baseline uncertainties |  |  |  |  |  |  |  |  |  | D |  |  |
| T2.3 | Review uncertainty methodologies |  |  |  |  |  |  |  |  |  |  | D |  |
| **WP3** | **Comparison Error Budget Closure** |  | D |  |  |  | D |  |  |  |  |  | D |
| T3.1 | Metrology uncertainties for systems |  |  |  | D |  |  |  |  |  |  |  |  |
| T3.2 | Metrology uncertainties for data |  |  |  |  |  |  |  | D |  |  |  |  |
| T3.3 | Software tools development |  |  |  |  |  |  |  | D |  | D | D |  |
| **WP4** | **Assessment of Systems and EO Data** |  | D |  |  |  | D |  |  |  |  |  | D |
| T4.1 | Assessment of new satellite missions |  |  |  | D |  |  |  | D |  |  |  | D |
| T4.2 | Develop infrastructure for dissemination |  |  |  |  |  | D |  |  |  |  |  |  |
| T4.3 | Develop software for evaluation of data |  |  |  |  |  |  |  |  |  |  | D |  |
| T4.4 | Methodology for cal/val of EO data |  |  |  |  |  |  |  |  |  |  |  | D |
| **WP5** | **Creation of Virtual Observatory** |  | D |  |  |  | D |  |  |  |  |  | D |
| T5.1 | Creation of collocation database |  |  |  |  |  |  |  | D |  | D |  |  |
| T5.2 | Creation of GUI to visualise EO data |  |  |  |  |  |  |  | D |  |  |  |  |
| T5.3 | Evaluation of virtual observatory |  |  |  |  |  |  |  |  |  |  |  | D |
| T5.4 | Roadmap for transition to operations |  |  |  |  |  |  |  |  |  |  |  | D |
| **WP6** | **Impact, Outreach and Dissemination** |  |  |  |  |  |  |  |  |  |  |  |  |
| T6.1 | User engagement |  | D |  | D |  |  | D |  |  |  |  | D |
| T6.2 | Production of gap assessment document |  | D |  | D |  | D |  | D |  |  |  | D |
| T6.3 | Prioritising remedies and improvements |  |  |  |  |  |  |  |  |  |  | D | D |
| **WP7** | **Project Management and Coord.** |  |  |  |  |  |  |  |  |  |  |  |  |
| T7.1 | Financial and document management |  |  |  |  |  |  |  |  |  |  |  |  |
| T7.2 | Documentation of project progress |  |  |  | D |  |  |  | D |  |  |  | D |
| T7.3 | Facilitating governance structure |  |  |  |  |  |  |  |  |  |  |  |  |
| T7.4 | Annual progress meetings |  |  |  | D |  |  |  | D |  |  |  | D |
| T7.5 | Participating in pilot open research data |  | D |  |  |  |  |  | D |  |  |  |  |

#### Table 3.1a Work Package Descriptions

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Workpackage Number** | WP1 | **Start date or starting event** | | | | Month 1 | | |
| **WP Title** | | Geographical capabilities mapping | | | | | | |
| **Participants number** | | **3** | 14 | 9 | 2 | | 8 | 6 |
| **Participant short name** | | **CNR** | UniBergamo | FMI | BIRA | | MPG | KNMI |
| **Person months per participant** | | 34 | 33 | 22 | 12 | | 10 | 7 |
| **Participants number** | | 7 | 10 | 19 | 5 | | 17 | 1 |
| **Participant short name** | | ECMWF | UBremen | KIT | BKS | | UH | NERSC |
| **Person months per participant** | | 6 | 6 | 6 | 4 | | 4 | 3 |
| **Participants number** | | 15 | 4 | 12 |  | |  |  |
| **Participant short name** | | EUMETSAT | MO | GCOS |  | |  |  |
| **Person months per participant** | | 3 | 3 | 1 |  | |  |  |
|  | | | | | | | | |
| **Objectives** | | | | | | | | |
| The goal of this work package is to identify the geographical gaps in the existing surface-based and sub-orbital observing capabilities at the European and at the global scale for the 3D mapping of the atmosphere.   * To document and define system properties for each layer in a system of systems approach to enable rigorous EO data characterization. * To provide a geographical identification, at European and at the global scale, of current surface-based, balloon-based and airborne observing capabilities on an ECV by ECV basis for parameters which can be obtained using space-based observations from past, present and planned satellite missions. * Preparation for the creation of a “Virtual Observatory” of ground based and satellite data by establishing common formats for metadata. * Provision of a 3D tool for the online visualization of the current surface-based observing capability to facilitate the selection of the best available ensemble of station records for the satellite cal/val, with respect to several parameters (e.g. time, space and vertical coverage). * To provide a rigorous scientific assessment of geographical gaps in the system of systems of surface-based and sub-orbital observing capabilities both designing and implementing advanced geostatistical approaches and using existing global chemistry climate and inversion models applied to a subset of ECVs at the continental and/or global scale. | | | | | | | | |
| **Description of work, lead partner and role of participants** | | | | | | | | |
| **Task 1.1 Definition of system of systems approach** (lead: NERSC; involved: CNR, EUMETSAT, ECMWF, GCOS)  GAIA-CLIM Project objectives addressed: S1, O1  Start: M1 End: M9  Report or peer reviewed paper (D1.1) reviewing existing system of systems approaches posited by e.g. GCOS and GEO and documenting criteria and data characteristics for each layer to be used in subsequent GAIA-CLIM work. Adaptation of the application- and process-maturity models developed in the frame of the EC project CORE-CLIMAX to calibration/validation datasets and a system of systems observing architecture. These models currently address issues such as fitness-for-purpose and process maturity (metadata completeness; uncertainty characterization; user documentation; public access, feedback and update mechanisms; usage; software readiness). This task will review and extend the process maturity model to ensure its applicability to defining, in addition, the data properties in a system of systems architecture.  NERSC: will lead the production of this document.  EUMETSAT, ECMWF, CNR, and GCOS: will provide the basis set of process documentation and the necessary critical scientific insight to ensure a rigorous set of criteria are developed and contribute to the drafting.  NERSC, EUMETSAT, ECMWF, GCOS and CNR: will contribute to capacity-building by providing training/guidance to other members of the consortium in applying derived objective classification criteria to calibration/validation datasets. The outputs defined in this task will directly inform the assessment undertaken in Task 1.2. | | | | | | | | |
| **Task 1.2 Mapping geographical capabilities** (Lead: CNR; involved: BIRA, MO, BKS, KNMI, FMI, UBremen, MPG, UH, ECMWF)  GAIA-CLIM Project objectives addressed: S2, O1  Start: M1 End: M18  This task entrains expertise from several institutions to enable a comprehensive mapping of capabilities and classification of the reviewed datasets according to the criteria derived in Task 1.1. The task will review the current observing capability at European and global level for at least the core ECVs (bolded in Table 1, Section 1) and will be based on measurement metadata. A survey for establishing a protocol for a common metadata format will be carried out. Stations and networks where metadata are not yet available will be asked to complete a survey in order to establish a suitable metadata protocol. Metadata from existing networks will be collected and reviewed.  The metadata survey will include also new products such as black and brown carbon [Arola et al., 2011] as well as products useful for the correction of spurious effects affecting spectra measured from satellite sensors (e.g. effects of the surface albedo). This will offer an extension of the mapped surface-based, sonde and airborne capabilities available for the validation of EO space sensors.  EO sensor characterisation capabilities will be geographically identified according to the EO instrument characterisation requirements of the current and upcoming satellite missions, described by CEOS in The Earth Observation Handbook [http://www.eohandbook.com/]. This analysis will also include the degree of temporal sampling mismatch for those measurements which are discontinuous in nature whereby there can exist a range of sampling time offsets to different EO platforms depending upon their orbital configuration e.g 00 and 12Z sondes provide a better time match to a 10 am orbit than a 5 pm overpass by a polar orbiter. This analysis will allow EO providers and users to maximize the value of existing observations and forms the basis for the mapping facility developed under Task 1.3. | | | | | | | | |
| CNR: Coordinate the review of the current observing capability at European and global level for at least the core ECVs through an intensive effort for the collection of metadata and the establishment a common protocol also for those stations where metadata are not yet delivered. This work will take advantage of the leadership of CNR in networks and projects like EARLINET and ACTRIS. CNR will also coordinate the collection of metadata for ECVs related to the “Ocean” and “Land” domains, fully exploiting the role of its existing participation at European level in the relevant Research Infrastructures.  MO: Provide a study to identify the current coverage and targeting for future commercial aircraft-based observation enhancement within Europe. The current aircraft-based observing capability in Europe has gaps but work is needed to identify options within the data sparse regions that may be suitable (and prioritised) for provision of observation data.  FMI: Include in the metadata survey new products such as black and brown carbon [Arola et al., 2011].  UBremen: Include in the metadata survey new products such as products useful for the correction of spurious effects affecting spectra measured from satellite sensors (e.g. effects of the surface albedo).  MPG: Identify capabilities for the ECVs related to GHGs taking advantage of their involvement in IAGOS.  BIRA: Identify capabilities for the several atmospheric ECVs taking advantage of their involvement in NDACC.  KNMI: Identify capabilities for the several atmospheric ECVs taking advantage of their involvement in GRUAN and the QA4ECV (Quality Assurance for Essential Climate Variables) FP7 research project.  BKS: Identify capabilities for several atmospheric ECVs taking advantage of their coordination role in GRUAN and their involvement in NDACC and ozone measurements at the global scale.  UH: Identify capabilities for several atmospheric ECVs taking advantage of their coordination role in the Pan Eurasian Experiment program, and their collaboration with US Department of Energy within SMEAR-II measurement site for studying biogenic aerosols.  ECMWF: Advise on how the approach and results of this Task contribute to the System of Systems approach for satellite validation/calibration. | | | | | | | | |
| **1.3 3D tool design for the online visualization of existing measurements** (lead: CNR; involved: BIRA, KNMI)  GAIA-CLIM Project objectives addressed: S2, S6, T1, O1, O4, O5  Start: M12 End: M24  The mapped observing capabilities arising from task 1.2 will be used to populate a tool developed to provide a 3-D description of all identified reference-quality stations available which are monitoring ECVs worldwide. This tool will form a component of the ‘virtual observatory’ (WP5). The tool will also be designed with the possibility to immediately read the data accessed through the link provided by each network facility and to plot it on the Earth’s 3D shape.  The visualization tools will be able to filter according to metadata criteria such as spatial and temporal coverage, vertical range, number and type of ECVs, degree of harmonization, variable maturity level, standardization of the monitoring methods etc. It will be possible to visualize subsets of available measurements according to the filtering criteria. This will enable the selection of the best available ensemble of station records for the validation of a chosen satellite sensor for a selected application. The graphical interface will also allow to highlight the corresponding geographical gaps arising from Task 1.4.  CNR: Design and provide the tool based on an open-source software and will be designed in a modular way (to make it easy to be upgraded) with a user-friendly web interface. Web Services Description Language (WSDL) or Simple Object Access Protocol (SOAP) will be used to enable easy access to and management of the metadata.  BIRA: Provide consultancy, based on its experience with similar tools develop in other projects (e.g GEOMon, GECA, NORS).  KNMI: Support the CNR in the development of the graphical interface of the online visualization tool. | | | | | | | | |
| **Task 1.4 Statistical assessment of geographical gaps** (lead: UniBergamo; involved: CNR, FMI, UBremen, ECMWF)  GAIA-CLIM Project objectives addressed: S6  Spatial, temporal, climatic and environmental factors will be considered to assess the geographical gaps in the current surface-based and sub-orbital observing capabilities of the system of systems. This will be accomplished through the implementation of advanced geostatistical modelling based on a heteroskedastic functional regression technique [ Fassò and Finazzi, 2013; Berrocal et al., 2010]. Such a technique enables the decomposition of the total uncertainty into its different contributions. Work will also be undertaken on modern efficient Monte Carlo simulation methods, such as the adaptive Markov chain Monte Carlo [MCMC - Haario et al., 2006].  The uncertainty related to monitoring network gaps will be quantified through the statistical characterization of the variability of underlying fields of atmospheric ECVs. The proposed approaches will be tested on a selection of GAIA-CLIM target ECVs for demonstration. Examples using only one ECV and examples with more than one ECV will be also considered to study the impact of synergy with respect to a rational exploitation of available measurements.  UniBergamo: Design and provide advanced geostatistical modelling able to take into account the various forms of variability due to spatial, temporal, climatic and environmental factors and decomposing the total uncertainty accordingly. The model will be able to differentiate natural variability and network uncertainty, including non linear effects and the analysis of extreme values [Abarbane et al., 1992; Fassò et al, 2013, Delicado et al., 2010, and Caballero et al., 2013]. The output will be a network uncertainty map for a subset of ECVs based on modern space-time statistical models for complex data [Cressie and Wikle, 2011; Haario et al., 2006] capable of identifying gaps, i.e. parts of the map with high uncertainty.  FMI: Design and provide modern efficient Monte Carlo simulation methods. This will include a statistical characterization of the variability of underlying fields of atmospheric parameters by the structure function [Yaglom, 1987], which will be estimated using chemistry-transport models and experimental data. Recent development and applications of this approach [Sofieva et al., 2008; Sofieva et al., 2014a, b] have demonstrated its potential in assessment of natural variability, sampling uncertainty, and validation of precision estimates  UBremen: Provide measurements from TCCON sites for the geostatistical assessment of the geographical gaps.  CNR: Prepare the datasets of ECVs to be used as input for the geostatistical approaches, taking advantage of its consolidated experience in handling surface-based measurements from multiple in-situ and remote sensors.  ECMWF: Advise on how the approach and results of this Task contribute to the System of Systems approach for satellite validation/calibration. | | | | | | | | |
| **Task 1.5 Model-based assessment of gaps** (lead: KIT; involved: BIRA-IASB, FMI, MPG; ECMWF)  GAIA-CLIM Project objectives addressed: S6  This task involves gaining insights through model-based analyses of the possible impacts of gaps in observing system capabilities upon our knowledge of and ability to characterise the quality of EO measures. It will address questions such as:   * Where the in-situ capabilities are noted to have gaps, or to lack a transfer standard, then do these need to be filled by additional in-situ data, or is a model-based interpolation or analysis based field estimate a plausible alternative means of EO sensor characterisation? * Where, based upon our understanding of atmospheric processes, would additional measurements add most interpretative value to EO sensor characterisation? * Does measurement frequency, scheduling or quality matter more? What would be the trade off between these in terms of our ability to characterise EO sensor performance? * Do fewer measurements with lower uncertainties have benefits over more measurements but with higher uncertainties?   The proposed work will be based on existing model runs and some new simulations from the full range of modelling tools at our disposal for diagnosing insights to GAIA-CLIM core ECVs (Table 1, Section 1.3). These include various types of reanalyses, existing global chemistry climate models and inversion models, already developed and being run by the participants (no model development is to occur in this task). Taken together Task 1.4 and 1.5 will provide both a robust assessment of the effects of geographical gaps on our ability to characterise EO observations. | | | | | | | | |
| KIT: Will lead the task. KIT will also make global chemistry climate model simulations to address different climate or emission scenarios, and verify the ability of the current ground-based networks to retrieve climate change signals. The main objective is to work to provide chemistry climate model results primarily for the NDACC stations, with a possible extension to the other observations: (1) for the past one or two decades to better help characterizing representativeness, gaps and accuracy of the network and (2) for the future to assess what the expected changes are under different climate changes/emission scenarios and how the measurement networks need to be improved or augmented to capture these expected changes.  BIRA-IASB: will use the chemistry transport model IMAGES and its adjoint-based inversion system to assess gaps in the Observation System for CO and their impact on inverse modelling studies. The inversion system will be used to determine the impact of (1) additional network stations, (2) changes in temporal sampling and (3) improved vertical resolution (in the case of vertical column measurement) on the inversion of emissions, i.e. on posterior flux uncertainties and on the ability of the system to differentiate between different sources. The requirements for a simultaneous inversion of CO sources and chemical sinks will be also explored.  MPG: will use the global tracer transport model TM3 and the Jena Inversion System, to assess the variability of CO2 and CH4 in the atmosphere, and to identify regions of high variability on different time scales (synoptic, seasonal, and interannual) where the sampling of currently available measurements are insufficient to capture and characterize this variability. This will be done through a combination of assessment of forward and inverse simulations. The mathematical framework of the inverse modelling framework allows for the calculation of posterior flux uncertainties based upon hypothetical networks as well, which is useful to test the impact of additional in-situ data.  FMI: will use ECHAM-HAM in nudged mode to assess gaps in the Observation System for aerosols.  KNMI: will use C-IFS-TM5-BASCOE to assess gaps in the Observation System for UTLS ozone, in collaboration with ECMWF. The assessment will be based on in-house experience with C-IFS, the leading role of KNMI in  the MACC/COPERNICUS service validation as well as the leading role of KNMI in the development of tools to utilize IAGOS opertional aircraft (ozone) observations for satellite validation (I-GAS project). No specific simulations with C-IFS are foreseen for the gap analysis.  ECMWF: Will advise on how the approach and results of this Task contribute to the System of Systems approach for satellite validation/calibration, including appropriate use of ECMWF reanalysis/NWP systems. | | | | | | | | |
|  | | | | | | | | |
| **Deliverables** | | | | | | | | |
| **D1.1** – Initial input from WP1 to the gap analysis and impacts document (CNR; M4)  **D1.2** - Modelling studies of the impacts of gaps - experimental design (KIT; M6)  **D1.3** – Report on system of systems approach adopted and rationale (NERSC; M9)  **D1.4** – Review of and input to Gap Analysis and impacts document aspects relevant to WP1 (CNR; M16)  **D1.5** - Summary of initial model-based study results and plans for remainder of project (KIT; M16)  **D1.6** – Report on data capabilities by ECV and by system of systems layer for ECVs measurable from space. (CNR; M18)  **D1.7** – Report on the collection of metadata from existing network and on the proposed protocol for a common metadata format (CNR; M18)  **D1.8** – Provision of a 3D tool for the online visualization of existing measurements (CNR; M24)  **D1.9 –** Report on the scientific assessment of gaps using a statistical approach based on heteroskedastic functional regression (UniBergamo; M34)  **D1.10 -** Report on the scientific assessment of gaps based on forward, inverse, and data assimilation modelling frameworks, (KIT, M34) | | | | | | | | |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Workpackage Number** | WP2 | **Start date or starting event** | | | | Month 1 | | |
| **WP Title** | | Measurement uncertainty quantification | | | | | | |
| **Participants number** | | **5** | 3 | 2 | 14 | | 6 | 9 |
| **Participant short name** | | **BKS** | CNR | BIRA | NPL | | KNMI | FMI |
| **Person months per participant** | | 24 | 14 | 11 | 10 | | 8 | 8 |
| **Participants number** | | 11 | 19 | 10 | 4 | | 20 | 12 |
| **Participant short name** | | TUT | KIT | UBremen | MO | | NASA JPL /CALTECH | GCOS |
| **Person months per participant** | | 6 | 6 | 6 | 4 | | 4 | 1 |
|  | | | | | | | | |
| **Objectives** | | | | | | | | |
| * To define reference quality measurement capabilities for instruments in reference quality networks and sub-orbital (sonde and airborne) measurement capabilities currently lacking full traceability. * To quantify uncertainties in baseline network measurement capabilities * To quantify uncertainties in comprehensive observing network capabilities * To provide a scientific assessment summarizing the uncertainties in all three types of network (reference, baseline and comprehensive observing network) including the existing gaps in our knowledge of the actual measurements uncertainties. * To add the uncertainty assessment for the measurement capabilities to the online tool for the visualization of existing measurements capabilities for each ECV (developed in WP1). | | | | | | | | |
|  | | | | | | | | |
| **Description of work, lead partner and role of participants** | | | | | | | | |
| **Task 2.1. Development of reference quality measurement capabilities and uncertainty quantification** (lead: BKS, involved: BIRA, CNR, KNMI, FMI, KIT, UBremen, MO, TUT, NASA JPL/CALTECH)  start: M1, end: M24  GAIA-CLIM Project objectives addressed: S3, O1, T3, T4  From the complete list of key ECVs targeted within this project (Section 1.3, Table 1), we have selected a subset of ECVs measured with techniques mature enough to be very likely candidates for data streams of reference quality (Section 1.3, Table 2). This includes not only the development of reference quality measurement capabilities and uncertainty quantification at reference sites but also on airborne platforms.  This task consists of several sub-tasks that will build on the efforts previously made by groups and networks such as GRUAN, NDACC, TCCON, EARLINET, and EUFAR to improve our understanding of the fundamental measurement uncertainties. The ECV/instrument combinations omit many of the evidently important ECVs such as T, humidity and wind measured by e.g. RS 92 radiosondes because these data products are already of reference quality (Table 2). These existing reference streams will be included along with the newly developed reference data streams within this task into the subsequent WPs.  Full traceability and uncertainty quantification for each instrument type is needed and a process similar to that discussed in Immler et al. [2010] will be followed to define measurement protocols which will achieve this task. These protocols need to be homogenized across similar instruments at different locations. To this end, the operating procedures and available metadata must be assessed thoroughly. The information collected in the metadata survey completed under WP1 will be utilized here.  Each of the ECV/instrument combinations will be investigated in individual subtasks. The analysis algorithm and error characterization is to be undertaken by instrument experts within the consortium in consultation with the wider scientific community and literature reviews. Each sub-task will result in a technical document describing the measurement procedure, the existing gaps in the uncertainty assessment, and also aim to deliver a peer-reviewed publication describing the measurement traceability and its uncertainty (the latter not determined as a deliverable specifically). | | | | | | | | |
| **Task 2.1.1. Aerosol, H2O, O3, and temperature profiles measured by lidar** (lead: KNMI; involved: CNR, NASA JPL / CALTECH)  GAIA-CLIM Project objectives addressed: S3, O1, T3, T4  The team of lidar experts will collaborate closely on the following topics:   * Investigate aerosol optical properties and humidity in the upper troposphere / lower stratosphere (UTLS) retrieved using the Raman pure rotational and Raman roto-vibrational lidar techniques. * Provide a comprehensive characterization of the total uncertainty budget for the measurements of aerosol optical properties, water vapour, ozone and temperature. * Provide a clear description of vertical resolution for the measurements of ozone (ground to 50 km) and temperature (10 to 80 km) by lidar. * Use of DIAL (differential absorption lidar) to measure tropospheric ozone. * Incorporate previous work done by networks such as EARLINET, ACTRIS and NDACC, and especially work done under NDACC/GEWEX/ISSI on NDACC lidar algorithms and uncertainties. * Homogenise the methodologies with common input, output and terminology – aiming at easy use – with emphasis on techniques not covered in previous work (e.g. HSRL for aerosol optical properties). * Assess the sensitivity, stability and the random and bias component of the uncertainty affecting the measurements in the UT/LS where both the aerosol optical depth and the water vapour content are very low but nevertheless critical in the global/regional climate system and the geochemical cycle.   CNR: Provide a comprehensive characterization of the total uncertainty budget for the measurements of aerosol optical properties. Contribute to the characterization of relative calibration methods of Raman lidar water vapor profiles based on the use of ancillary measurements from surface-based remote sensing techniques and on their intercomparison with the absolute or hybrid calibration methods.  KNMI: Provide a clear error description for pure rotational Raman techniques for aerosol optical properties and temperature, and establish measurement and metadata guidelines for the lidar data products, incorporating cross-linking with networks such as NDACC and EARLINET.  NASA-JPL/CALTECH: Provide comprehensive and fully-quantified measurement and algorithm uncertainty budgets for lidar, as well as consistent NDACC-standardized definitions of vertical resolution, building on ISSI Team on Lidar Algorithms Recommendations and Guidelines [2014]. These standardized definitions will be implemented in the GRUAN Lidar Analysis Software Suite (GLASS), the centralized data processing software for GRUAN water vapour, ozone and temperature lidars currently under development. The GLASS can be used as a cost effective means to collect and process the raw data and send products to the virtual observatory. | | | | | | | | |
| **Task 2.1.2. Temperature and H2O profiles measured by microwave radiometers** (CNR)  GAIA-CLIM Project objectives addressed: S3, O1, T3, T4  Define reference quality measurement capabilities for ground-based tropospheric temperature and humidity profiling by multichannel microwave radiometers (MWR). Review and report the MWR observation protocols currently adopted at reference sites for temperature and humidity profile retrievals. Evaluate the actual uncertainties of MWR retrievals, depending upon proper calibration, maintenance, measurement strategy (e.g. scanning), as well as retrieval method. Associate a traceable level of uncertainty to current observations and to identify gaps towards the full traceability. Provide validation against nearly simultaneous and collocated reference quality measurements (e.g. RS92 radiosonde) at selected reference quality sites (e.g. GRUAN).  CNR**:** Coordination of this task. Definition of reference quality measurements. Quantification of uncertainties. Cooperation with GRUAN Task Team on Ancillary Measurements and MWR Working Group of the EU COST Action TOPROF (Towards Operational ground based PROFiling with ceilometers, Doppler lidars and microwave radiometers for improving weather forecasts). | | | | | | | | |
| **Task 2.1.3. CH4, CO2, O3, H2O and N2O columns and profiles measured by FTS** (lead: BIRA; involved: FMI, KIT, UBremen)  GAIA-CLIM Project objectives addressed: S3, O1, T3, T4  Analyse FTS data processing uncertainties using flexible retrieval software, allowing sensitivity and non-linearity assumptions studies. In particular, investigate, summarize and report FTS data processing uncertainties regarding CO2 and CH4 total column measurements within the TCCON network.  BIRA, UBremen, KIT: Jointly analyse the uncertainties with regard to noise and an offset for total column and profiles measured by FTS spectrometers within NDACC and TCCON. Analyse the results for selected sites for a whole year. Investigate the uncertainties as a function of temperature, humidity, and pollution level. Perform sensitivity studies for all trace gases to assess the impact of the apriori concentration profiles on the total columns and profiles since e.g. spectral line parameters and new retrieval strategies (for example including line-mixing or non-Voigt assumptions on the line-shape) influence the retrieved results. Investigate these effects by using different analysis packages.  FMI: Contribute to investigation of FTS data processing uncertainties regarding TCCON retrieval of CO2 and CH4 total column amounts. Measurements by the AirCore system will be applied to investigate influence of a priori profiles on the retrieval quality. Use MCMC retrieval algorithm for actual computation of the posterior distributions. | | | | | | | | |
| **Task 2.1.4. O3 total column measured by UV/visible spectroscopy** (lead: BKS, involved: BIRA)  GAIA-CLIM Project objectives addressed: S3, O1, T3, T4  Define reference quality measurement capabilities for total column ozone abundances by UV/visible spectroscopy. Investigate and review measurement protocols. Investigate the total column ozone measurements for gaps in the uncertainty assessments. This will include, in addition to the DOAS (Differential Optical absorption Spectroscopy) zenith-sky instruments run under the umbrella of the NDACC, also UV/visible spectroscopy instruments making use of direct-sun observations. Liaise with EURAMET project team on outcome of their investigation on improving the characterization and calibration of the Dobson and Brewer instruments with the aim to increase the traceability for atmospheric total column ozone measurements. Study the link between DOAS instruments and other total ozone measuring techniques (Brewer, Dobson, FTIR) by using existing data sets from co-located instruments such as available at the calibration site of Izana, on the Tenerife island.  BKS: Coordination of this task and the uncertainty assessment reporting including the overall uncertainty gap analysis. In-depth uncertainty analysis at the instrumental level and at the DOAS analysis level for total column ozone from zenith-sky and direct-sun measurements. Liaise with EURAMET team to investigate the inclusion of Dobson and Brewer measurements.  BIRA: In-depth uncertainty analysis of the air mass factor calculations required to convert the measured slant columns into the total vertical column. Investigation of ozone data comparison between co-located instruments. | | | | | | | | |
| **Task 2.1.5. Tropospheric O3 measured by MAX-DOAS, Pandora** (lead: BIRA, involved: BKS, FMI)  GAIA-CLIM Project objectives addressed: S3, O1, T3, T4  Perform a full in-depth error analysis, considering instrumental issues (e.g. the role of stray-light), spectral analysis issues (DOAS), radiative transfer calculations and inversion techniques necessary to convert MAX-DOAS scan measurements into total and tropospheric ozone column data. Link with algorithm developments being carried out in an ESA-funded project (CEOS ICal). Include Pandora systems alternating direct-sun and MAX-DOAS scan measurements (in addition to the MAX-DOAS instruments run under the umbrella of the NDACC).  Link assessment of the uncertainty of tropospheric ozone measurements by UV/Visible instruments to uncertainty assessment of other ozone measuring techniques such as FTS (task 2.1.3), and DIAL (2.1.1). The establishment of such a link will rely on existing co-located measurements at several observation sites of the NDACC (e.g. Reunion Island and Izana). Consider vertical sensitivity and horizontal representativeness issues based on the experience developed within the NORS project on comparing measurements capabilities from different techniques.  BIRA: Coordination of this task. Uncertainty analysis based on radiative transport calculations and inversion techniques issues. Establish links with the NORS project to gain access to the expertise already developed within NORS e.g. for the inter-comparison of measurement capabilities for different instruments.  BKS: In-depth uncertainty analysis and spectral analysis issues. Liaise with CEOS ICal team to link in with algorithm development made under CEOS ICal. Responsible for final report.  FMI: Analysis of Pandora measurement procedures with emphasis on high latitudes and liaise with other Pandora experts. | | | | | | | | |
| **Task 2.1.6. Total Column Water Vapour measured by GNSS** (lead: TUT, involved: MO)  GAIA-CLIM Project objectives addressed: S3, O1, T3, T4  Substantial work has been undertaken to understand the uncertainties in advancing from phase delay measurements (traceable to SI units of time) to measures of TCWV. The present processing lacks complete traceability because the Zenith Total Delay (ZTD) is a field provided by a third party. This task would advance GNSS-PW estimates to full traceability by augmenting existing procedures to enable a fully traceable processing. This task will realise synergies with COST action ES1206 and associated software developers - MIT (developers of GAMIT/GLOBK) and EPOS (GFZ) or Bernese (AIUB).  It will contribute to clarification of the background of derivation of the ZTD (as a final product of IGS) with uncertainty, claimed <=4mm. This uncertainty dominates GNSS-PW uncertainty. It is known that this 4mm is a formal error dependent on GNSS-data processing methods and software. Therefore clarification for both Precise Point Positioning (PPP) and Double Differenced (DD) methods and at least for two GNSS-data processing software suites is needed. The work comprises both analysis of the methods and models used within the data processing software. The relevant issues with the PPP method will be supported by outcomes of COST ES1206 WP1 partners (GFZ and NGAA) tasks and efforts on GNSS data processing methods.  TUT: Coordination of this task. Will contribute mostly on DD method and GAMIT/GLOBK software analysis. Supporting experimental studies will be planned together with MO. Clarify how both software solutions define the ZTD formal error and define what the components and their contributions to this formal error are.  MO: Contributes to DD method and Bernese software analysis. Close collaboration with TUT on other parts of the task. | | | | | | | | |
| **Task 2.2. Quantification of uncertainties in baseline and comprehensive measurement capabilities** (lead: BKS; involved: CNR, KNMI, MO, GCOS)  start: M12, end: M30  GAIA-CLIM Project objectives addressed: S3, O1  For the subset of ECVs for which WP1 designated a baseline network capability, this work task will identify, to the best of ability given available material in both published and grey literature, a defensible set of bias and uncertainty estimates for these measures. An extensive characterisation of the ‘accepted best practice’ used within the measurement protocols, the uncertainty assessment and traceability of the ECVs of interest will be undertaken. For comprehensive network measurements a best guess value will be provided. This also includes an investigation of measurement uncertainties and traceability of observations made on airborne platforms. A summary of these estimates will be fully documented in a report and, if deemed appropriate one or more papers.  BKS: Coordination of this task. Liaise with the relevant science community on the commonly used best practice measurement procedures. Undertake extensive literature review to establish uncertainty estimate and lead write-up of resulting documentation.  CNR: Provide input via the review of current observing capability for the core ECVs through metadata collection under WP1. Contribute with sharing of ACTRIS quality assurance instrumental protocols and best practice, and contribute to the literature review and report.  KNMI: Provide input from the satellite community form various mission CAL/VAL documents and teams. Contribute to literature review and report.  MO: Analyse and characterise the measurement bias of aircraft-based observations. For improved bias correction the dependence of flight mode is needed, i.e. in ascent, en-route and descent modes, when difference in aircraft speed and time lags cause biases to differ (also by airline & aircraft type). Characterise biases of aircraft-based observations against nearby traceable radiosondes.  GCOS: Provide input on the GSN and GUAN baseline network capabilities and their uncertainty quantification through liaison with CIMO, WIGOS and NMSs. | | | | | | | | |
| **Task 2.3. Review of the methodologies and tools used for uncertainty quantification (**lead NPL; involved: BKS**)**  start: M12, end: M36  GAIA-CLIM Project objectives addressed: S3, O1  Continuous review of the methodology and tools devised in Tasks 2.1 and 2.2 to ensure that the uncertainty traceability and quantification techniques rigorously follow best practice and that the procedures used for the different instruments and measurements techniques are demonstrably comparable.  NPL:   * Review of the initial methodology devised by the task partners, with consultation on best practice and accordance with the GUM. * Independently verify the methods for a few example instrument/methods /tools detailing the steps taken and necessary considerations. The examples chosen will include a straightforward (simple) case and a more complex case that exemplifies the additional considerations necessary. * Feed into the task of the WP partners where needed to ensure a robust treatment that is aligned with that of related techniques for EO applications. * Review of the resultant traceability, uncertainty quantification and measurement protocols to ensure that these follow the original methodology. * Create a best-practice document, detailing the philosophy of the methods, and worked example execution including the resulting uncertainty quantification to facilitate the applications of these techniques to other instruments by the wider community.   BKS: Liaise with work packages partners on all subtasks under Task 2.1 to ensure that the uncertainty assessments and outcomes from the work package subtasks will be used appropriately and ensure feed-back to the individual subtask teams. Contribute to the write-up of the best practice document. | | | | | | | | |
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| **Deliverables** | | | | | | | | |
| **D2.1** – Initial report on measurement uncertainty gap analysis (BKS; M4)  **D2.2** – Intermediate report on measurement uncertainty gap analysis (BKS; M16)  **D2.3** – Uncertainty assessment for the measurement capabilities provided to WP5 (BKS; M21)  **D2.4** – A best-practice document including the resulting uncertainty quantification (NPL; M24)  **D2.5** – Report summarizing the uncertainty estimates for the ECVs identified in task 2.2 (BKS; M30)  **D2.6** – Final report on measurement uncertainty gap analysis from each subtask under task 2.1 (Various; M33)  **D2.7** – Final review of and update to the GAID from the perspective of WP2 (BKS; M34) | | | | | | | | |

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| **Workpackage Number** | WP3 | **Start date or starting event** | | | | Month 1 | | |
| **WP Title** | | Comparison error budget closure - Quantifying metrology related uncertainties of data comparisons | | | | | | |
| **Participants number** | | **2** | 15 | 14 | 9 | | 11 | 3 |
| **Participant short name** | | **BIRA** | UniBergamo | NPL | FMI | | TUT | CNR |
| **Person months per participant** | | 33 | 18 | 14 | 14 | | 12 | 9 |
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| **Objectives** | | | | | | | | |
| * What a measurement system really sees: To understand and quantify the additional errors of one-dimensional retrievals of the atmospheric column/profile, resulting from their actual space-time smoothing and sampling of the atmospheric field. * How to compare two measurement systems: To understand and quantify irreducible measurement mismatch (smoothing and sampling) impacts on resulting data comparisons * Transfer into Virtual Observatory: To develop and provide software tools to enable the handling of measurement mismatch uncertainties in the Virtual Observatory (WP5). | | | | | | | | |
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| **Description of work, lead partner and role of participants** | | | | | | | | |
| **Task 3.1. Metrology uncertainties of individual measurement systems** (lead: BIRA; involved: UniBergamo, CNR, FMI, NPL)  Start: M1 End: M32  GAIA-CLIM Project objectives addressed: S4, T2, O1, O4  WP1 provides descriptions of existing measurement systems (instruments, networks and satellites). In WP2 measurement uncertainties are derived for these systems with the assumption that a one-dimensional profile is measured in a homogeneous atmosphere. Here, in Task 3.1, we investigate and quantify additional uncertainties resulting from the space-time smoothing and sampling of the real atmospheric field (with gradients and variability).  BIRA: Coordination of this task; work plan; contribution of expertise on trace gases; use of OSSSMOSE system: generic observation operators developed in FP6 GEOmon (zenith-sky DOAS, balloon-sondes, lidars, 5 key families of satellites) and FP7 NORS (FTIR, MAX-DOAS) describing the multi-dimensional smoothing/sampling of ground-based and satellite measurements will be applied to reanalyses fields in order to quantify sampling and smoothing uncertainties associated with them; sensitivity studies vs. measurement parameters like Solar Zenith Angle (SZA) and temperature.  UniBergamo (with BIRA): Task 1.4 (gap analysis) studies the sampling properties of the atmospheric signals and structures and detects potential gaps in the coverage offered by existing global systems. Task 3.1 will carry out similar studies (on a test case basis only) but including the multi-dimensional smoothing/sampling aspects to assess their impact. Task 1.4 (1D) and Task 3.1 (3D/4D) results will be compared.  CNR, FMI, NPL: Contribution of expertise on aerosols, water vapour and temperature, and on statistical approaches. | | | | | | | | |
| **Task 3.2.** **Metrology uncertainties of data comparisons** (lead: BIRA; involved: UniBergamo, CNR, NPL, FMI)  Start: M6 End: M32  GAIA-CLIM Project objectives addressed: S4, T2, O1, O4  Both statistical approaches and physically explicit descriptions will be adopted to investigate measurement mismatch impacts on data comparisons for the global measurement systems considered in WP2 (and pre-existing reference measurements – see Section 1.3, Table 2) and WP5:  BIRA: Coordination of this task; work plan; assessment of total uncertainty of data comparisons uniting measurement/retrieval uncertainties from WP2 and comparison errors obtained by explicit physical description of smoothing/sampling errors (all targeted ECVs)  UniBergamo: Statistical assessment of collocation mismatch errors extending the approach of heteroskedastic functional regression introduced in Fassò et al. [2013]. This flexible approach is used in task 1.4 as a basis for geostatistical analysis of single vertical profiles and is used here for decomposing the collocation mismatch errors into relevant components (all targeted ECVs).  CNR: Support to UniBergamo and in addition specific collocation mismatch studies on aerosols  NPL: Quantification of temporal mismatch in vertical temperature profiles. In addition, NPL will assess the metrological traceability of the comparison error budget, starting from the generic guidelines established in FP7 QA4ECV and adapting them to the data comparisons envisaged here.  FMI: Quantification of collocation mismatch uncertainties for water vapour and aerosols | | | | | | | | |
| **Task 3.3. Software tools for WP3 results implementation in WP5** (lead: TUT; involved: BIRA, CNR, FMI, NPL, UniBergamo)  Start: M1 End: M32  GAIA-CLIM Project objectives addressed: T2, O4  The knowledge resulting from WP3 must be transferred into the Virtual Observatory designed in WP5, the latter including (a) the creation of a collocation database associated with all necessary uncertainty information and metadata to perform evaluation and calibration of satellite data, and (b) the development of an interface front end to allow visualization of the resulting comparisons and quality indicators derived. This Task 3.3 consists in developing software tools ensuring proper definition of collocation criteria for the VO and proper consideration of collocation mismatch uncertainties (3D/4D smoothing and sampling issues) in the comparisons and quality indicators derived.  TUT: Coordination of this task; work plan; in parallel with scientific developments of Tasks 3.1 and 3.2 by other WP partners, TUT will develop software tools to ensure appropriate transition of WP3 knowledge and results into WP5 Virtual Observatory.  BIRA, CNR, FMI, NPL, UniBergamo: Contribution of scientific expertise from Tasks 3.1/3.2. | | | | | | | | |

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| **Deliverables** |
| **D3-1 -** Initial input from WP3 to the gap analysis and impacts document (BIRA; M4)  **D3-2 –** Paper/TN describing generic metrology aspects (individual errors from WP2 plus smoothing and sampling issues) of an atmospheric composition measurement and of data comparisons, with a view to feeding the Virtual Observatory characterisation/visualisation developed in other WPs. (BIRA; M12)  **D3-3** - Review of and input to Gap Analysis and impacts document aspects relevant to WP3 (BIRA; M16)  **D3-4** – Paper/TN reporting on measurement mismatch studies (Task 3.2) and their impact on data comparisons, for all ECVs (UniBergamo, M24)  **D3-5** – Beta set of tools for quantification of collocation mismatch and smoothing uncertainties and associated documentation for integration in the development of the virtual observatory (TUT; M24)  **D3-6** – Library of (1) smoothing/sampling error estimates for key atmospheric composition measurement systems, and (2) smoothing/sampling error estimates for key data comparisons. (BIRA; M30)  **D3-7** - Final version of tools for quantification of collocation mismatch and smoothing uncertainties and associated documentation for integration in the virtual observatory that reflects any subsequent updates arising as a result of a. feedback from WP5 and b. any subsequent finessing in Tasks 3.1 and 3.2 (TUT; M32)  **D3-8** - Final review of and update to the GAID from the perspective of WP3 (BIRA; M34) |

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| **Workpackage Number** | WP4 | **Start date or starting event** | | | | Month 1 | | |
| **WP Title** | | Assessment of reference data in global assimilation systems and characterisation of key satellite datasets | | | | | | |
| **Participants number** | | **4** | 7 |  |  | |  |  |
| **Participant short name** | | **MO** | ECMWF |  |  | |  |  |
| **Person months per participant** | | 88 | 44 |  |  | |  |  |
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| **Objectives** | | | | | | | | |
| * Demonstrating the capability of NWP and Reanalysis systems to validate measurements from key new meteorological satellites. * Developing, *as a demonstrator of a general approach*, the infrastructure required to ingest and monitor reference network data (GRUAN) in NWP and reanalysis (global) models and produce near real-time statistics on the comparison. * Defining the measurement performance requirements for reference data sources for the validation of NWP and Reanalysis models and hence satellite observations. * Illustrating how the methods developed in this WP, targeting Level 1 datasets for temperature and humidity estimation, extend to a broad range of atmospheric, land surface and ocean ECVs. | | | | | | | | |
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| **Description of work, lead partner and role of participants** | | | | | | | | |
| **Task 4.1 Complete the assessment of new satellite missions** (lead: MO, partner: ECMWF)  start: M1, end: M36  GAIA-CLIM Project objectives addressed: S5, T3, O1  Carry out a comprehensive calibration and validation of data from several new satellite missions. To include as a minimum: SSMIS-F19 (US), FY-3C (China) and GCOM-W (Japan) as well as (data availability permitting) FY-3D (China); JPSS-1 (US) and MetOp-C (Europe). MO will focus on characterising the spatial variability, geophysical state dependence and instrument state dependence of observed biases using a data assimilation system designed for near-real-time global weather forecasting. This will elucidate the physical mechanisms causing observed biases, allowing parameterised corrections to be developed. Sensitivity to the underlying assimilation system will be examined by equivalent diagnostics from the MO and ECMWF NWP systems for those satellite datasets common to both. In addition, the links to longer-term drifts will be assessed. | | | | | | | | |
| **Task 4.2 Develop infrastructure for near real time dissemination of reference data.** (lead: MO, Partner: ECMWF)  start: M1, end: M24  GAIA-CLIM Project objectives addressed: S5, T3, O1  Acquisition infrastructure for different configurations: nrt for operational NWP (MO), offline-reanalysis suitable for generic reprocessed datasets and anticipating quasi-real-time reanalysis (ECMWF). Data from operational GRUAN reference sites will be archived as close to nrt as possible. Data archived within 1-2 weeks of measurements will be available for reanalysis and dedicated off-line runs of full NWP data assimilation systems at ECMWF and Met Office. Software systems will be implemented to ingest, archive and monitor receipt of the GRUAN reference data. | | | | | | | | |
| **Task 4.3 Develop software infrastructure for the monitoring of reference data with respect to global assimilation systems.** (lead: MO, partner: ECMWF)  Start: M19 End: M34  GAIA-CLIM Project objectives addressed: S5, T3, O1  Design and code observation operators in ECMWF and Met Office systems that make full use of the reference data mentioned in Task 4.2, including associated uncertainty estimates. Design and code post-processing systems, to include estimation of 1D model error covariances with respect to reference data and estimation of model biases with respect to reference-quality observations. Provide these diagnostics to the collocation database user tool to be developed in WP5. | | | | | | | | |
| **Task 4.4 Develop a general methodology for using reference data for the cal/val of EO data using data assimilation systems** (lead: MO partner: ECMWF)  Start: M24 End: M36  GAIA-CLIM Project objectives addressed: S5, O1  Develop outline plans for other variables and domains based upon experience with demonstrator data streams processed in task 4.1 through 4.3, and consultation with *in-house* (and external) experts on land surface, ocean and composition data assimilation systems. Capacity-building in the form of training and support for users of the WP5 database on use of the data assimilation information provided, especially the workshop (targeting users but also inducting future training providers) and documentation. | | | | | | | | |
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| **Deliverables** | | | | | | | | |
| **D 4.1** - Initial input from WP4 to the gap analysis and impacts document (MO; M4)  **D 4.2 –** Individual reports on validation of satellites (MO; M12, M24, M34):   * GCOM-W AMSR-2 (MO; M12); * FY-3C (MO; M24) and; * SSMIS F-19 (MO; M34) * Data availability permitting the same will be delivered for FY-3D (China) JPSS-1 (US) (MO; M34)   **D 4.3 -** Review of, and input to, Gap Analysis and impacts document aspects relevant to WP4 (MO; M16)  **D 4.4 –** Publicly available web-based monitoring pages showing a comparison of GRUAN observations with MO and ECMWF data assimilation systems as an input to the virtual observatory. (MO; M24)  **D 4.5 –** Report detailing approach to the calibration and validation of (atmospheric state variable) EO data, and detailing proposed approach to other ECVs and associated EO data. (MO; M34)  **D 4.6 –** Workshop, to be organised through relevant global agency/initiative (e.g. WMO, GSICS), to disseminate findings of WP4; and training material and practical sessions to induct future training providers. (MO; M34)  **D 4.7** - Final review of and update to the GAID from the perspective of WP4 (MO; M34) | | | | | | | | |

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| **Workpackage Number** | WP5 | **Start date or starting event** | | | | Month 1 | | |
| **WP Title** | | Creation of a ‘virtual observatory’ visualization and data access facility | | | | | | |
| **Participants number** | | **15** | 11 | 17 | 19 | | 2 | 13 |
| **Participant short name** | | **EUMETSAT** | TUT | NOAA | USTL | | BIRA | NPL |
| **Person months per participant** | | 35 | 30 | 24 | 24 | | 4 | 2 |
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| **Objectives** | | | | | | | | |
| * Creation of a collocation database for satellite and reference measurements including NWP model-based (re)analyses. * Creation of data interrogation and visualization tools building upon existing European and global infrastructure capabilities. * Evaluation of Virtual Observatory to demonstrate its utility for scientific/statistical analysis of respective observations, performance characteristics and the monitoring of instrument and product behaviour over time. * Provision of a transition roadmap for the ‘virtual observatory’ (including outputs from WP1 through WP4) from research to operational status enabling operational use in Copernicus services. | | | | | | | | |
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| **Description of work, lead partner and role of participants** | | | | | | | | |
| **Task 5.1 Collocation database for satellite and reference measurements** (lead: EUMETSAT, partners: BIRA, NOAA, TUT, USTL)  Start: M1 End: M30  GAIA-CLIM Project objectives addressed: T4, O1, O4, O5, O6  This task develops tools that in a semi-automated manner create collocations within time and space windows optimising the use of the reference data. This involves capturing the space-based measurement and any ancillary information required for its interpretation such as radiometric quality, geometrical sampling, etc. as well as the reference measurement and its uncertainty.  Additional ancillary information such as NWP model based reanalysis and analysis data as well as Observation-Analysis feedback files delivered by WP4 will be attached to the collocations. Both satellite and reference data and uncertainties are to be retained in parameter and radiance space as much as possible to enable L1 through L3 evaluation/calibration.  The Virtual Observatory will also consider satellite instruments that have the potential to serve as reference for ground-based data sources such as radio occultation data for temperature profiles measured by radiosondes.  The technical work will begin by making an inventory of the existing software solutions at consortium partner sites similar to the FP7 project CRISMA to develop an optimal set up including a consideration of cost efficiency. The inventory will clearly document the existing tools and technologies that are accessible to the consortium partners. This is an essential step to guide the development and integration of software modules for the virtual observatory. | | | | | | | | |
| EUMETSAT: will provide the infrastructure for the collocation data bases and develop and integrate necessary software. Furthermore EUMETSAT will provide collocations at Level 1 and 2 for EUMETSAT MetOp and Meteosat instruments and third party missions as indicated in WP4 back to the start of available reference network measurements. Collocations with geostationary instrument data are benefiting from a much higher temporal sampling of the satellite data and provide useful evaluations of the reference observations. This includes forward radiative transfer applied to the reference measurements using RTTOV or more complex radiative transfer models if needed. The radio occultation data will be used to evaluate the quality of the reference measurements (atmospheric profiles) in particular for the upper troposphere and stratosphere.  BIRA**:** supports TUT in the set up of the technology inventory based on its experiences with WP3 (collocation mismatch uncertainties and comparison error budget), with the NORS validation server and with the ESA GECA project. In addition BIRA will consult TUT on the determination of collocations with the data from NDACC and MACC analyses.  NOAA**:** will support the building of the technology inventory, and provide guidance on software developments with a focus on temperature and humidity measurements. In addition, NOAA will consult with EUMETSAT on the use of radio occultation data and the validation of radiative transfer models used to create radiances from the reference measurements.  TUT**:** will use the inventory of the existing software solutions at project partner sites to develop an optimal set up including cost efficiency. In addition, TUT will support EUMETSAT in the development of web based applications needed for delivering diagnostic results on the collocations.  USTL: supports TUT in the set up of the technology inventory based on its experience with the ICARE validation platform <http://www.icare.univ-lille1.fr/extract>. In addition U Lille will provide collocations concerning satellite observing systems such as POLDER for aerosol optical depth. | | | | | | | | |
| **Task 5.2 Graphical user interface and tools** (lead: TUT, partners: BIRA, EUMETSAT, NOAA, TUT, USTL)  Start: M1 End: M30  GAIA-CLIM Project objectives addressed: T1, T2, T3, T4, O1, O4, O5, O6  The objective is the development of an interface front end to allow visualization of the resulting comparisons and derived quality indicators and downloading of data in at least two user friendly formats including CF-compliant NetCDF. Task 5.2 also involves the incorporation of the mapping facility output from WP1 Task 1.3.  EUMETSAT, BIRA, NOAA, and USTL:will develop the set of diagnostic measures and associated graphics needed for data quality evaluation, instrument monitoring and eventually estimation of calibration, benefitting from operational monitoring diagnostics at EUMETSAT and the platforms mentioned for Task 5.1. These diagnostics will span from verifying the integrity of the collocations (pre-analysis) to being able to subsample, e.g., spatially, regionally, meteorologically, per satellite, etc and perform analysis.  TUT: develops the graphical user interface based on the design chosen.  EUMETSAT:will import and deploy the software delivered by TUT and WP1 and WP3 on the hardware that serves the Virtual Observatory and operate it at the end of the project. | | | | | | | | |
| **Task 5.3 Evaluation of Virtual Observatory** (lead: EUMETSAT, partners: BIRA, USTL, NPL)  Start: M25 End: M36  GAIA-CLIM Project objectives addressed: T4, O1, O2, O3  The collocated instrument and product data and the various forward simulations of sensor data from NWP type analysis and reference data will be analysed with respect to their performance in product validation and the monitoring of instrument and product behaviour over time. Results will be compared with existing operational real time instrument and product monitoring and satellite-satellite collocation data bases. An example for the latter is the referencing of geostationary IR measurements to the IASI instrument used for GSICS type instrument inter-satellite calibration. As the outcome from Task 5.3, requirements for the different applications for ground-based reference networks will be derived in terms of spatiotemporal sampling and needed accuracy.  EUMETSAT: will perform an analysis for the monitored instruments L1 data and temperature and humidity ECVs and document the relative value of the reference data versus comparison to NWP type data and direct satellite-satellite collocations with respect to instrument evaluation/calibration.  BIRA: will evaluate the functionalities and suitability of the Virtual Observatory for the quality assessment of the satellite data for atmospheric composition ECVs, based on the NDACC data and also for the aspects of collocation mismatch uncertainties estimated in WP3.  USTL: will evaluate the functionalities and suitability of the Virtual Observatory for the quality assessment of the satellite data for the ECV aerosol, based on AERONET data.  NPL: will evaluate the Virtual Observatory in terms of the principle of the Quality Assurance service developed in the FP7 project QA4ECV, and address suitability of inclusion into that framework. | | | | | | | | |
| **Task 5.4 Transition roadmap from research to operations** (lead: EUMETSAT, partners: USTL)  Start: M30 End: M36  GAIA-CLIM Project objectives addressed: T4, O1, O4, O5, O6  Task 5.4 will plan the transfer of the Virtual Observatory into an operational facility with the potential to continuously run as part of the Evaluation and Quality Control Pillar of the Copernicus Climate Change Service. The objective is to quality control the input data to the Climate Data Store as well as all data records produced as part of the CCCS. Task 5.4 will provide a plan for the automation and extension of all data flows, as well as developing more diagnostic tools and standardised graphical output.  EUMETSAT: will coordinate the development of the plan with the idea to integrate the Virtual Observatory into its operational facilities for climate data record generation.  USTL: will support the development of the plan specifically considering options for a distributed system that includes the ICARE centre. | | | | | | | | |
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| **Deliverables** | | | | | | | | |
| **D5.1** - Initial input from WP5 to the gap analysis and impacts document (EUMETSAT; M4)  **D5.2** - Review of and input to Gap Analysis and impacts document aspects relevant to WP5 (EUMETSAT; M16)  **D5.3** – Technological platform for collocation database (EUMETSAT, M24)  **D5.4** – Graphical user interface (TUT, M24)  **D5.5** –Virtual Observatory Product User Guide and Implementation Description (TUT, M30)  **D5.6** - Final review of and update to the GAID from the perspective of WP5 (EUMETSAT; M34)  **D5.7** – Report on the evaluation of the Virtual Observatory (EUMETSAT, M36).  **D5.8** – Transition roadmap for the Virtual Observatory (EUMETSAT, M36). | | | | | | | | |

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| **Workpackage Number** | WP6 | **Start date or starting event** | | | | | | Month 1 | |
| **WP Title** | | Impact, outreach and dissemination | | | | | | | |
| **Participants number** | | **2** | 9 | 7 | 1 | 6 | 13 | | 3 |
| **Participant short name** | | **BIRA** | FMI | ECMWF | NERSC | KNMI | NPL | | CNR |
| **Person months per participant** | | 7 | 7 | 5 | 5 | 5 | 3 | | 2 |
| **Participants number** | | 15 | 5 | 4 |  |  |  | |  |
| **Participant short name** | | EUMETSAT | BKS | MO |  |  |  | |  |
| **Person months per participant** | | 2 | 2 | 2 |  |  |  | |  |
|  | | | | | | | | | |
| **Objectives** | | | | | | | | | |
| * To interact with the expert user communities to inform the project strategy and to undertake an assessment of the gaps diagnosed in WP1 through WP5 and provide a set of potentially actionable remedies to address these gaps in capabilities and / or knowledge. * To work with the user communities to prioritise the resulting possible actions based upon science and user needs. * To address issues of better coordination of global and European networks and research infrastructures to better serve cal/val of EO data. * To interact regularly with users and the underlying work packages to ensure that project outcomes meet user needs. | | | | | | | | | |
|  | | | | | | | | | |
| **Description of work, lead partner and role of participants** | | | | | | | | | |
| **Task 6.1 Sustained external stakeholder and user engagement** (lead: BIRA; involved: FMI, KNMI, ECMWF, NERSC, CNR, BKS, EUMETSAT, NPL)  Start: M1 End: M36  GAIA-CLIM Project objectives addressed: O1, O2, O3, O7  The call for proposals text recognises the paramount importance of global buy-in to the outcomes of the GAIA-CLIM project. In particular the tools and recommendations developed within the project will only be used and acted upon if there is sustained, pro-active and user oriented engagement throughout the project lifecycle.  Task 6.1 exists to address this need. Through a combination of user surveys and workshops significant efforts will be made to engage users. The task is split into a number of sub-tasks. The task brings together the WP lead institutes together with partners KNMI, FMI, NPL and ECMWF. These nine partners have significant experience in user outreach and themselves represent some of the major user and external stakeholder communities thus ensuring significant reach into target communities. Between them the partners in Task 6.1 serve to a broad variety of users some of the most used data products in geosciences in both near real time and delayed mode. The WP lead has been the coordinator of NORS and brings considerable user engagement experience from having undertaken that project which will be used to ensure that Task 6.1 is executed to a high standard. | | | | | | | | | |
| **Task 6.1.1 User requirements survey** (lead: FMI; involved: CNR, BIRA, BKS, MO, EUMETSAT, ECMWF, KNMI, NERSC, NPL)  Start: M1 End: M5  GAIA-CLIM Project objectives addressed: O1, O2, O3, O7  This task will collect feedback and information from the potential users of the virtual observatory and other envisaged GAIA-CLIM project outcomes and products via a questionnaire disseminated for different target groups and user forums. The survey will be carried out early in the project and provide a baseline set of user expectations as well as help in identifying the group of ore users who may be invited to future workshops (D6.1.2 through D6.1.4). The envisaged timeline of this task is:   * List of potential users and target groups (Month 1). * Final questionnaire agreed (Month 2). * Survey undertaken (Month3-4) * Final report of the survey (Month 5).   FMI: will lead task 6.1.1 and undertake the survey and synthesis of results. FMI recently successfully completed such a survey exercise for the CORE-CLIMAX project and the lessons learnt will be applied to this survey to ensure its success.  CNR, BIRA, BKS, MO, EUMETSAT, ECMWF, KNMI, NERSC, NPL: will help in informing the survey design, facilitate internal testing of the questionnaire through WP members, promote responses to the survey from contacts and their own product users, and aid FMI in the analysis of the survey responses. | | | | | | | | | |
| **Task 6.1.2 First workshop with external users** (lead: BIRA; involved: CNR, BKS, MO, EUMETSAT, ECMWF, KNMI, NERSC, FMI, NPL)  Occur: M9  GAIA-CLIM Project objectives addressed: O1, O2, O3, O7  This workshop will bring together key consortium members and identified target users to discuss GAIA-CLIM aims and objectives and early progress. Key synergistic EU funded activities will be invited to attend and present their view on how to assure value is realised (see Table 5). A range of users including, but not limited to, modellers, data analysts, and climate service providers will also be invited.  The workshop will take as its basis: the project plan for GAIA-CLIM, the first version point of the GAID document (Task 6.2), the summary of the user survey (Task 6.1.1), and the underlying gap analysis deliverables from WPs 1 through 5. Participants will discuss the planned work under GAIA-CLIM, critically review the adequacy of the first version of the GAID document and provide guidance on user requirements from a variety of end-user perspectives.  The workshop summary will constitute a deliverable from WP6 and include a match-up table between available information and user requirements. The outcomes will also lead to an update of the GAID including any revisions to structure necessary to account for feedback received from users. It will help the GAIA-CLIM consortium members to identify or refine important user aspects under WP1 through WP5 to assess gaps and their impact, and to verify suggested remedies possible under the GAIA-CLIM project.  BIRA: Will take the lead role in organizing the workshop and be responsible for writing a report summarizing the principle outcomes.  KNMI: Shall update the GAID to reflect the principal outcomes and guidance received from workshop participants.  CNR, BKS, MO, EUMETSAT, ECMWF, KNMI, NERSC, FMI, NPL: Will inform the setting of the workshop agenda, partake in the workshop and help to summarize and publicise its outcomes as well as reporting back to each of WP 1 through 5 the relevant outcomes to inform their strategic development. | | | | | | | | | |
| **Task 6.1.3. Second workshop with external users** (lead: BIRA; involved: CNR, BKS, MO, EUMETSAT, ECMWF, KNMI, NERSC, FMI, NPL)  Occur: M21  GAIA-CLIM Project objectives addressed: O1, O2, O3, O7  This meeting will discuss progress of gap assessments and recommendations to date, reviewing the latest version of the GAID. It will start to develop a prioritisation from a user perspective of the gaps identified and solicit from the user community potential remedies including, inter alia, potential roles of dedicated campaigns and instrumental technology developments (amongst others). The outcomes of the meeting will inform a new version of the GAID living document. Principal outcomes shall be documented in a deliverable summarising the workshop.  BIRA: Will take the lead role in organizing the workshop and be responsible for writing a report summarizing the principle outcomes.  KNMI: Shall update the GAID to reflect the agreed upon outcomes.  CNR, BKS, MO, EUMETSAT, ECMWF, KNMI, NERSC, FMI, NPL: Will inform the setting of the workshop agenda, partake in the workshop and help to summarize and publicise its outcomes as well as reporting back to each of WP 1 through 5 the relevant outcomes to inform their next steps. | | | | | | | | | |
| **Task 6.1.4. Final workshop with external users** (lead: BIRA; involved: CNR, BKS, MO, EUMETSAT, ECMWF, KNMI, NERSC, FMI, NPL)  Occur: M33  GAIA-CLIM Project objectives addressed: O1, O2, O3, O7  This workshop will afford an opportunity to showcase to external users the principal outcomes of WPs 1 through 5 including the Virtual Observatory facility beta version. Workshop participants will also be able to review the GAID for adequacy and discuss an advanced version of the recommendations document arising from Task 6.3 which is intended to constitute the key final GAIA-CLIM project delivery to users and data providers such as the Copernicus services providers who would enact many of the recommendations.  BIRA: Will take the lead role in organizing the workshop and be responsible for writing a report summarizing the principle outcomes.  KNMI: Shall update the GAID to reflect the agreed upon outcomes.  NERSC: Shall update the recommendations document under Task 6.3 to reflect the agreed upon outcomes and user inputs on prioritisations.  CNR, BKS, MO, EUMETSAT, ECMWF, KNMI, NERSC, FMI, NPL: Will inform the setting of the workshop agenda, partake in the workshop and help to summarize and publicise its outcomes as well as reporting back to each of WP 1 through 5 the relevant outcomes to inform their next steps. | | | | | | | | | |
| **Task 6.2 Production of a Gaps Assessment and Impacts Document (GAID)** (lead: KNMI; involved: BKS, BIRA, CNR, NERSC, MO, EUMETSAT, FMI, NPL)  Start: M4 End: M36  GAIA-CLIM Project objectives addressed: S6, O2, O3  This task will result in a living gaps assessment and impact document (GAID), hosted on the project website and disseminated through other appropriate means.  Inputs to this document are the gap analyses results from WP1 to WP5 and any other user feedback collected in Task 6.1. The Cal/Val gap analysis will include gaps based upon:   * Geographical coverage * Measurement capabilities / characterisation * User needs * Technological impediments and opportunities * National and international measurement strategies and governance   Regular updates of the GAID will be provided throughout the project duration (Figure 8, Section 2.2). Also intermediate versions of the GAID will be made publicly available and communicated to the stakeholders to ensure timely feedback on the impact assessment. Several means of collecting reviews from third parties will be pursued to ensure broad review.  KNMI: will lead the production of the document, have close interaction with the project partners on their inputs and will help to translate identified gaps to impact assessments as relevant for the Copernicus services, for satellite agencies and for other users.  BKS, BIRA, CNR, MO and EUMETSAT: will ensure that identified gaps in the underlying work packages are communicated to KNMI and appropriately documented within the GAID through a series of WP deliverables arising from WP 1 through WP 5.  FMI: Will provide input based upon the user survey detailed in Task 6.1.1  BIRA, ECMWF, BKS, CNR, MO, EUMETSAT, FMI, NPL and NERSC: will ensure adequate review of the document and appropriate dissemination of its results. | | | | | | | | | |
| **Task 6.3 Prioritising potential gap remedies and improvements in capabilities** (Lead: NERSC; involved: KNMI, ECMWF, NERSC, CNR, BKS, EUMETSAT, FMI, NPL)  Start: M24 End: M36  GAIA-CLIM Project objectives addressed: S1, S2, S6, O1, O2, O3  Based upon the results from WP1 to WP5, and in particular the GAID, create a set of recommendations to:   * improve the utility of the surface and sub-orbital components of the global observing system for EO characterisation * improve consistency, harmonisation, and coordination of the ground-based and sub-orbital components of the Observing System to better meet the needs of EO characterisation. * Improve understanding of the metrological properties of the surface and sub-orbital observing capabilities. * Identify the need for dedicated observation campaigns * Identify required new developments and follow on work from GAIA-CLIM   NERSC: will lead the drafting of the document and be responsible for its final delivery.  KNMI: will provide the Gap Analysis and Impacts Document as input.  BIRA: will provide input from the user engagement workshops in Task 6.1.  FMI: Will ensure the results of the user survey are adequately accounted for.  CNR, BKS, BIRA, MO and EUMETSAT: will provide suggestions and reviews for adequacy, correctness, prioritisation and completeness from the perspective of Work Packages 1 through 5.  ECMWF: Will provide critical review from a Copernicus services user / provider perspective.  NPL: Will provide critical input from a national measurement institute standpoint and an interface to BIPM. | | | | | | | | | |
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| **Deliverables** | | | | | | | | | |
| **D6.1 –** Report on results of user survey (FMI, M5)  **D6.2 –** Living Gap Assessment Document (KNMI, M6, M12, M18, M24, M36)  **D6.3 –** Summary of first workshop with external users (BIRA, M11)  **D6.4** – Summary of second workshop with external users (BIRA, M20)  **D6.5** – First complete draft of recommendations document available for participants of final external users workshop (NERSC, M31)  **D6.6 –** Final external users workshop report including user feedback and recommendations (BIRA, M34)  **D6.7 –** Recommendations document to address gaps in observing capabilities (NERSC, M36) | | | | | | | | | |

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| **Workpackage Number** | WP7 | **Start date or starting event** | | | | Month 1 | | |
| **WP Title** | | Project management and coordination | | | | | | |
| **Participants number** | | **1** |  |  |  | |  |  |
| **Participant short name** | | **NERSC** |  |  |  | |  |  |
| **Person months per participant** | | 44 |  |  |  | |  |  |
|  | | | | | | | | |
| **Objectives** | | | | | | | | |
| * To organize and coordinate the project work * To carry out financial management, documentation and reporting * To communicate with the European Commission * Website build and maintenance * To clarify the role of participants and facilitate the project collaboration * To lead the project technical coordination group * To facilitate the science advisory panel * To ensure the project conforms to expectations under the Pilot on Open Research Data | | | | | | | | |
|  | | | | | | | | |
| **Description of work, lead partner and role of participants** | | | | | | | | |
| **Task 7.1 Financial and documentation management** (lead: NERSC)  Start: M1 End: M36  The NERSC administrative staff will manage the documentation and financial accounting for the project. This will include transfer of funds and checking of documentation, milestones, and deliverables. The project coordinator will organize the work on the project reports and other necessary documents. | | | | | | | | |
| **Task 7.2 Documentation of the project progress** (lead: NERSC)  Start: M1 End: M36  The dissemination of project results is documented in Section 2 and WPs 5 and 6. The documentation task includes in addition to WP5 and WP6 tasks a number of tasks to do with process communication that will be discharged under WP7: website maintenance, support for research publications, and conference presentations by the participants and consortium members and others as they arise. | | | | | | | | |
| **Task 7.3 Facilitation of groups under the governance structure** (lead: NERSC)  Start: M1 End: M36  Ensure that the technical coordination group and scientific advisory panel discharge the agreed duties to the project as outlined in Section 3.2. | | | | | | | | |
| **Task 7.4 Annual project meetings** (lead: NERSC)  Occur: M12, M24, M36  NERSC will be responsible for organizing annual assemblies of the consortium. These will occur at different locations, ordinarily associated with a project consortium partner. | | | | | | | | |
| **Task 7.5 Participation in Pilot on Open Research Data** (lead: NERSC)  Start: M1 End: M36  NERSC will be responsible for ensuring GAIA-CLIM conforms to the Pilot on Open Research Data | | | | | | | | |
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| **Deliverables** | | | | | | | | |
| **D7.1** – Data management plan commensurate with Pilot on Open Research Data (NERSC, M5, M24)  **D7.2** – Annual project reports (NERSC, M12, M24)  **D7.3** – Final project report (NERSC, M36) | | | | | | | | |

#### Table 3.1b Work Package List

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| --- | --- | --- | --- | --- | --- | --- |
| **Work Package** | **Work Package Title** | **Lead Participant No.** | **Lead Participant Short Name** | **Person Months** | **Start Month** | **End Month** |
| WP1 | Geographical capabilities mapping | 3 | CNR | 154 | 1 | 36 |
| WP2 | Measurement uncertainty quantification | 5 | BKS | 102 | 1 | 36 |
| WP3 | Comparison error budget closure – Quantifying metrology related uncertainties of data comparisons | 2 | BIRA | 100 | 1 | 36 |
| WP4 | Assessment of reference data in global assimilation systems and characterisation of key satellite datasets | 4 | MO | 132 | 1 | 36 |
| WP5 | Creation of a ‘virtual observatory’ visualization and data access facility | 16 | EUMETSAT | 119 | 1 | 36 |
| WP6 | Impact, outreach and dissemination | 2 | BIRA | 40 | 1 | 36 |
| WP7 | Project management and coordination | 1 | NERSC | 44 | 1 | 36 |
|  |  | TOTAL | | 679 |  |  |

#### Table 3.1c List of Deliverables

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Del. no.** | **Deliverable name** | **WP no.** | **Lead Participant** | **Type** | **Dissemination level** | **Delivery month** |
| D1.1 | Initial input from WP1 to the gap analysis and impacts document | 1 | CNR | R | PU | 4 |
| D1.2 | Modelling studies of the impacts of gaps - experimental design | 1 | KIT | R | PU | 6 |
| D1.3 | Report on system of systems approach adopted and rationale | 1 | NERSC | R | PU | 9 |
| D1.4 | Review of and input to Gap Analysis and impacts document aspects relevant to WP1 | 1 | CNR | R | PU | 16 |
| D1.5 | Summary of initial model-based study results and plans for remainder of project | 1 | KIT | R | PU | 16 |
| D1.6 | Report on data capabilities by ECV and by system of systems layer for ECVs measurable from space | 1 | CNR | R | PU | 18 |
| D1.7 | Report on the collection of metadata from existing network and on the proposed protocol for a common metadata format | 1 | CNR | R | PU | 18 |
| D1.8 | Provision of a 3D tool for the online visualization of existing measurements | 1 | CNR | OTHER | PU | 24 |
| D1.9 | Report on the scientific assessment of gaps using a statistical approach based on heteroskedastic functional regression | 1 | UniBergamo | R | PU | 34 |
| D1.10 | Report on the scientific assessment of gaps based on forward, inverse, and data assimilation modelling frameworks | 1 | KIT | R | PU | 34 |
| D2.1 | Initial report on measurement uncertainty gap analysis | 2 | BKS | R | PU | 4 |
| D2.2 | Intermediate report on measurement uncertainty gap analysis | 2 | BKS | R | PU | 16 |
| D2.3 | Uncertainty assessment for the measurement capabilities provided to WP5 | 2 | BKS | R | PU | 21 |
| D2.4 | A best-practice document including the resulting uncertainty quantification | 2 | NPL | R | PU | 24 |
| D2.5 | Report summarizing the uncertainty estimates for the ECVs identified in task 2.2 | 2 | BKS | R | PU | 30 |
| D2.6 | Final report on measurement uncertainty gap analysis and possible peer reviewed publication(s) from each subtask under task 2.1 | 2 | BKS | R | PU | 33 |
| D2.7 | Final review of and update to the GAID from the perspective of WP2 | 2 | BKS | R | PU | 34 |
| D3.1 | Initial input from WP3 to the gap analysis and impacts document | 3 | BIRA | R | PU | 4 |
| D3.2 | Paper/TN describing generic metrology aspects (individual errors from WP2 plus smoothing and sampling issues) of an atmospheric composition measurement and of data comparisons, with a view to feeding the Virtual Observatory characterisation/visualisation developed in other WPs | 3 | BIRA | R | PU | 12 |
| D3.3 | Review of and input to Gap Analysis and impacts document aspects relevant to WP3 | 3 | BIRA | R | PU | 16 |
| D3.4 | Paper/TN reporting on measurement mismatch studies (Task 3.2) and their impact on data comparisons, for all ECVs | 3 | UniBergamo | R | PU | 24 |
| D3.5 | Beta set of tools for quantification of collocation mismatch and smoothing uncertainties and associated documentation for integration in the development of the virtual observatory | 3 | TUT | OTHER | PU | 24 |
| D3.6 | Library of (1) smoothing/sampling error estimates for key atmospheric composition measurement systems, and (2) smoothing/sampling error estimates for key data comparisons | 3 | BIRA | OTHER | PU | 30 |
| D3.7 | Final version of tools for quantification of collocation mismatch and smoothing uncertainties and associated documentation for integration in the virtual observatory that reflects any subsequent updates arising as a result of a. feedback from WP5 and b. any subsequent finessing in Tasks 3.1 and 3.2 | 3 | TUT | OTHER | PU | 32 |
| D3.8 | Final review of and update to the GAID from the perspective of WP3 | 3 | BIRA | R | PU | 34 |
| D4.1 | Initial input from WP4 to the gap analysis and impacts document | 4 | MO | R | PU | 4 |
| D4.2 | Individual reports on validation of satellites | 4 | MO | R | PU | 12, 24, 34 |
| D4.3 | Review of, and input to, Gap Analysis and impacts document aspects relevant to WP4 | 4 | MO | R | PU | 16 |
| D4.4 | Publicly available web-based monitoring pages showing a comparison of GRUAN observations with MO and ECMWF data assimilation systems as an input to the virtual observatory | 4 | MO | DEC | PU | 24 |
| D4.5 | Report detailing approach to the calibration and validation of (atmospheric state variable) EO data, and detailing proposed approach to other ECVs and associated EO data | 4 | MO | R | PU | 34 |
| D4.6 | Workshop, to be organised through relevant global agency/initiative (e.g. WMO, GSICS), to disseminate findings of WP4; and training material and practical sessions to induct future training providers | 4 | MO | OTHER | PU | 34 |
| D4.7 | Final review of, and update to, the GAID from the perspective of WP4 | 4 | MO | R | PU | 34 |
| D5.1 | Initial input from WP5 to the gap analysis and impacts document | 5 | EUMETSAT | R | PU | 4 |
| D5.2 | Review of and input to Gap Analysis and impacts document aspects relevant to WP5 | 5 | EUMETSAT | R | PU | 16 |
| D5.3 | Technological platform for collocation database | 5 | EUMETSAT | OTHER | PU | 24 |
| D5.4 | Graphical user interface | 5 | TUT | OTHER | PU | 24 |
| D5.5 | Virtual Observatory Product User Guide and Implementation Description | 5 | TUT | R | PU | 30 |
| D5.6 | Final review of and update to the GAID from the perspective of WP5 | 5 | EUMETSAT | R | PU | 34 |
| D5.7 | Report on the evaluation of the Virtual Observatory | 5 | EUMETSAT | R | PU | 36 |
| D5.8 | Transition roadmap for the Virtual Observatory | 5 | EUMETSAT | R | PU | 36 |
| D6.1 | Report on results of user survey | 6 | FMI | R | PU | 5 |
| D6.2 | Living Gap Assessment Document | 6 | KNMI | R | PU | 6, 12, 18, 24, 36 |
| D6.3 | Summary of first workshop with external users | 6 | BIRA | R | PU | 11 |
| D6.4 | Summary of second workshop with external users | 6 | BIRA | R | PU | 20 |
| D6.5 | First complete draft of recommendations document available for participants of final external users workshop | 6 | NERSC | R | PU | 31 |
| D6.6 | Final external users workshop report including user feedback and recommendations | 6 | BIRA | R | PU | 34 |
| D6.7 | Recommendations document to address gaps in observing capabilities | 6 | NERSC | R | PU | 36 |
| D7.1 | Data management plan commensurate with Pilot on Open Research Data | 7 | NERSC | R | PU | 5, 24 |
| D7.2 | Annual project reports | 7 | NERSC | R | PU | 12, 24 |
| D7.3 | Final project report | 7 | NERSC | R | PU | 36 |

**KEY**

Numbering convention <WP number>.<number of deliverable within the WP>

For example, deliverable 4.2 is the second deliverable in work package 4.

**Type:**

R Document, report (excluding periodic and final reports)

DEM Demonstrator, pilot, prototype, plan design

DEC Websites, patents filing, press and media actions, videos, etc.

OTHER Software, technical diagram, etc.

**Dissemination level:**

PU Public, fully open, e.g. web

CO Confidential, restricted conditions set out in Model Grant Agreement

CI Classified information as referred to in Commission Decision 2001/844/EC

**Delivery Date:**

Measured in months from the project start date (month 1)

## MANAGEMENT STRUCTURE AND PROCEDURES

GAIA-CLIM is a project comprised of 19 consortium members organized into seven work packages with a number of inter-dependencies (Figure 9). A management structure has been set up that includes the work package leads within a technical coordination group to ensure that these inter-dependencies are integral to management decisions. A key stated requirement of the project is to ensure global buy-in. To this end a scientific advisory panel has been set up which is populated by international data providers and data users who represent key constituencies for project success. Annual assemblies, to which all consortium members will be invited, will inform decisions made by the technical coordination group. The management structure is given in Figure 10.

**Figure 10**. Project management structure.

#### Project coordinator

The project will be managed and coordinated by NERSC. Peter Thorne will spend 50% time on scientific coordination, contributions to specific WP tasks, and reporting. In addition an experienced project manager will provide logistical support on 100% time which will include: day-to-day management, financial management, administrative support and maintenance of the project website. All reporting to the EU will be undertaken by NERSC. In addition the project coordinator shall represent the project at meetings and to the media as the need arises. The project coordinator and manager will make all day-to-day decisions and ensure communication with other aspects of the management structure. Decisions requiring more substantive discussion will be referred to the technical coordination group. The project coordinator may call a virtual meeting of the technical coordination group so long as greater than 2 working days notice is given and more than half the group are available to partake.

#### Technical coordination group

The project will have a technical coordination group that consists of the project coordinator and manager and the remaining WP leads (5 males, 2 females and a TBD project manager). This group will meet not less than bi-monthly by remote telecon and not less than annually in person. The group consists of those individuals summarized in Table 3.

|  |  |  |
| --- | --- | --- |
| **Name** | **Institution** | **Project role** |
| Peter Thorne | NERSC | Project coordinator (and technical coordination group chair) |
| NN | NERSC | Project manager (and technical coordination group secretary) |
| Fabio Madonna | CNR | Lead of WP1 |
| Karin Kreher | BKS | Lead of WP2 |
| Jean-Christopher Lambert | BIRA | Lead of WP3 |
| Bill Bell | MO | Lead of WP4 |
| Joerg Schulz | EUMETSAT | Lead of WP5 |
| Martine De Maziere | BIRA | Lead of WP6 |

**Table 3.** Technical coordinator group members and project roles.

Major decisions in GAIA-CLIM will be made by the technical coordination group. The technical coordination group will make the final decision in any disputes or if any of the coordinator’s decisions are appealed by a member of the project consortium. Decision-making will be by simple majority vote, with the coordinator’s vote deciding in the case of a tie.

All consortium members are active in numerous international collaborations including EU funded projects. Therefore conflict is not foreseen. Nonetheless conflict either between a partner and the project as a whole or between some subset of partners cannot be excluded. Were such conflicts to occur their resolution would be the responsibility of the technical coordination group. In such cases the following steps would be taken:

* One or more parties in dispute to inform project coordinator in writing of dispute and its principal causes including potential remedies.
* Unless the conflict arises with the project coordinator, initial mediation by the project coordinator or his representatives within one month of receipt of notification in writing.
* EC consultation
* Vote by technical coordination group

The technical coordination group will monitor the general progress of the project. It will also ensure the flow of information between work packages. The technical coordination group will also make decisions regarding such matters of strategy as publication issues (such as special journal issues), press releases etc.

#### Scientific advisory panel

Scientific input will be provided by a science advisory panel, which will meet at least annually in person with the project technical coordination group, preferably in combination with annual assemblies, to be updated on progress and provide scientific input. The science advisory panel will consist of representatives from contributing measurement networks and representatives from various posited user groups of the project outputs (Table 4). It shall include members from outside Europe, consistent with the stated aim in the call text for global reach and buy-in. Membership will be drawn primarily from institutions who are not members of the consortium to ensure impartial advice. Members will include representatives from synergistic ongoing European projects and international research programmes. The science advisory panel may meet virtually in calls facilitated by the project coordinator between in person meetings. Such calls may be initiated either at the request of two or more science advisory panel members or at the request of the technical coordination group.

|  |  |  |
| --- | --- | --- |
| **Name** | **Institution (country)** | **Expertise** |
| *P. Lecomte (Head of ESA Climate Office)* | *ESA (International)* | *Satellite agency and end-user* |
| Ken Jucks | NASA (USA) | Satellite agency and end user |
| Stephan Bojinski | WMO (International) | WMO Space programme, formerly GCOS secretariat |
| Andrea Merlone | INRiM (Italy) | Metrology. Chair of Meteomet2 – Euramet project of metrology for meteorology and climate |
| *Bernard Pinty* | *EC Copernicus Climate Office (International)* | *Climate services* |
| Rainer Hollman | DWD (Germany) | CM-SAF (representing users for climate datasets / monitoring) |
| Folkert Boersma | KNMI (Netherlands) | QA4ECV project coordinator |

**Table 4**. Science advisory panel members for the project (confirmed unless italicized)

#### Annual assemblies

Annual assemblies, to which all consortium members will be invited, shall afford an opportunity to review the project progress as a whole, agree to program variants to propose, and provide guidance to the project coordinator and the project technical coordination group. Between annual assemblies at least two additional remote participation teleconference meetings will be offered to consortium participants to review critical items.

#### Table 3.2a List of Milestones

The GAIA-CLIM milestones are key events, deliverable dates, or control points at which substantial decisions are needed with regard to the subsequent work within the project. In most cases milestones relate either to a major result / event or where attainment of an intermediate product from another WP is critical to attaining the next steps in work of a WP. Of particular import is interactions between the underlying WPs 1 through 4 and WP5, the virtual observatory / WP6, the impacts, outreach and dissemination work package. Many milestones relate to attaining the desired interactions between these WPs.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Milestone no.** | **Milestone name** | **Related work package(s)** | **Estimated date** | **Means of verification** |
| 1 | Project kick-off | All | M1 | Kick-off minutes available on project website |
| 2 | Necessary deliverables available for initial gap analysis and impacts document first version development | All | M5 | D1.1, D2.1, D3.1, D4.1, D5.1 and D6.1 |
| 3 | First external users workshop | WP6 | M9 | D6.3 |
| 4 | First Annual Review | All | M12 | D7.2 |
| 5 | Necessary deliverables available for update to gap analysis and impacts document | WP1 – WP5 | M16 | D1.4, D2.2, D3.3, D4.3 and D5.2 |
| 6 | Second external users workshop | WP6 | M18 | D6.4 |
| 7 | Necessary tools available to implement virtual observatory available in at least beta form from underlying WPs | WP1 – WP4 | M24 | D1.8, D2.3, D3.5, D4.4 |
| 8 | Second annual review | All | M24 | D7.2 |
| 9 | Virtual observatory facility available | WP5 | M30 | D5.5 |
| 10 | Final external users workshop | WP6 | M33 | D6.6 |
| 11 | Necessary deliverables available for final update to gap analysis and impacts document and recommendations document | WP1 – WP6 | M34 | D1.9, D1.10, D2.6, D3.8, D4.7, D5.6 and D6.6 |
| 12 | Final reports and recommendations including gap analysis and impacts document, recommendations document, and final project report | All | M36 | D6.2, D6.7, D7.3 |

### Critical Risks

The GAIA-CLIM project is exclusively based around development of classification schema and analysis tools to support EO sensor characterisation by end-users. Rather than collecting primary data the project instead provides value added products to data collected and provided under third party auspices by existing research infrastructures and networks (comparator data) and satellite agencies (EO data). Therefore the risks associated with data collection are not considered to be risks within project scope and are not further discussed here. Principal remaining critical risks are whether the scientific project aims can be fully met and whether users and data providers buy-in to the GAIA-CLIM project outcomes.

#### Table 3.2b Critical Risks for Implementation

|  |  |  |
| --- | --- | --- |
| **Description of risk** | **Work Packages involved** | **Proposed risk-mitigation measures** |
| Lack of stakeholder and user buy-in to project outcomes | All, but in particular WPs 5, 6 and 7 | * Significant stakeholder communication and consultation efforts have been built in to all aspects of the project. * Consortium has been built from a basis of including significant observational network stakeholders as key members. * The science advisory panel membership has been selected to ensure stakeholder buy-in. * Consortium members will disseminate outcomes via numerous international programs and governance structures on which they sit. |
| Gap analysis and impacts assessment and resulting set of recommendations incomplete | All, but particularly WP6 | * Efforts to engage users throughout to ensure consortium members are aware of their requirements. * GAID document to be a living document with several versions published to enable iterative feedback. * Defined milestones at which WPs 1-5 provide input. |
| Virtual observatory outcomes either over-ambitious or impacted by delays in underlying WPs | WP5 | * Virtual observatory will by preference be built from existing, proven, resources such as NORS, ICARE and NPROVS. * Project milestone for WPs 1 through 4 to produce advanced version of inputs to WP5 by month 24. |
| Redundancy with other similar efforts leading to lack of project innovative outcomes | All | * Explicit cross-linkages with relevant European projects. * Cross-linkage with global governance and science activities. |
| Gaps in traceability chain of measurements | WPs 2 through 5 | * Consideration is to be limited to instruments deemed close to reference quality and already well understood. |
| Lack of explicit linkages to ESA climate activities arising from funding call restrictions on direct ESA funding. | WPs 5 and 6 | * We have ESA CCI participating institutions onboard in NERSC, FMI, BIRA, KIT, UBremen, MO (MO lead the Climate Modelling Users Group) and these consortium members will ensure appropriate linkages. |

## CONSORTIUM AS A WHOLE

The consortium consists of 19 partners arising from 10 countries with representation from 2 pan-European organizations (ECMWF and EUMETSAT) and one international organization (GCOS). It consists of a mix of leading EU research institutes and universities across a broad scope of measurements and understanding of atmospheric ECVs. Collectively the consortium has the right mix of skills and expertise both to achieve the ambitious project aims and to ensure global buy-in to the project outcomes.

Ground based instrumentation

The consortium contains many globally recognised experts in the deployment, maintenance and analysis of ground-based sounding (balloon borne) and profiling (remote sensing) measurement capabilities of the atmosphere. Consortium members are active in many national, regional and global measurement programs, and have been instrumental in the instigation and propagation of reference-quality measurement systems and networks over the past decade. The consortium members bring decades of collective experience to those instruments targeted for development as new reference quality data streams in WP2. This expert knowledge is also key to appropriately classifying existing ground-based measurement capabilities as part of WP1.

Aircraft instrumentation

Consortium partners have a great deal of experience and long history in deployment, maintenance and analysis of airborne instrumentation on atmospheric research aircraft, including physical parameters, chemical species, in-situ and remote sensing observations. The BAe146-301 FAAM (Facility for Airborne Atmospheric Measurements), which is part of the EUFAR fleet, is extensively used, as well as other EUFAR and American research quality aircraft. The consortium uses and analyses data from other aircraft (e.g. AMDAR, IAGOS, WVSS-II). This airborne instrumentation knowledge and experience will be used in WP1 and 2.

Data analysis

Members of the consortium bring considerable expertise in different approaches to data analysis, which will be key to completing both WP3 and WP4. For statistical and metrological approaches to be pursued in WP3 decades of experience in these aspects, including previous, successful EU projects, will assure substantive progress is achieved. For the approach of data assimilation techniques the project brings together two of the foremost groups globally in data assimilation and NWP / reanalyses.

Data provision

The consortium brings together many members who already provide data to end-users for a number of the target ECVs. These data are delivered in a number of delivery streams, facets of which will inform the eventual ‘virtual observatory’ envisaged in WP5. The project will leverage these tools and the expertise provided by consortium members to create the ‘virtual observatory’ facility.

Data users

A number of users of ground-based and sub-orbital data for EO data characterization are included within the consortium. This includes a number of users with experience in the creation and analysis of EO sensor CDRs and derived products for climate monitoring and analysis. The lessons learnt from these analyses will prove invaluable in informing decisions around how to provide and present the project outcomes to meet user needs. Consortium members include key users and providers of Copernicus atmospheric and climate services.

International programmatic reach

The consortium includes the European principals of the high quality in-situ measurement networks GRUAN, NDACC and TCCON, which provides significant reach into three of the principal international confederations of high quality ground-based measurement sites for atmospheric state and composition measurements. Several European organizations and infrastructures (e.g. ACTRIS) taking such measurements are also included. It also includes some of the foremost providers (EUMETSAT, NOAA) and users (ECMWF, MO, NOAA, KNMI, FMI) of satellite data.

Between consortium members there is broad reach into global governance of measurement capabilities. Amongst others consortium members hold positions within: GCOS, GEO, CEOS, WMO (including WIGOS), and WCRP. This mix of consortium members, taken together with the posited membership of the science advisory panel will assure both European and global buy-in to many of the project outcomes.

Experience in European projects

The consortium partners have considerable experience in present and historical EU projects (Table 5, Section 4.1). Therefore the consortium members are well versed in how to successfully undertake an EU project and what is required in terms of process and reporting. This experience will prove invaluable in ensuring a successful outcome to the GAIA-CLIM project.

Leveraging synergies with existing funded EU projects

A number of ongoing or recently completed FP7 funded projects or ESA sponsored activities are of direct relevance to and synergistic with the GAIA-CLIM project. These include research and innovation actions and research infrastructure actions. These existing projects, how they would interact with the GAIA-CLIM project and who the principal link partners are in each case is summarized in Table 5.

|  |  |  |
| --- | --- | --- |
| **Existing EU project and funded period** | **Principal synergies with GAIA-CLIM** | **Principal link partners (project coordinator when bolded)** |
| ACTRIS  (2011-2015) | Provide long-term measurements at the continental scale of aerosol and clouds related ECVs, using both surface based profiling and in-situ measurements, performed using well consolidated quality assurance program and traceability protocol, also shared with GAIA-Clim project. | **CNR**, BIRA |
| CHARMe (2013-2015) | Characterisation of metadata to enable high-quality climate applications and services. | MO, ECMWF, KNMI |
| CORE-CLIMAX  (2013-2015) | System Maturity Matrix and Application Performance Metric approaches as part of a QA system (also used in QA4ECV); Use of observation feedback from reanalysis in assessing CDR quality | EUMETSAT, ECMWF |
| COST action ES1206 | Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate. Will interface with Task 2.1.6. | **MO**, FMI, TUT |
| EMPIR MetEOC2 (2014-2017) | Establish full SI traceable uncertainty chain for SST, LAI and fAPAR, and establishment of EMCEOC EO climate metrology centre. | **NPL** |
| EMRP METEOMET (2011-2014) and METEOMET2 (2014-2017) | Measurement traceability and uncertainty of ground based and airborne measurements of atmospheric ECVs principally temperature, humidity, and air flow | NPL, MO, KNMI, TUT |
| ERA-CLIM2  (2014-2016) | Global Reanalysis inclusive of observation feedback to input data consisting mostly of satellite radiances | **ECMWF**, EUMETSAT, MO |
| ESA-CCI (Phase II: 2014-2016) | GAIA-CLIM outputs will form potential inputs to ESA-CCI projects. | **FMI, MO, BIRA, UBremen,** NERSC, KIT |
| EU COST Action ES1303 TOPROF (2013 - 2017) | Instrument (ceilometers, microwave radiometers, Doppler wind lidars) characterization and networking for operational profiling | **CNR**, FMI, MO, KNMI |
| EUMETSAT O3M (2012-2017) | Operational provision of atmospheric constituent products such as ozone, nitrogen dioxide, water vapour (H2O), and bromine oxide (BrO) | **FMI, KNMI, BIRA** |
| EUMETSAT CM SAF | Operational provision of atmosheric temperature and humidity profiles | EUMETSAT, KNMI, FMI, MO |
| EUMETSAT NWP SAF | Aims to improve and support the interface between satellite data/products and European activities in NWP. Will gain synergies through GAIA-CLIM WP4. | **MO** |
| ICOS\_inwire (2013-2015) | Provide ground based long-term observations on greenhouse gases from the ICOS network, observation harmonization, measurement traceability | **UH** |
| I-GAS | Provision of observations on-board passenger aircraft from the IAGOS infrastructure operationally for Copernicus and other users. Provision of tools to validate satellite and other remote sensing observations of short- and long-lived greenhouse gases and their precursors | **MPG**, KNMI, KIT, ECMWF |
| MACC-II/III (2011-2014/2014-2015) | Copernicus Atmosphere Core Service. ECMWF will ensure appropriate synergies. | **ECMWF**, BIRA, KNMI |
| NORS (2011-2014) | Characterisation of target NDACC data including error budgets evaluations. Development of a validation server (nors-server.aeronomie.be) and algorithms for making comparisons between model data and NDACC data according to QA4EO best practices - that can be easily adapted to comparisons with satellite data for validation purposes. | **BIRA**, UBremen, KIT |
| QA4ECV (2014-2017) | Traceable quality assurance system for multi-decadal ECVs. QA framework for satellite and in-situ algorithms applied to ECVs (NO2, HCHO, CO) as part of the Copernicus climate change service. | **KNMI**, BIRA, EUMETSAT, MPG, NPL, MO |
| StratoClim (2014-2017) | Research carried out within the EU FP7 project StratoClim will benefit from improved measurement uncertainty assessment and traceability studies proposed within GAIA-CLIM | BKS, UBremen, KIT, CNR, MPG |
| UERRA (2014-2018) | Regional Reanalysis could provide additional data in high resolution to VO | MO, ECMWF, KNMI |

Table 5. Linkages between the consortium and existing, synergistic, EU funded projects.

### Non-EU Partners

The Satellite Applications Division of the US National and Oceanic and Atmospheric Administration is a no-cost partner. They bring decades of experience in the management of EO data and its comparison to ground-based and sub-orbital measurements. Their participation is essential in meeting the stated requirements of global buy-in and they bring significant scientific and technical value to the proposal and in particular the envisaged work and outcomes under WP5.

The Lidar group at the Jet Propulsion Laboratory (a NASA / California Institute of Technology facility) is a no-cost partner. The laboratory employs some of the foremost Lidar experts in the world. In particular Dr. Leblanc has been instrumental in advancing our knowledge of Lidar measurement uncertainties through leading a multi-year ISSI facilitated program as chair of the NDACC Lidar group. Their participation is essential both to ensure this knowledge is propagated and also because the data collection and analysis client they are planning on developing is a required synergy to realise the objectives of the sub-task on Lidars under WP2.

## RESOURCES TO BE COMMITTED

#### Table 3.4a Summary of Staff Effort

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Participant number/short name** | **WP1** | **WP2** | **WP3** | **WP4** | **WP5** | **WP6** | **WP7** | **Total Person Months Per Participant** |
| 1 NERSC | 3 |  |  |  |  | 5 | 44 | **52** |
| 2 BIRA | 12 | 11 | 33 |  | 4 | 7 |  | **67** |
| 3 CNR | 34 | 14 | 9 |  |  | 2 |  | **59** |
| 4 MO | 3 | 4 |  | 88 |  | 2 |  | **97** |
| 5 BKS | 4 | 24 |  |  |  | 2 |  | **30** |
| 6 KNMI | 7 | 8 |  |  |  | 5 |  | **20** |
| 7 ECMWF | 6 |  |  | 44 |  | 5 |  | **55** |
| 8 MPG | 10 |  |  |  |  |  |  | **10** |
| 9 FMI | 22 | 8 | 14 |  |  | 7 |  | **51** |
| 10 UBremen | 6 | 6 |  |  |  |  |  | **12** |
| 11 TUT |  | 6 | 12 |  | 30 |  |  | **48** |
| 12 GCOS | 1 | 1 |  |  |  |  |  | **2** |
| 13 NPL |  | 10 | 14 |  | 2 | 3 |  | **29** |
| 14 UniBergamo | 33 |  | 18 |  |  |  |  | **51** |
| 15 EUMETSAT | 3 |  |  |  | 35 | 2 |  | **40** |
| 16 NOAA |  |  |  |  | 24 |  |  | **24** |
| 17 UH | 4 |  |  |  |  |  |  | **4** |
| 18 USTL |  |  |  |  | 24 |  |  | **24** |
| 19 KIT | 6 | 6 |  |  |  |  |  | **12** |
| 20 NASA JPL / CALTECH |  | 4 |  |  |  |  |  | **4** |
| **Total Person Months** | **154** | **102** | **100** | **132** | **119** | **40** | **44** | **679** |

#### Table 3.4b Other Direct Costs

|  |  |  |
| --- | --- | --- |
| **Participant   1 NERSC** | **Cost**  **(€)** | **Justification** |
| **Travel** | 64,000 | This money will cover the T&S for the scientific advisory panel and the project principal and manager. |
| **Equipment** | - |  |
| **Other goods and services** | - |  |
| **Total** | 64,000 |  |

|  |  |  |
| --- | --- | --- |
| **Participant   2 BIRA** | **Cost**  **(€)** | **Justification** |
| **Travel** | 115,000 | €90,000 of this T&S will cover the T&S of interested parties to attend key workshops of this project as part of the outreach under WP6 which BIRA leads so as maximise the impact of the project results. |
| **Equipment** | - |  |
| **Other goods and services** | - |  |
| **Total** | 115,000 |  |

# MEMBERS OF THE CONSORTIUM

## PARTICIPANTS

|  |  |  |
| --- | --- | --- |
| **No** | **Name** | **Country** |
| **1** | **Nansen Environmental and Remote Sensing Center (NERSC)** | **Norway** |
| **Expertise and experience of the organization**  Nansen Environmental and Remote Sensing Center (legal name: STIFTELSEN NANSEN SENTER FOR MILJO OG FJERNMALING) is a non-profit research center affiliated with the University of Bergen, with focus on marine and Arctic science. NERSC is a project-based center with major funding from Norwegian Research Council, the European Union research programmes, the European Space Agency, the Norwegian Space Center, industry and other governmental and international agencies. From 2012 the Center became a national environmental institute with basic funding from the Norwegian Ministry of Environment. In 2013 the Center participates in 19 EC funded projects, of which 6 are coordinated by the Center. A main research area at NERSC is to develop an integrated ocean and ice monitoring and forecasting system for the Arctic Ocean using satellite EO and in situ data, in combination with modeling and data assimilation. The results are disseminated by ArcticROOS, http://arctic-roos.org/, which provides daily updated Arctic sea ice and ocean information. The staff comprises 63 persons from 17 countries (2013), including scientific personnel, Ph.D. candidates, and administrative/technical personnel. The scientific production of the Nansen Center in 2013 included 55 referee and book publications. | | |
| **Role in the project**  NERSC shall coordinate the overall project, providing scientific coordination and project management. They shall lead the management work package and also single tasks in Work Packages 1 and 6. | | |
| **Key personnel CVs**  ***Dr. Peter Thorne (male)*** is a researcher who joined the G.C. Rieber Climate Institute of NERSC in 2013 as a senior scientist having previously been employed by NOAA’s National Climatic Data Center and before that the UK Met Office’s Hadley Centre. He has over a decade’s experience of analysis of climate data from in-situ and satellite measurements and has published over 50 peer-reviewed papers on climate data analyses and model intercomparisons, including in Nature, Science and PNAS. This includes several papers on surface and upper-air reference measurement capabilities.  Dr. Thorne was a Lead Author on the atmospheric observations chapter of the most recent 5th Assessment Report of the IPCC Working Group 1, attending the final Stockholm plenary and contributing to the SPM. He has also been a lead author on the forthcoming 2013 US National Climate Assessment and the first US Climate Change Science Program report on temperature trends in the lower atmosphere published in 2006. Since 2004 he has been chair and then subsequently co-chair of the GCOS Working Group on the GCOS Reference Upper Air Network. In that time the network has gone from an idea in the first GCOS Implementation Plan to a physical reality producing data streams of reference quality data from several sites. He is involved in scoping the new GCOS Implementation Plan refresh process. He has also been a past co-chair of the International TOVS Working Group’s Climate group. Peter Thorne is the proposed project scientific coordinator. | | |
| **Publications**  Mears, C. A., Thorne, P. et al. (2012) “Assessing the value of Microwave Sounding Unit-radiosonde comparisons in ascertaining errors in climate data records of tropospheric temperature” J. Geophys. Res., 117, D19103, doi:10.1029/2012JD017710.  Thorne, P. W., J. R. Lanzante et al. (2011). “Tropospheric temperature trends: History of an ongoing controversy.” WIRES: Climate Change. **2:** 66-88.  Thorne, P. W., P. Brohan, et al. (2011) “A quantification of uncertainties in historical tropical tropospheric temperature trends from radiosondes” Journal of Geophysical Research - Atmospheres, doi:10.1029/2010JD015487  Immler, F. J., J. Dykema, et al. (2010). "Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products." Atmospheric Measurement Techniques **3**(5): 1217-1231.  Seidel, D. J., F. H. Berger, et al. (2009). "REFERENCE UPPER-AIR OBSERVATIONS FOR CLIMATE Rationale, Progress, and Plans." Bulletin of the American Meteorological Society **90**(3): 361+ | | |
| **Previous Projects**  European: MEGAPOLI, SIREOC, ESA Ocean Colour CCI, ESA Sea-Ice CCI, SMOS Aquarius synergy, MONARCH-A  National: MACESIZ, ROLARC, ARCWARM, CLIMARC, EUROPEWEATHER | | |

|  |  |  |
| --- | --- | --- |
| **No** | **Name** | **Country** |
| **2** | **Belgian Institute for Space Aeronomy (BIRA)** | **Belgium** |
| **Expertise and experience of the organization**  BIRA-IASB is a Belgian Federal Scientific Institute established in 1964, where about 90 scientists carry out research and scientific services in space aeronomy. BIRA-IASB has a pioneering expertise in the remote sensing and numerical modelling of chemistry and physics of the atmosphere of the Earth, planets and comets, and of space physics. It performs fundamental research but also delivers scientific services in the fields of space weather, chemical weather, UV index and stratospheric ozone monitoring etc. Its Atmospheric Composition Division carries out a suite of observational and modelling studies of the troposphere and the stratosphere in relation to climate change, stratospheric ozone, global air quality, polar processes, and the evolution of greenhouse gases and other ECVs in support of the Kyoto Protocol. Its expertise in atmospheric remote sensing covers all types of platforms, and includes the development and operation of space missions and instruments, retrieval algorithms, validation activities and geophysical data exploitation. Its expertise in numerical modelling spans radiative transfer, chemical-transport modelling, chemical data assimilation and inverse modelling in the troposphere and stratosphere. BIRA-IASB is involved in major past, current and future EO satellite missions, esp. of ESA and EUMETSAT, like GOME, SCIAMACHY, GOME-2, IASI, ACE-FTS, OMI, and the Copernicus Sentinel-5P and Sentinels 4 and 5. It plays a leading role in the NDACC monitoring network. It is involved in several EU, ESA and EUMETSAT projects: EU GEOmon, NORS, QA4ECV, ACTRIS, Marco Polo, MACC-II/III, ESA CCI, GECA, GLOBEMISSION, Multi-TASTE, SACS and EUMETSAT O3M SAF. | | |
| **Role in the project**  Five different research units of the Atmospheric Composition Division at BIRA-IASB will be involved in the project. Among those, three units active in the NDACC Steering Committee, and involved in EU GEOmon, NORS and QA4ECV projects, in ESA’s CCI (Ozone and GHG) and ESA Quality Working Groups and Multi-TASTE project, and in EUMETSAT O3M-SAF:  • The Infrared unit (IR) and the UV-visible unit (UVVIS), with specific expertise in infrared and UV-visible remote sensing and laboratory studies, respectively. Active in NDACC and TCCON measurement working groups, they will contribute to WPs 1, 2, 5 and 6 (as coordinator).  • The Data Synergies unit (SYN), with specific expertise in the metrology of remote sensing, satellite validation and the integrated use of atmospheric data obtained by complementary measurement systems. Active in the NDACC Satellite WG and in the CEOS Cal/Val group, it will coordinate WP3 and contribute to several other WPs.  Two other research units of BIRA-IASB will contribute modelling expertise as users:  • The tropospheric modelling team (TMOD) will contribute expertise in inverse modelling.  • The stratospheric modelling team (SMOD) will contribute expertise in chemical data assimilation and stratospheric (re)analyses. | | |
| **Key personnel CVs**  **Prof. Dr. M. De Mazière (female)** is Director General a.i. of BIRA-IASB, and an invited professor at the University of Gent in tropospheric and stratospheric chemistry and global changes. With BIRA-IASB since 1988, she has acquired a broad expertise in all aspects of the remote sensing of atmospheric composition using infrared spectrometric techniques, from ground and space, including development of instruments and retrieval algorithms, data analysis and validation, and geophysical studies. She is PI of two FTIR instruments at Ile de La Réunion, operated as part of the NDACC and TCCON networks. She co-chaired the NDACC Infrared WG (2006-2013) and is now a NDACC Co-chair. Activity coordinator in EU FP6 GEOmon and UFTIR and in ESA’s GECA, she coordinates at present the FP7 project NORS, participates in the CEOS Cal/Val Infrastructure WG, is involved in the ESA CCI-GHG and aerosol projects, in EU FP7 InGOS and ICOS\_Inwire, and in a project aiming at the demonstration of aircore launches at Ile de La Reunion for the calibration of TCCON-type GHG data. | | |
| **Dr. ir.** **Jean-Christopher Lambert (male)** is head of the Data Synergies Research Unit at BIRA-IASB, where he has developed since 1994 expertise in ECV remote sensing, metrology, satellite validation, and synergistic use of satellites and ground-based networks. Active in the development of data quality strategies, he has contributed atmospheric expertise in the GEO-CEOS QA4EO framework, in ESA’s GECA and in Copernicus Atmosphere pilot projects (MACC-I/II, PROMOTE, PASODOBLE). He is a member of the Mission Advisory Group for Copernicus Sentinels 4 and 5, of the NORS Steering Committee, of the International Ozone Commission (IO3C), Vice-chair of CEOS Cal/Val WG / Atmospheric Composition SG, Co-chair of the NDACC Satellite WG and of SCIAMACHY Validation, and QA/Validation coordinator in EU (GEOmon, QA4ECV), ESA (CHEOPS, Multi-TASTE, CCI Ozone), EUMETSAT (O3M-SAF) and SPARC (SI2N) projects. | | |
| **Dr. Tijl Verhoelst (male)** is a remote sensing scientist in the Data Synergies unit at BIRA-IASB, which he joined in 2011 after a 10-year career in observational astrophysics. Expert in metrology aspects of remote sensing and data comparisons, he plays a key role in the development of the OSSSMOSE observing system and intercomparison simulator, with which he participates in ESA’s Multi-TASTE and CCI\_Ozone validation activities. He contributes remote sensing metrology expertise also to the SPARC Data Assimilation WG and to the new FP7 project QA4ECV | | |
| **Dr.** **Corinne Vigouroux (female)** is first assistant in the IR Research Unit at IASB-BIRA. She has participated in the NDACC Infrared Working Group since 2003. She was involved in the EU projects UFTIR and HYMN. She participates now in the SPARC/IO3C/WMO-IGACO/NDACC (SI2N) Assessment on Past Changes in the Ozone Profile by deriving ozone trends at several NDACC stations from FTIR measurements, a contribution to the next WMO Scientific Assessment of Ozone Depletion (2014). | | |
| **Dr. M. Van Roozendael (male)** is head of the UV-visible DOAS Research Unit at IASB-BIRA, where he has developed expertise in UV-visible retrievals of ECVs from satellites and ground-based instruments. He is the coordinator of ESA’s CCI Ozone ECV project, Co-chair of the NDACC UV-visible WG, member of GOME and SCIAMACHY Science Advisory Groups and of Copernicus atmospheric Sentinel-5p Mission Advisory Group. He is the PI of several UV-visible DOAS instruments measuring the target ECVs and is an expert in satellite validation. | | |
| **Dr. J.-F. Müller (male)** is head of the Tropospheric Modelling group at BIRA-IASB. Interested in tropospheric chemistry and emissions since 1988, he has developed a broad expertise in the development of emission inventories and of detailed chemical mechanisms for biogenic VOCs, and in the use of satellite data in conjunction with a global CTM for the derivation of improved emission estimates of tropospheric compounds, including NOx, CO, and VOCs. | | |
| **Dr. Q. Errera (male)** joined the Stratospheric Modelling group of BIRA-IASB in 1995. After a PhD on chemical data assimilation, he contributed to the building of BIRA-IASB’s 4D-var data assimilation system BASCOE, with which he took part in the EU FP5 ASSET project and in ESA’s PROMOTE Stratospheric Ozone service. He contributes now to the development of C-IFS-TM5-BASCOE within FP7 MACC-II/III. He is an ACP/ACPD Editor and a Co-chair of the SPARC Data Assimilation WG. | | |
| **Publications**  Dils, B., M. Buchwitz, M. Reuter, O. Schneising, H. Boesch, R. Parker, S. Guerlet, I. Aben, T. Blumenstock, J. P. Burrows, A. Butz, N. M. Deutscher, C. Frankenberg, F. Hase, O. P. Hasekamp, J. Heymann, M. De Mazière, J. Notholt, R. Sussmann, T. Warneke, D. Griffith, V. Sherlock, and D. Wunch, The Greenhouse Gas Climate Change Initiative (GHG-CCI): comparative validation of GHG-CCI SCIAMACHY/ENVISAT and TANSO-FTS/GOSAT CO2 and CH4 retrieval algorithm products with measurements from the TCCON network, *Atmos. Meas. Tech. Discuss.*, 6, 8679-8741, 2013  Hassler, B., I. Petropavlovskikh, J. Staehelin, T. August, P. K. Bhartia, C. Clerbaux, D. Degenstein, M. De Mazière, B. M. Dinelli, A. Dudhia, G. Dufour, S. M. Frith, L. Froidevaux, S. Godin-Beekmann, J. Granville, N. R. P. Harris, K. Hoppel, D. Hubert, Y. Kasai, M. J. Kurylo, E. Kyrölä, J.-C. Lambert, P. F. Levelt, C. T. McElroy, R. D. McPeters, R. Munro, H. Nakajima, A. Parrish, P. Raspollini, E. E. Remsberg, K. H. Rosenlof, A. Rozanov, T. Sano, Y. Sasano, M. Shiotani, H. G. J. Smit, G. Stiller, J. Tamminen, D. W. Tarasick, J. Urban, R. J. van der A, J. P. Veefkind, C. Vigouroux, T. von Clarmann, C. von Savigny, K. A. Walker, M. Weber, J. Wild, and J. Zawodny, SI2N overview paper: ozone profile measurements: techniques, uncertainties and availability, *Atmos. Meas. Tech. Discuss.*, 6, 9857-9938, 2013.  Lambert, J.-C., C. De Clercq, and T. von Clarmann, Comparing and merging water vapour observations: A multi-dimensional perspective on smoothing and sampling issues, Chapter 9 (p. 177-199) of book “Monitoring Atmospheric Water Vapour: Ground-Based Remote Sensing and In-situ Methods”, N. Kämpfer (Ed.), ISSI Scientific Report Series, Vol. 10, Edition 1, 326 p., ISBN: 978-1-4614-3908-0, DOI 10.1007/978-1-4614-3909-7\_2, © Springer New York 2012.  Stavrakou, T., J-F. Müller, J. Peeters, A. Razavi, L. Clarisse, C. Clerbaux, P-F. Coheur, D. Hurtmans, M. De Mazière, C. Vigouroux, N. M. Deutscher, D. W. T. Griffith, N. Jones, and C. Paton-Walsh, Satellite evidence for a large source of formic acid from boreal and tropical forests, *Nature Geoscience*, 5, 26–30, 2012. (doi:10.1038/ngeo1354)  Viscardy, S., Q. Errera, Q., Y. Christophe, S. Chabrillat, and J.-C. Lambert, Evaluation of ozone analyses from UARS MLS assimilation by BASCOE between 1992 and 1997, *Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, Vol. 3:2, 190-202, 2010. | | |
| **Previous Projects**  **EU:** FP5 ASSET;FP6 GEOmon, GEMS, UFTIR, HYMN; FP7 MACC, PASODOBLE, EVOSS, NORS, InGOS, ICOS\_Inwire  **ESA:** GECA, CHEOPS-GOME, CHEOPS-SCIA, ESA CCI-O3, ESA-CCI GHG, SIROCCO, TASTE, Multi-TASTE, TASTE-F, SACS, GLOBEMISSION  **National:** AGACC-II, UAV\_Reunion, BAAF  **Bilateral:** AMFIC | | |

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| **No** | **Name** | **Country** |
| **3** | **CNR** | **Italy** |
| **Expertise and experience of the organization**  CIAO is located in Potenza at the IMAA (Istituto di Metodologie per l’Analisi Ambientale), an Institute of the Italian National Research Council (CNR), a public organization of great relevance in the field of scientific and technological research. The main research activities of CNR-IMAA regard the study of the atmosphere and the Earth’s surface using remote sensing techniques, environmental and geophysical monitoring, the evaluation of the impacts of the anthropogenic activities and the implementation of models to assess the best resources allocation.  The CNR-IMAA research activities involve more than 100 researchers and make use of laboratories and facilities of international relevance in the field of the Earth Observation. CNR-IMAA is characterized by a high scientific productivity and a concrete support and technological transfer to end users. IMAA participated in a large number of national and international projects.  At present, CNR-IMAA is coordinating ACTRIS FP7 infrastructure, arisen on the basis of the EARLINET-ASOS and EUSAAR FP6 projects, the first of which coordinated also by the CNR-IMAA in support of the activity of EARLINET network for aerosol research. CNR-IMAA has been partner in several FP6 and FP7 projects, like GEOMON, WEZARD, ITARS and involved or coordinating ESA projects like ESA-VALID, ESA-CALIPSO. CNR-IMAA is involved in several international networks like AEORNET, CLOUDNET, GALION, GRUAN The infrastructure has been involved in several international experiments for the study of clouds and its modelling, such as EAQUATE, LAUNCH-2005, COPS-2007, LUAMI, PEGASOS, ChArMex. | | |
| **Role in the project**  CNR will be the interface with ACTRIS (Aerosols, Clouds, and Trace gases Research Infrastructure Network) EU FP7 project and with a few of the main international initiatives for aerosol monitoring at the global scale like GALION, the GAW Aerosol Lidar Observation Network, the Scientific Advisory Group for Aerosols of the Global Atmosphere Watch (GAW) aerosol program of WMO and the Scientific Advisory Group on Volcanic Ash (VA-SAG) of WMO and IUGG supporting ICAO (International Civil Aviation Organization).  CNR will also coordinate the interaction with EU infrastructures for the “Ocean” and “Land” domains, fully exploiting the role of it participants at European level.  CNR has a leader role in the remote sensing community both for lidar due to the coordination EARLINET and the microwave radiometry remote sensing, due to the coordination of of MWRnet (an International Microwave Radiometer Network). CNR is largely involved in GRUAN, as one of the stations and through the membership to WG-GRUAN and the coordination of GATNDOR (GRUAN Analysis Team for Network Design and Operations Research).  CNR will specifically contribute to:   * Coordinate the review of the current observing capability at European and global level for at least the core ECVs; * Provide a comprehensive characterization of the total uncertainty budget for the measurements of aerosol optical properties including all other higher order effects affecting the aerosol measurements in the UT/LS; * Define reference quality measurements and quantification of uncertainties for microwave techniques; * Provide support to collocation mismatch studies on aerosol and water vapor | | |
| **Key personnel CVs**  **Dr. Fabio Madonna** **(male)** is a researcher at the Istituto di Metodologie per l’AnalisiAmbientale of the Italian National Research Council (CNR) since 2008. He has ten years of experience in the application of the lidar, radar and microwave techniques and in their integration to improve the profiling of atmospheric parameters, such as temperature, water vapour, aerosol and cloud liquid water. He is working on the aerosol-clouds interactions. He is also involved in the development of multi-wavelength lidar systems for the investigation of atmospheric aerosol.  He has participated in several international experiments, such as EAQUATE, LAUNCH-2005, COPS-2007 and LUAMI. He is the contact person for the CNR-IMAA in the cooperation with the Cloudnet (Development of a European pilot network of stations for observing cloud profiles) community where the CNR-IMAA is involved in. He is also the team leader of the Topic “Quantifying the Value of Complementary Observations” in the frame of the research programme GATNDOR (GRUAN Analysis Team for Network Design and Operations Research), related to GRUAN (GCOS Upper-Air Reference Network) and he has been nominated chair of the program. He is also part of GCOS AOPC Working Group on Atmospheric Reference Observations (WG-ARO) that coordinates GRUAN activities. He is task leader in the WP20 of ACTRIS FP7 infrastructure project and a lead scientist in the MarieCurie ITN project ITARS (Initial Training for Atmospheric Remote Sensing). | | |
| **Dr. Gelsomina Pappalardo (female)** (born in 1962, Laurea Degree in Physics, Ph.D. Methods and Technologies for Environmental Monitoring, Head of Lidar Group at the “Istituto di Metodologie per l’Analisi Ambientale del Consiglio Nazionale delle Ricerche, CNR-IMAA) and of the CNR-IMAA Atmospheric Observatory (CIAO).  Dr. Pappalardo has over 20 years of research experience in the field of atmospheric studies with lidar techniques. She has authored or co-authored more than 50 papers in the peer-reviewed literature. Dr. Gelsomina Pappalardo participated as PI in several national and international projects. In particular, she coordinated the CNR-IMAA research activity in the validation program of the NASA LITE experiment; she coordinated the validation activity for MIPAS water vapour data in the framework of ENVISAT/Cal/Val/ESA project. PI of the ESA projects: “Aerosols and Clouds: Long Term Database from Spaceborne Lidar Measurements”, “Multi-Mission Quality Analysis by LIDAR” and “CEOS Intercalibration of Ground-Based Spectrometers and Lidars”. PI of the EC FP6 Project “Global Earth Observation and Monitoring” (GEOMon) and of the EC FP7 Project “Weather hazards for aeronautics” (WEZARD).  She was the coordinator of the FP6 Project “European Aerosol Research Lidar Network – Advanced Sustainable Observation System (EARLINET-ASOS)” [2006-2011] and she is the EARLINET speaker since 2006.  She was member of the EarthCARE Joint Mission Advisory Group (ESA-JAXA) [2007-2012].  Dr. Pappalardo is the coordinator of ACTRIS (Aerosols, Clouds, and Trace gases Research Infrastructure Network) EU FP7 project [2011-2015].  She is co-chair of GALION, the GAW Aerosol Lidar Observation Network. She is member of the Scientific Advisory Group for Aerosols of the Global Atmosphere Watch (GAW) aerosol program of WMO and of the Scientific Advisory Group on Volcanic Ash (VA-SAG) of WMO and IUGG supporting ICAO (International Civil Aviation Organization). She is Chair of the ESFRI Strategic Working Group for Environmental Science. | | |
| **Dr. Domenico Cimini (male)** is researcher at CNR-IMAA since 2010. He received the laurea (cum laude) and Ph.D. degrees in Physics from the University of L'Aquila, Italy. Since 2002, he has been Researcher at the Center of Excellence for Remote Sensing and Modeling of Severe Weather (CETEMPS, L'Aquila, Italy), Research assistant at the Cooperative Institute for Research in Environmental Sciences (CIRES, University of Colorado, Boulder, USA), Adjunct Professor at the Department of Electrical and Computer Engineering (University of Colorado, Boulder, USA). He has more than ten years experience with radiometer calibration techniques, microwave radiative transfer, ground- and satellite-based passive microwave and infrared radiometry.  Dr. Cimini participated as investigator and co-principal investigator to several international projects funded by the European FP7 (EURAINSAT, FUTUREVOLC), the European Space Agency (METAWAVE), the U.S. Atmospheric Radiation Measurement program (WVIOP), and the Italian Space Agency (FLORAD, ROSA 2G). He participated in several field campaigns (TUC, HyMeX), including three Water Vapor Intensive Operational Periods (WVIOP).  Dr. Cimini co-authored more than 45 peer-reviewed papers (13 as first author). Since 2013 he is Associate Editor for Atmospheric Measurement Techniques of the European Geosciences Union.  Currently Dr. Cimini is sharing the coordination of an International Microwave Radiometer Network (MWRnet), grouping more than 20 meteorological institutions. He is co-chair of the Microwave Radiometer working group of the EU COST Action ES1303 TOPROF. | | |
| **Publications**  Sawamura, P., J P Vernier, et al. (2012). Stratospheric AOD after the 2011 eruption of Nabro volcano measured by lidars over the Northern Hemisphere. ENVIRONMENTAL RESEARCH LETTERS, vol. 7, p. 1-9, ISSN: 1748-9326, doi: 10.1088/1748-9326/7/3/034013  Pappalardo, G., Wandinger U., et al. (2009), EARLINET correlative measurements for CALIPSO: first intercomparison results, J. Geophys. Res., 115, D00H19, 2010.  Pappalardo, G., Mona L., et al.: Four-dimensional distribution of the 2010 Eyjafjallajökull volcanic cloud over Europe observed by EARLINET, Atmos. Chem. Phys., 13, 4429-4450, doi:10.5194/acp-13-4429-2013, 2013.  Madonna, F., Amodeo, A., Boselli, A., Cornacchia, C., Cuomo, V., D'Amico, G., Giunta, A., Mona, L., and Pappalardo, G.: CIAO: the CNR-IMAA advanced observatory for atmospheric research, Atmos. Meas. Tech., 4, 1191-1208, doi:10.5194/amt-4-1191-2011, 2011.  Madonna; F., A. Amodeo,; G. D'Amico, G. Pappalardo (2013), A study on the use of radar and lidar for characterizing ultragiant aerosol, Journal of Geophysical Research: Atmospheres, Volume 118, Issue 17, pages 10,056–10,071, 16 September 2013. | | |
| **Previous Projects**  EU FP7: ITARS, ACTRIS, WEZARD  EU FP6: EARLINET - ASOS, GEOmon, EARLINET, CEE/CNR n.EV5V-CT92-0131  COST: 720, ES-0702, ES1303  ESA: ESA-VALID, ESA-CEOS, ESA-CALIPSO, ENVISAT validation  National: OSCAR, RECCO-NextDATA, COS-OT, PON, Meris/AATSR/MWR/RA-2/AVHRR/HIRS/IASI cloud Mask, MURST-CNR,Project Sud  Bilateral: CNR-DWD (Germany), CNR and BAS (Bulgaria) | | |

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| **No** | **Name** | **Country** |
| **4** | **Met Office** | **UK** |
| **Expertise and experience of the organization**  The Met Office is the UK’s national weather and climate service and is responsible for all aspects of operational weather forecasting. This includes the continuous development of operational numerical weather prediction (NWP) models including a global model with a horizontal resolution of 17km, and a regional model with a horizontal resolution of 1.5 km. Satellite data plays a key role in the data assimilation systems used to provide the initial conditions for these numerical models and around 70 staff are involved in research and development towards the improved use of satellite data in these assimilation systems. Met Office staff are involved, through WMO, in the specification of requirements for the global observing system. Through EUMETSAT and ESA Met Office scientists have played a central role in the detailed specification of meteorological satellites, in the pre-launch calibration of instruments, and in the post-launch on-orbit validation of operational missions led by Europe and the US. Through this pioneering work the Met Office has developed close links to other emerging operational space agencies in China and Japan and these links will be critical in delivering the work planned in WP4.  The Met Office is home to the Hadley Centre for climate prediction and research which provides guidance on the science of climate change and is the primary focus in the UK for climate science. Hadley Centre scientists routinely use satellite derived datasets for the validation of climate models and will provide authoritative steer on user perspectives of the project.  The Met Office has an international observation network, with a programme of over 160 staff. Observations are essential to all Met Office activities and the data collected are used both on their own and in various products and services including: initialisation of Numerical Weather Prediction models, forecast verification, provision of evidence of climate change and support to weather and climate consultancy services. The quality controlled observations range from marine to upper air to surface and use a wide range of techniques including active and passive remote sensing, and in-situ observations. Teams specialise in aircraft observations and upper air observations and will input into WP1 and 2. | | |
| **Role in the project**  Scientists from the Satellite Applications and Data Assimilation sections of the Met Office will lead and deliver WP4 in conjunction with their counterparts at ECMWF. The main deliverables of WP4 concern the validation of a set of satellite instruments due for launch just prior to, or within, the timeframe of the project, and developing a real time monitoring capability for reference data from the GRUAN network. Finally, the expertise in the Met Office in diverse areas, including: operational ocean assimilation and forecasting; land surface data assimilation; climate research and the maintenance and development will be used to ensure the methods developed in WP4 can be credibly extended and applied to other domains and ECVs.  Scientists from the Observations section of the Met Office will contribute to WP 1 and 2 specifically on aircraft and sonde gap analysis and measurement uncertainty quantification, and on GNSS. | | |
| **Key personnel CVs**  **Dr. William Bell (male)** leads the satellite radiance assimilation group at the Met Office, a group of 10 scientists responsible for the operational assimilation of microwave and infrared radiance data. He completed his PhD in High Resolution Infrared Spectroscopy in 1992 and joined the Met Office in 2001 after 11 years with the UK’s National Physical Laboratory - the UK’s national metrology institute - where he worked on the development of very high resolution infrared interferometers for the remote sensing of stratospheric composition. During his time at the Met Office (2001-2008, 2012 - present) he has been engaged in work aimed at the validation and improved assimilation of radiance data from a range of satellite instruments. He joined the Satellite Section at ECMWF on secondment from 2008-12 where he was engaged in the continued development of ECMWF’s use of new sources of microwave sounding and imaging data. He has been a member of several satellite Cal / Val teams in the US ( SSMIS, ATMS, CrIS) , is a member of EUMETSAT’s Scientific Advisory Group for the Metop-Second Generation MWI and ICI missions, and was joint winner of the WMO’s 2012 Vaisala Prize for his work on validation of a Chinese polar orbiting mission (FY-3A). He will be responsible for the overall management, coordination and delivery of WP4. | | |
| **Nigel Atkinson** **(male)** joined the Met Office in 1990, following a physics degree at the University of Oxford. For his first 6 years he was involved in the development of aircraft and balloon instrumentation for cloud physics and atmospheric chemistry research.. In 1990 he joined the remote sensing group that was responsible for the procurement, pre-launch calibration and post-launch support of the AMSUB series of microwave radiometers; he was initially involved with hardware testing, and later with the analysis of in-orbit data. He is currently an Expert Scientist in the Satellite Applications group. He has conducted several studies on requirements for future microwave and infrared instruments. He also co-chairs the Products Working Group of the International TOVS Working Group (ITWG). In this project he will be responsible for the validation of the Level 1 radiances from the satellite studied in WP4. | | |
| **Andrew Smith (male)** Completed a first degree in Physics in 1995 and subsequently joined the Satellite Applications section at the Met Office. There he has worked on numerous projects on the use of satellite data in meteorology, including initial simulation studies of AMSU radiances, assimilation of TOVS and ATOVS data, generation of imagery from geostationary satellites, ice-scattering simulations for AMSUB,and latterly the assimilation of CrIS data. He designed and developed the processing code that is used for the assimilation of all satellite radiances and is currently engaged in the development of a new system for the monitoring of operational satellite data. In this study he will be responsible for the development of the software infrastructure required for the monitoring of the GRUAN data and for coding the observation operators for the GRUAN observations. | | |
| **Dr. Clare Lee (female)** is a scientific manager in the Observation Based Research Group at the Met Office. She has worked in the Met Office for over 10 years on airborne, satellite and ground based data and instrumentation, including several international field campaigns. She obtained her PhD in Atmospheric Physics in 1997 and has since worked as a researcher as a University Postdoc and Fellow on airborne instrumentation and analysis. She has strong collaborative links throughout the Met Office and in the scientific community. | | |
| **Dr. Edmund Stone (male)** is a scientist working within Observations Research and Development at the Met Office. He joined the office in 2012 after completing an experimental physics PhD in plasmonics. Since joining the office he has been primarily involved in deriving meteorological data from messages received from aircraft (Mode-S/ADS-B) including deploying receiving stations, developing decoding software and the characterisation of error statistics for the data. He is also involved in the development of aircraft based sensors and currently working on optimising aircraft observation flight selection systems. | | |
| **Dr Jonathan Jones (male)** is head of Global Navigation Satellite System meteorology research and development work for the Met Office. Jonathan has worked for the Met Office for over 10-years developing his GNSS expertise incorporating a strong blend of academic, commercial and cross government understanding through current and previous partnerships. Jonathan has both technical and GNSS processing expertise and has successfully delivered the operational GNSS-meteorology project and product management as well as partner channel expansion for the Met Office. | | |
| **Publications**  P. P. Weston, **W. Bell** and J. R. Eyre (2013), “Accounting for correlated error in the assimilation of high resolution sounder data”, Accepted Q. J. R. Meteorol. Soc  Qifeng Lu, **W. Bell** N. Bormann, P. Bauer, C. Peubey, A. Geer (2011), “Improved Assimilation of Data from China’s FY-3A Microwave Temperature Sounder (MWTS)”, Atmospheric Science Letters, DOI: 10.1002/asl.354.  **W.Bell,** S. Di Michele, P. Bauer, T. McNally, S. J. English and J. Charlton (2010), “The Radiometric Sensitivity Requirements for Satellite Microwave Temperature Sounding Instruments for NWP”, Journal of Atmospheric and Oceanic Technology*,* Volume 27, Issue 3 pp. 443-456 doi: 10.1175/2009JTECHA1293.1  Gaffard, C., Nash, J., Walker, E., Hewison, T. J., **Jones, J.**, and Norton, E. G., (2008), “High time resolution boundary layer description using combined remote sensing instruments”, Ann. Geophys., 26, 2597-2612  **Jones, J., (**2010), “An Assessment of the Quality of GPS Water Vapour Estimates and their use in Operational Meteorology and Climate Monitoring”, PhD Thesis, Institute of Engineering, Surveying and Space Geodesy, the University of Nottingham | | |
| **Previous Projects**  **EUMETNET:** E-GVAP, E-AMDAR, E-PROFILE, SESAR, OPERA  **EUMETSAT**: EUMETSAT CM SAF, EUMETSAT NWP SAF, EUMETSAT ROM SAF, Cal/val of: SSMIS, ATMS, CrIS  **ESA**: ESA-CCI, ESA GlobTEMP  **WMO:** GRUAN GNSS-PWV, WIGOS, GCOS  **EU:** CHARMe, HYMEX, QA4ECV, UERRA, ERA-CLIM2  **COST:** EG-CLIMET, TOPROF, GNSS4SWEC | | |

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| **No** | **Name** | **Country** |
| **5** | **BK Scientific GmbH (BKS)** | **Germany** |
| **Expertise and experience of the organization**  BK Scientific is an independent research and consulting company that provides data, scientific expertise, consulting services, data analysis services, and software development to clients in Europe and elsewhere including government agencies, research institutions, universities, and other commercial research companies. The company is managed by its owners. The focus of the services provided is primarily in the fields of environmental and climate change science. The company provides unique services to its clients in form of but not limited to: Software development for the validation and interpretation of satellite-based measurements of atmospheric composition, development of retrieval algorithms for remote sensing of the atmosphere, data processing, trend analyses, analysis of climate prediction indicators, organisation and implementation of international measurement campaigns and meetings. | | |
| **Role in the project**  BKS will lead WP2 on ‘measurement uncertainty quantification’ and will also contribute to WP1 and WP6. Main objective will be the management of WP2 and the assessment and quantification of several ozone measurement technique uncertainties. | | |
| **Key personnel CVs**  **Dr. Karin Kreher (female)** is the director of BK Scientific and has previously worked as research scientist for NIWA (National Institute of Water and Atmospheric Research). She has 15 years of experience in satellite validation and contributed to calibration/validation projects such as TASTE and Multi-TASTE. Karin was recently contracted by the Deutsche Wetterdienst (DWD) to participate in the validation of Metop A and Metop B GOME ozone profiles. She is part of the NDACC (Network for the Detection of Atmospheric Composition Change) steering committee and has a good understanding of ground-based observation techniques. Karin was also involved with GRUAN as the Lauder co-site representative for 2011-2012. | | |
| **Dr. Greg Bodeker (male)** is the co-owner of BK Scientific and co-chair of GRUAN. He has nearly 20 years of experience in satellite calibration/validation. He has led a number of research projects to create long-term climate data records of upper air essential climate variables, with a particular emphasis on ozone. He has worked extensively to make, understand and interpret ozonesonde measurements of the vertical distribution in the atmosphere. As co-chair of GRUAN and the author of the *GRUAN Guide to Operations*, he is well aware of the requirements in terms of measurement uncertainties for reference quality measurement records. | | |
| **Publications**  Brunner, D., J. Staehelin, J. A. Maeder, I. Wohltmann, and G. E. Bodeker, Variability and trends in total and vertically resolved stratospheric ozone based on the CATO ozone data set, *Atmos. Chem. Phys.*, *6*, 4985–5008, 2006.  Bodeker, G. E., B. Hassler, P. J. Young, and R. W. Portmann, A vertically resolved, global, gap-free ozone database for assessing or constraining global climate model simulations, *Earth System Science Data*, *5*, 31-43, 2013.  Hassler, B.; Bodeker, G.E.; Solomon, S. and Young, P.J., Changes in the polar vortex: Effects on Antarctic total ozone observations at various stations, *Geophys. Res. Lett.*, 38, L01805, doi:01810.01029/02010GL045542, 2011.  Roscoe, H.K.; Van Roozendael, M.; Fayt, C.; du Piesanie, A.; Abuhassan, N.; Adams, C.; Akrami, M.; Cede, A.; Chong, J.; Clémer, K.; Friess, U.; Gil Ojeda, M.; Goutail, F.; Graves, R.; Griesfeller, A.; Grossmann, K.; Hemerijckx, G.; Hendrick, F.; Herman, J.; Hermans, C.; Irie, H.; Johnston, P.V.; Kanaya, Y.; Kreher, K. et al., Intercomparison of slant column measurements of NO2 and O4 by MAX-DOAS and zenith-sky UV and visible spectrometers, *Atmos. Meas. Tech.,*3*,* 1629-1646, 2010.  Piters, A.J.M.; Boersma, K.F.; Kroon, M.; Hains, J.C.; Van Roozendael, M.; Wittrock, F.; Abuhassan, N.; Adams, C.; Akrami, M.; Allaart, M.A.F.; Apituley, A.; Bergwerff, J.B.; Berkhout, A.J.C.; Brunner, D.; Cede, A.; Chong, J.; Clémer, K.; Fayt, C.; Frieß, U.; Gast, L.F.L., Gil-Ojeda, M.; Goutail, F.; Graves, R.; Griesfeller, A.; Großmann, K.; Hemerijckx, G.; Hendrick, F.; Henzing, B.; Herman, J.; Hermans, C.; Hoexum, M.; van der Hoff, G.R.; Irie, H.; Johnston, P.V.; Kanaya, Y.; Kim, Y.J.; Klein Baltink, H.; Kreher, K. et al., The Cabauw Intercomparison campaign for Nitrogen Dioxide measuring Instruments (CINDI): design, execution, and early results*, Atmos. Meas. Tech.,*5, 457-485, 2011. | | |
| **Previous Projects**  EU: FP7 StratoClim | | |

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| **No** | **Name** | **Country** |
| **6** | **Koninklijk Nederlands Meteorologisch Instituut (KNMI)** | **Netherlands** |
| **Expertise and experience of the organization**  KNMI is the Dutch national weather service and centre for climate research. The institute combines in house operational as well as strategic research tasks. As an integral part of the Ministry of Infrastructure and Environment KNMI provides on a day-to-day basis advice on weather and climate to national, regional and local authorities. KNMI is participating in many European projects on both climate and space research and keeps close ties with many of its stakeholders. The space research division has a long-standing experience and expertise with satellite missions observing atmospheric composition including GOME, SCIAMACHY, OMI and GOME-2. KNMI’s satellite research division hosts both the OMI Principal Investigator (Prof.dr. P.F. Levelt) as well as the TROPOMI (launch 2015) Principal Investigator (Dr. P. Veefkind). KNMI has led and executed many large international space projects including ESA projects on observational requirements (CAPACITY, CAMELOT and ON-TRAQ). KNMI participates in many SAF groups in cooperation with Eumetsat. KNMI is currently coordinating different EU projects, including QA4ECV and EURO4M. The EURO4M project covers all non-composition atmospheric ECVs as well as SST and snow cover over the European area. The modeling research division is leading in climate and Earth-System modeling and coordinator of the EC-Earth consortium and includes authors as well as lead authors contributing to IPCC 5AR and WMO ozone assessments. The modeling division is responsible for the prognostic air quality forecasting system for the Netherlands based on the regional air quality model LOTOS-EUROS. In the context of the Copernicus Atmosphere Core Service KNMI coordinates the validation sub-group in the MACC project. KNMI is providing a variety of state-of-the-art climate services including tailored climate scenarios for the Netherlands using the in-house developed regional climate model RACMO. KNMI hosts the Cabauw Experimental Site for Atmospheric Research (CESAR), which is the national focal point for atmospheric research and monitoring. CESAR is one of the so-called supersites for climate monitoring in Europe and is an ACTRIS main site where key parameters of the atmospheric state and air quality are measured. CESAR data is used for long term records, process studies as well as test beds for model evaluation and satellite validation. Advanced techniques for atmospheric profiling are used and are continuously developed. Quality controlled observations are part of several networks, such as BSRN, Aeronet, EARLINET, CloudNet and ACTRIS. CESAR is also a candidate site for GRUAN. | | |
| **Role in the project**  KNMI participates in the project with the objective to contribute to improved operational and non-operational services using the atmospheric composition products that are retrieved from satellite data, including the Sentinels (4, 5, 5p). Improvements in the validation and quality of the COPERNICUS atmosphere services is a secondary aim. This will be achieved by the application of advanced assimilation methods using both ground-based and satellite data within the MACC framework. KNMI will contribute to GAIA-Clim with data sets from ground-based instruments (CESAR, GRUAN), as well as to the outreach and embedding activities with assimilation/modelling studies and ECV gap analysis  Contribution to WP1, 2, 6 | | |
| **Key personnel CVs**  **Mr. Arnoud Apituley (male)** is senior scientist at KNMI. He has research experience in ground based and space borne remote sensing applications including tropospheric ozone, clouds, aerosols and water vapour. His main interest is in integrating in-situ and ground based and space borne remote sensing techniques, for the study of air quality and climate change at the Cabauw Experimental Site for Atmospheric Research (CESAR). He contributed to experimental campaigns for air quality and climate related effects of aerosols and clouds and to several satellite validation studies (GOME, Envisat, LITE, CALIPSO, OMI). He contributed to studies using synergies between different remote sensing techniques and studies linking satellite remote sensing data to ground based observations. He is coordinator of the Sentinel-5p/TROPOMI Level 2 working group and the TROPOMI Level 2 CAL/VAL team. He has served on the different international committees for LIDAR applications, including the EARLINET council, and as expert on an ISO working group for ground based laser remote sensing, and is vice chair of the WMO CIMO working group on new technologies and testbeds. He is member of the GRUAN working group and site representative of the candidate GRUAN site Cabauw/De Bilt. He is an active participant in ACTRIS. | | |
| **Dr. Henk Eskes (male)** joined the KNMI Atmospheric Composition Research Section in 1996. His expertise is on the assimilation of observations of GOME, SCIAMACHY and OMI in global chemistry-transport models. He has developed 4D-Var and statistical interpolation data assimilation schemes for ozone. He has developed a combined retrieval-assimilation approach to NO2 which is still in use for SCIAMACHY, GOME-2 and OMI. He has participated in the EU projects (SODA, DARE, GODIVA, ASSET, EVERGREEN, COST actions, GEMS, MACC, MACC-II), and the SCIAMACHY validation project. He has coordinated the EU project GOA (GOME assimilated and validated O3 and NO2 fields for scientific users and model validation). He was involved in the ESA TEMIS (Tropospheric Emission Monitoring Internet Service) and the ESA-GSE PROMOTE projects. He is part of the GEMS, MACC and MACC-II management team and is coordinator of the MACC-II VAL sub-project. Since 2006 he is involved in the development of a prognostic air quality forecasting system for the Netherlands, in collaboration with TNO and RIVM. In MACC-II he is contributing to the regional air quality sub-projects with daily forecasts and analyses, and yearly reanalyses based on the LOTOS-EUROS model. | | |
| **Dr. Michiel van Weele (male)** has more than 20 years of experience in multi-disciplinary atmospheric research. In 1996 he did his PhD research on the analysis of actinic flux, photolysis, and chemistry measurements, and their interpretation with ultraviolet radiative transfer models. Since 1997 he is employed as atmospheric scientist at the Climate Research Department of KNMI. He has been leading in the definition of satellite user and data requirements for future Operational Atmospheric Chemistry Monitoring Missions (CAPACITY, 2003-2005), contributed to Post-EPS Eumetsat requirements and requirements for Sentinel 4 and 5 through ESA, and first authored the science requirements document for TROPOMI which will be flown as Sentinel-5 precursor in the 2015+ timeframe. He was a member of the PREMIER Mission Advisory Group (2009-2013) and led the definition of the scientific and L2 data requirements for PREMIER. He contributes to the inclusion of climate-composition couplings in the Earth System model EC-Earth and the development of C-IFS within MACC-II. Currently he contributes to ESA Ozone-CCI, EU FP7 SPECS and EU FP7 GMES-Pure. | | |
| **Publications**  Huijnen, V., Eskes, H. J., Poupkou, A., Elbern, H., Boersma, K. F., Foret, G., Sofiev, M., Valdebenito, A., Flemming, J., Stein, O., Gross, A., Robertson, L., D'Isidoro, M., Kioutsioukis, I., Friese, E., Amstrup, B., Bergstrom, R., Strunk, A., Vira, J., Zyryanov, D., Maurizi, A., Melas, D., Peuch, V.-H., and Zerefos, C., Comparison of OMI NO2 tropospheric columns with an ensemble of global and European regional air quality models, Atmos. Chem. Phys., 10, 3273-3296, doi:10.5194/acp-10-3273-2010, 2010.  Huijnen, V., Flemming, J., Kaiser, J. W., Inness, A., Leitao, J., Heil, A., Eskes, H. J., Schultz, M. G., Benedetti, A., Dufour, G., and Eremenko, M., Hindcast experiments of tropospheric composition during the summer 2010 fires over Western Russia, Atmos. Chem. Phys. 12, 4341-4364, doi:10.5194/acp-12-4341-2012, 2012.  De Laat, A.T.J., and M. van Weele, The 2010 Antarctic ozone hole: Observed reduction in ozone destruction by minor sudden stratospheric warmings, Sci. Rep., 1, 38; DOI:10.1038/srep00038 , 2011.  van der A, R. J., Allaart, M. A. F., and Eskes, H. J., Multi sensor reanalysis of total ozone, Atmos. Chem. Phys., 10, 11277-11294, doi:10.5194/acp-10-11277-2010.  Graaf, M. de, A. Apituley and D.P. Donovan, Feasibility study of Integral property retrieval for tropospheric aerosol from Raman lidar data using principle component analysis, Appl. Optics, 2013, 52, 10, 2173-2186, doi:10.1364/AO.52.002173.  Piters, A. J. M., Boersma, K. F., Kroon, M., Hains, J. C., Van Roozendael, M., Wittrock, F., Abuhassan, N., Adams, C., Akrami, M., Allaart, M. A. F., Apituley, A., et al., The Cabauw Intercomparison campaign for Nitrogen Dioxide measuring Instruments (CINDI): design, execution, and early results, Atmos. Meas. Tech., 5, 457-485, doi:10.5194/amt-5-457-2012, 2012. | | |
| **Previous Projects**  CAPACITY (Composition of the Atmosphere: Progress to Applications in the user CommuITY, 2003-2005); GEMS (Global and regional Earth-system monitoring using satellite and in-situ data, 2005-2009, partner); MACC (Monitoring Atmospheric Composition and Climate), 2009-2011, partner); MACC-II (Monitoring Atmospheric Composition and Climate, 2011-2014, partner); PASODOBLE (Promote Air Quality Services integrating Observations – Development Of Basic Localised Information for Europe), 2010-2013, partner); Post-EPS user requirements (Eumetsat, 2006); PROMOTE (PROtocol MoniToring for the GMES Service Element, 2004-2008, coordinator); EARLINET-ASOS (European Aerosol Research Lidar Network - Advanced Sustainable Observation System, 2006 - 2010); ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network, 2011- 2015) | | |

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| **No** | **Name** | **Country** |
| **7** | **ECMWF** | **International** |
| **Expertise and experience of the organization**  The European Centre for Medium-Range Weather Forecasts (ECMWF) is an international organisation supported by 34 States: 19 Members (Belgium, Denmark, Germany, Greece, Iceland, Spain, France, Ireland, Italy, Luxembourg, the Netherlands, Norway, Austria, Portugal, Switzerland, Finland, Sweden, Turkey, United Kingdom) and 15 Co-operating Members (Bulgaria, Croatia, Czech Republic, Estonia, the former Yugoslav Republic of Macedonia, Hungary, Israel, Latvia, Lithuania, Montenegro, Morocco, Romania, Serbia, Slovakia and Slovenia).  ECMWF’s principal objectives are the development of numerical methods for medium-range weather forecasting; production of medium-range and long-range weather forecasts for distribution to the meteorological services of the Member States; scientific and technical research directed to the improvement of these forecasts; the collection and storage of appropriate meteorological observations. ECMWF’s computer facility includes supercomputers, archiving systems and networks. A detailed description is available at http://www.ecmwf.int/services/computing/overview  ECMWF, through its partnerships with EUMETSAT, ESA, the EU and the European Science base, has established a leading position for Europe in the exploitation of satellite data for operational numerical weather prediction, for operational seasonal forecasting with coupled atmosphere-ocean-land models, and for climate reanalysis. | | |
| **Role in the project**  ECMWF participation in the project is based on its expertise in data assimilation and experience with global reanalysis of observations from multiple sources. Its main contribution is to the integration and assessment of reference network data in NWP and reanalysis (work package 4). ECMWF will also contribute to the capability mapping and gap analysis (work package 1) by providing a critical assessment of the current strengths, weaknesses and limitations of reanalysis systems in its ability to combine satellite data with in-situ observations. | | |
| **Key personnel CVs**  **Dr. David Tan (male)** is a Senior Scientist at ECMWF, with extensive experience in satellite remote sensing, data assimilation, reanalysis, climate modelling, atmospheric dynamics and chemical transport modelling. He is a member of the GCOS Working Group on the GCOS Reference Upper Air Network. | | |
| **Dr. Paul Poli (male)** joined the ECMWF Reanalysis group as a Consultant seconded from Meteo-France in October 2008. He graduated from the Ecole Nationale de la Meteorologie, France in 1999 and the University of Maryland, Baltimore County, USA with a PhD in Atmospheric Physics in 2004. From 1999 to 2008, Paul conducted research at Meteo-France and at the NASA Goddard Space Flight Center in Maryland, USA. His expertise lies in Earth observations from satellites and their assimilation in NWP and reanalysis systems. Paul has experience working on transnational projects, has served as an editor, and as a reviewer for various journals and research projects. He is now a member of the Science Panel of the Global Geodetic Observing System. | | |
| **Dr Dick Dee (male)** is Head of the Reanalysis Section, in the Data Division of the Research Department at ECMWF. He played a pivotal role in the design and production of the ERA-Interim reanalysis, and is currently Coordinator of the FP7 ERA-CLIM/ERA-CLIM2 projects. Prior to joining ECMWF in 2005 he worked at NASA where he helped design and made major contributions to the GMAO data assimilation system. He is an expert in climate reanalysis with a strong background in data assimilation, Kalman filtering theory and applications, and observational quality control and bias correction techniques. | | |
| **Dr Jean-Noël Thépaut (male)**, is “Ingénieur en Chef des Ponts et Eaux et Forets” seconded from Météo-France at ECMWF. He is currently the Head of the Data Division and Deputy Director of the Research Department at ECMWF. This Division includes three groups of world-class scientists specialised in Satellite Data exploitation, Data Assimilation techniques, and Reanalysis activities. He is member of the Meteosat Third Generation Mission Team, member of the Post-EPS Mission Expert Team, member of the Scientific Steering Group of GMAO (NASA), and member of the ESA's Earth Scientific Advisory Committee (ESAC). He has considerable expertise in data assimilation (he was involved in the early development of the 3D and 4D-Var system at ECMWF and Météo-France, for which he developed an incremental formulation that is now used operationally worldwide) and in the exploitation of a wide variety of satellite data in Numerical Weather Prediction. | | |
| **Drs Carole Peubey, Rossana Dragani, Paul Berrisford, Patrick Laloyaux and Hans Hersbach** are senior scientists working in the ECMWF reanalysis section. Collectively their experience covers a wide range of aspects relevant to the proposal. | | |
| **Publications**  Dee, D. P., et al. "The ERA‐Interim reanalysis: Configuration and performance of the data assimilation system." Quarterly Journal of the Royal Meteorological Society 137.656 (2011): 553-597.  Simmons, A. J., et al. "Low‐frequency variations in surface atmospheric humidity, temperature, and precipitation: Inferences from reanalyses and monthly gridded observational data sets." Journal of Geophysical Research: Atmospheres (1984–2012) 115.D1 (2010).  Poli, P., S. B. Healy, and D. P. Dee. "Assimilation of Global Positioning System radio occultation data in the ECMWF ERA–Interim reanalysis." Quarterly Journal of the Royal Meteorological Society 136.653 (2010): 1972-1990.  Dee, D. P., and S. Uppala. "Variational bias correction of satellite radiance data in the ERA‐Interim reanalysis." Quarterly Journal of the Royal Meteorological Society 135.644 (2009): 1830-1841.  Uppala, S. M., et al. "The ERA‐40 re‐analysis." Quarterly Journal of the Royal Meteorological Society 131.612 (2005): 2961-3012. | | |
| **Previous Projects**  CHARMe, CORE-CLIMAX, Earth2Observe, EMBRACE, ERA-CLIM(2), EUCLIPSE, Geoland2, GEOWOW, IGAS, IMAGINES, MACCII/III, MyOcean(2), PANDA, SPECS, UERRA | | |

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| **No** | **Name** | **Country** |
| **8** | **MAX PLANCK GESELLSCHAFT ZUR FOERDERUNG DER WISSENSCHAFTEN E.V. – Max-Planck-Institut für Biogeochemie (MPG)** | **Germany** |
| **Expertise and experience of the organization**  The Max Planck Institute for Biogeochemistry, a research institute of the German Max Planck Society (MPG), was founded in 1997 in Jena. Its research mission is the investigation of global biogeochemical cycles and their interaction with the climate system. The institute combines strong observational expertise (in-situ and remote sensing GHG observations, vegetation-atmosphere fluxes etc.) with local to global scale biosphere and atmosphere modelling (e.g. carbon cycle).  The department of Biogeochemical Systems maintains regular long-term in-situ measurements of methane and carbon dioxide, among other trace gases and isotopes, at tall towers in western Siberia (ZOTTO), Germany (Ochsenkopf), Poland (Bialystok), and smaller measurements masts in Namibia, Cape Verde, and the Amazonian site ATTO, where a tall tower is currently being built. Flasks measurements are taken from the WMO GAW background sites in Alert and Shetland Islands. The departments contributes to the TCCON network of FTS measurements with its site at Ascension Island, providing total column measurements at a remote ocean site important for satellite validation. The department is also responsible for the greenhouse gas measurement package within the IAGOS project, which measures high precision atmospheric abundances of CO2, CH4, CO, and water vapour continuously in situ on board passenger aircraft. Other IAGOS measurement packages measure ozone, CO, NOy, and aerosols. The department uses these and other atmospheric measurements, including satellite measurements of atmospheric composition and surface properties, in a top-down modelling framework, including both global and regional scale inversion systems, to better understand the carbon cycle at a variety of spatial and temporal scales. | | |
| **Role in the project**  MPG will contribute to the project specifically with its expertise in the field of carbon dioxide and methane. Due to its long and comprehensive involvement in ground-based measurements, the institute can offer expert knowledge related to the existing ground-based measurement capabilities for these species, including a realistic characterization of the measurement uncertainties and the measurement representativeness in space and time. The existing data assimilation framework existing for these two gases will be exploited and expanded upon to assess the ground-based, aircraft-based and space-based measurement capabilities currently available, providing necessary information to improve on-going validation of satellite products, and to identify obvious gaps and short-comings in the current measurement system. Through this work the MPG will contribute to WP 1. | | |
| **Key personnel CVs**  ***Julia Marshall (female)*** is the head of the research group ‘Satellite-based remote sensing of greenhouse gases’ in the Biogeochemical Systems department. Her research involves applying satellite products in global tracer inversion as well as in regional scale modelling. She is a member of the Scientific Advisory Group for the joint German-French active methane satellite mission MERLIN. | | |
| ***Christoph Gerbig (male)*,** leader of the research group on ‘Airborne trace gas measurements and mesoscale modelling’ within the department of Biogeochemical Systems, is PI and steering committee member in the EU Projects ICOS and IAGOS-ERI. He has expertise in the development and deployment of instrumentation for airborne and ground based in-situ trace gas measurements, as well as in the development and application of high-resolution transport models (Lagrangian and Eulerian) for regional scale inversions. | | |
| **Publications**  Chen, H., J. Winderlich, C. Gerbig, A. Hoefer, C.W. Rella, E.R. Crosson, A.D. Van Pelt, J. Steinbach, O. Kolle, V. Beck, B.C. Daube, E.W. Gottlieb, V.Y. Chow, G.W. Santonie, and S.C. Wofsy, High-accuracy continuous airborne measurements of greenhouse gases (CO2 and CH4) using the cavity ring-down spectroscopy (CRDS) technique. Atmos. Meas. Tech., (2010) 3: 375-386.  Gerbig, C., A. J. Dolman, and M. Heimann (2009), On observational and modelling strategies targeted at regional carbon exchange over continents, Biogeosciences, 6(10), 1949-1959.  Houweling, S., I. Aben, F.-M. Bréon, F. Chevallier, N. Deutscher, R. Engelen, C. Gerbig, D. Griffith, H. Hungershöfer, R. Macatangay, J. Marshall, J. Notholt, W. Peters, and S. Serrar, The importance of transport model uncertainties for the estimation of CO2 sources and sinks using satellite measurements. Atmos. Chem. and Phys., (2010) 10: 9981-9992.  Hungershöfer, K., F.-M. Bréon, P. Peylin, F. Chevallier, P. Rayner, A. Klonecki, S. Houweling, and J. Marshall, Evaluation of various observing systems for the global monitoring of CO2 fluxes. Atmos. Chem. and Phys., (2010) 10: 10503-10520.  Pillai, D., C. Gerbig, J. Marshall, R. Ahmadov, R. Kretschmer, T. Koch, and U. Karstens, High resolution modeling of CO2 over Europe: implications for representation errors of satellite retrievals. Atmos. Chem. and Phys., (2010) 10: 83-94. | | |
| **Previous Projects**  Together Christoph Gerbig and Julia Marshall are currently coordinating and managing the FP7 project IGAS (IAGOS for the GMES Atmosphere Service), which, among other objectives, is developing a fully-traceable description of the uncertainty characterization for all IAGOS measurements. Currently they are also participating in the FP7 project ICOS-INWIRE and the European Research Infrastructures IAGOS and ICOS. Previous participation in FP7 projects includes CarboEurope-IP, GEMS, GHG-Europe, and Geocarbon. Participation in previous and current ESA projects includes GHG-CCI Phase 2, A-SCOPE, and LOGOFLUX. | | |

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| **No** | **Name** | **Country** |
| **9** | **Ilmatieteen laitos (FMI)** | **Finland** |
| **Expertise and experience of the organization**  The Finnish Meteorological Institute (FMI: http://www.fmi.fi/en) has the mandate of producing reliable scientific information on the state of the atmosphere, as well as contributing to scientific ends. FMI employs about 700 people, about 350 of which are involved in research programmes focused on Climate Change, Air Quality, Atmospheric composition and chemistry, Meteorology, Marine Research, Earth Observation, and Arctic Research. FMI participates in many (inter)national collaborative projects (e.g., currently ca. 40 FP7 projects) with in situ observations, satellite and ground-based remote sensing and modelling on local, regional and global scales of atmospheric composition (e.g., WMO/GAW, EMEP, AMAP, HELCOM/EGAP, GMES, GEOSS). FMI maintains several research stations, among which the PALLAS GAW-station in Finnish Lapland, a very clean subarctic background site. FMI’s research infrastructure includes a cloud radar and several lidars. FMI develops satellite retrieval algorithms for air quality and climate applications. Two groups focus on satellite remote sensing of aerosols (Science co-lead of ESA’s Aerosol-cci) and trace gases. FMI leads the Ozone-SAF and participates in several other SAFs (e.g. climate).  FMI contributes to the GRUAN activities through measurement programs at GRUAN station Sodankylä. Arctic Research Centre at Sodankylä (FMI-ARC) has hosted several international campaigns related to calibration and validation of satellite borne instruments. Since 2009 the FMI-ARC is involved in the Total Carbon Column Observing Network (TCCON). FMI also provides aerosol information from 5 sun photometers in Finland (part of AERONET and WMO-GAW-PFR), Ozone and UV information using Brewers in Joikionen (with 17 years one of the world’s longest time series) and Sodankylä. | | |
| **Role in the project**  FMI participates in the project with the objective to improve the quality of atmospheric composition products retrieved form satellite data from a better understanding of the retrieval process and underlying data sets from the comparison with well-characterized ground-based observations. This will be achieved by the application of advanced data analysis methods to both ground-based and satellite data. FMI will contribute data sets from both satellites (aerosols, trace gases) and ground-based instruments (sun photometers, PFR, Brewer, TCCON, GRUAN), as well as to the outreach with modelling activities. Contribution to WP1, 2, 3. | | |
| **Key personnel CVs**  **Prof. Dr. Gerrit de Leeuw (male)** holds a professorship in the field of Satellite Remote Sensing of Aerosol Physical and Optical Properties at the University of Helsinki and at FMI, since 1 January 2007. He has (co-) authored ca. 145 peer-reviewed articles in the fields of aerosols, remote sensing and ocean-atmosphere interaction and co-edited a book on ‘Aerosol Remote Sensing over Land’. He has participated as PI in 24 EU projects (3 as coordinator), 15 ESA projects (2 as coordinator, 1 as science co-leader), and many other (inter)national research projects. | | |
| **Dr. Rigel Kivi (male)** is a senior scientist at the Finnish Meteorological Institute. He has more than 20 years of experience in atmospheric research. At FMI Arctic Research Center he is currently a principal investigator of several measurement programs related to atmospheric ozone, aerosols, greenhouse gases and atmospheric water vapor. He is coordinating a Finnish Academy project on atmospheric water vapor. At FMI he is the Sodankylä site representative within GRUAN and TCCON. He has participated in several EU projects and satellite calibration/validation projects organised by NASA, ESA and EUMETSAT. | | |
| **Dr. Johanna Tamminen** **(female)** (Research Prof., tenure track at FMI) is currently leading the Atmospheric Remote sensing group at the FMI’s Earth Observation Unit. She is also Docent (Adj. Prof) in Applied Mathematics at the University of Helsinki. She is co-Principal Investigator of Dutch-Finnish Ozone Monitoring Instrument (OMI) flying on-board NASA’s EOS-Aura satellite. She is a member of ESA’s Sentinel 5 Precursor Mission Advisory Group and Envisat/GOMOS Quality Working Group. She is presently coordinating the WMO-IGACO-O3/UV secretariat. Her research interests cover, in atmospheric remote sensing as well as mathematical and statistical inverse problems. She has published about 60 peer refereed international journal articles. | | |
| **Dr. Antti Arola (male)** is a research professor (tenure-track) at FMI. He has expertise on several aspects of atmospheric radiation and on the effect of aerosols on solar radiation. He is the PI of surface UV product in the international OMI science team. He has participated in several EU-projects (e.g. GEMS, MACC, MAUVE, SUVDAMA, EDUCE). | | |
| **Publications**  de Leeuw, G., T. Holzer-Popp, S. Bevan, W. Davies, J. Descloitres, R.G. Grainger, J. Griesfeller, A. Heckel, S. Kinne, L. Klüser, P. Kolmonen, P. Litvinov, D. Martynenko, P.J.R. North, B. Ovigneur, N. Pascal, C. Poulsen, D. Ramon, M. Schulz, R.Siddans, L. Sogacheva, D. Tanré, G.E. Thomas, T.H. Virtanen, W. von Hoyningen Huene, M.Vountas, S. Pinnock (2013). Evaluation of seven European aerosol optical depth retrieval algorithms for climate analysis, Remote Sensing of Environment (2013), <http://dx.doi.org/10.1016/j.rse.2013.04.023>.  Arola, A., Schuster, G., Myhre, G., Kazadzis, S., Dey, S., and Tripathi, S. N.: Inferring absorbing organic carbon content from AERONET data, Atmos. Chem. Phys., 11, 215-225, doi:10.5194/acp-11-215-2011, 2011.  Arola, A. et al., A new approach to correct for absorbing aerosols in OMI UV, *Geophys. Res. Lett.*, 36, L22805, doi:10.1029/2009GL041137, 2009.  Smit, H., R. Kivi, H. Vömel, A. Paukkunen, Thin Film Capacitive Sensors, In: Monitoring Atmospheric Water Vapour, ISSI Scientific Report Series, Volume 10, Part 1, 11-38, DOI: 10.1007/978-1-4614-3909-7\_2, Springer, 2013.  Calbet X., Kivi R, Tjemkes S., Montagner F., Stuhlmann R., Matching radiative transfer models and radiosonde data from the EPS/Metop Sodankylä campaign to IASI measurements, Atmospheric Measurement Techniques, 4(6), 1177 – 1189, 2011 | | |
| **Previous Projects** | | |

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| **No** | **Name** | **Country** |
| **10** | **University of Bremen (UBremen)** | **Germany** |
| **Expertise and experience of the organization**  The Institute of Environmental Physics within the Faculty of Physics of the University of Bremen has more than ten years experience in remote sensing of the earths atmosphere, both from the ground and from space by satellites. The group of Justus Notholt has setup several measurements sites around the world, where atmospheric trace gases are measured from the ground by the solar absorption spectrometry. These observation sites are in Bremen/Germany, Bialystok/Poland, Orleans/France, Paramaribo/Surinam, and in Ny-Aalesund/Spitsbergen. In addition, ship cruise observations are performed regularly to measure the latitudinal variability of the trace gases. The measurements are accepted within the Network for Detection of Atmospheric Composition Change (NDACC) and the Total Column Carbon Observing Network (TCCON). Furthermore his group performs microwave observations to study the atmosphere in the mesosphere, and satellite studies to investigate sea ice properties. | | |
| **Role in the project**  The group of Justus Notholt runs 4 TCCON sites (Bremen, Bialystok, Orleans, Ny-Aalesund) and is the European chair of TCCON. Within these activities the group participates in H2O2 by studying the variability, accuracy, and representativeness of the observations performed at the TCCON sites, and is involved in finding gaps in the network. | | |
| **Key personnel CVs**  **Prof. Dr. Justus Notholt (male)** is the head of the remote sensing group at the Institute of Environmental Physics at the University of Bremen and has 20 years experience in ground based remote sensing of the atmosphere. He graduated in Solid State Physics at the University of Kassel in 1985 and received his PhD degree in Physical Chemistry at the same University in 1989. During a two years stay as postdoctoral fellow at the Joint Research Centre of the EC, Environment Institute, Ispra (Italy), he initialised DOAS observations applied to trace gas and aerosol measurements in the free atmosphere and to laboratory investigations. Since September 1990, he has been associated with the Alfred-Wegener-Institute for Polar and Marine Research. He began atmospheric trace gas measurements by FTIR-spectrometry in the high Arctic. The measurements using FTS systems have been extended for the NIR up to the UV/Vis. In 1994 he started the observations during ship cruises and in 2000 he performed a measurement campaign in Antarctica. In April 2002 he obtained a professorship at the university of Bremen. The FTS-activities in the high Arctic, during the ship cruises and in the tropics are conducted in close cooperation with AWI. In addition to the FTS-activities he performs observations by the Microwave radiometers to study processes in the mesosphere, and studies of the extent of properties of sea ice by operational satellites. | | |
| **Publications**  J. Notholt, Z. Kuang, C.P. Rinsland, G.C. Toon, M. Rex, N. Jones, T. Albrecht, H. Deckelmann, J. Krieg, C. Weinzierl, H. Bingemer, R. Weller, O. Schrems, Enhanced upper tropical tropospheric COS: Impact on the stratospheric aerosol layer, Science, 300, 307-310, 2003.  C. Frankenberg, K. Yoshimura, T. Warneke, I. Aben, A. Butz, N. Deutscher, D. Griffith, F. Hase, J. Notholt, M. Schneider, H. Schrijver, T. Röckmann, Dynamic Processes Governing Lower-Tropospheric HDO/H2O Ratios as Observed from Space and Ground, Science, 325, 1374-1377, 2009.  J. Messerschmidt, R. Macatangay, J. Notholt, C. Petri, T. Warneke, C. Weinzierl, Side by side measurements of CO2 by ground-based Fourier transform spectrometry (FTS), Tellus, 62, 5, 749–758, 2010.  D. Wunch, G.C. Toon, J.-F. L. Blavier, R. Washenfelder, J. Notholt, B.J. Connor, D.W.T. Griffith, V. Sherlock, P.O. Wennberg, The Total Carbon Column Observing Network, Phil. Trans. R. Soc. A., 369, 2087–2112, 2011.  G. Keppel-Aleks, P.O.Wennberg, R.A.Washenfelder, D. Wunch, T. Schneider, G.C. Toon, R. J. Andres, J.-F. Blavier, B. Connor, K.J. Davis, A.R. Desai, J. Messchmidt, J. Notholt, C. M. Roehl, V. Sherlock, B.B. Stephens, S.A. Vay, S.C.Wofsy, The imprint of surface fluxes and transport on variations in total column carbon dioxide, Biogeosciences, 9, 875-891, 2012. | | |
| **Previous Projects**  Prof. Notholt has been involved in many national and international projects. On the European level he was involved in the EU projects ESMOS, STAR, UFTIR, HYMN, SOGE, GEOMON, IMECC, NORS. | | |

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| **No** | **Name** | **Country** |
| **11** | **Tallinn University of Technology (TUT)** | **Estonia** |
| **Expertise and experience of the organization**  The mission of TUT is to provide educational, research and innovation services in the fields of engineering and entrepreneurship, which are internationally competitive and significant for Estonia's sustained development. Through its development (founded in 1918), TUT has established a well-rooted engineering education tradition. TUT has a wide range of expertise, as well as a multiplicity of international links in engineering, economics, social science and biomedical research areas. The Laboratory for Proactive Technologies (Lab)focuses in cooperation with other departments of TUT and SME partners on theoretical and experimental study of systems of systems built from stationary and/or mobile software-intensive components including, or closely cooperating with, human experts/operators. The research is organized in two computational threads: interactive computation, in particular situation-aware models of computation, and architecture, computation and communication in *ad hoc* (sensor) networks. TUT has expertise in sensor networks for environmental monitoring, including GNSS techniques for atmospheric research. It employs a co-chair of the GRUAN GNSS-PW Task Team. It has expertise in web-based software solutions, GIS and numerical modelling (particularly Agent-Based Modelling and Simulations); modelling of situation awareness in networked systems by autonomous (proactive) agents and their self-organizing communities; a novel approach of self-organising dynamic maps, applied for knowledge based decision support systems.  The Lab is closely collaborating with FMI Arctic Research Centre (ARC) at Sodankylä in frames of GNSS data processing; Institute of Mathematics of the University of Tartu (numerical modelling of geophysical processes); TUT Tartu College (monitoring and modelling of environmental processes); SME IB Krates (tools for and development of embedded systems’ software); SME Defendec (wireless sensor networks and their applications); IMECC - Estonian Competence Centre for Innovative Manufacturing Engineering Systems, the lab is responsible for Self-organising systems with on-line monitoring and diagnostics. | | |
| **Role in the project**  TUT (Laboratory for Proactive Technologies) will contribute to Work Package WP2, with coordinating a subtask quantifying GNSS-PW uncertainty (particularly concentrating on derivation of ZTD uncertainty as a main contributor to GNSS-PW uncertainty). In WP3, by coordination of a task on developing software tools to ensure appropriate transition of WP3 knowledge and results into WP5 Virtual Observatory. In WP5 contributing into creating a collocation database by making inventory of the existing software solutions at project partner sites and will support EUMETSAT in the development of web based applications needed for delivering diagnostic results on the collocations; develops the graphical user interface for the Virtual Observatory. | | |
| **Key personnel CVs**  ***Dr. Kalev Rannat* (male)** is a senior research scientist at Tallinn University of Technology. His scientific activities are related to modelling of geophysical processes and monitoring of environment with large sensor networks (including *ad hoc* sensor networks and GNSS systems).  He is working on developing software for simulation and modelling of environmental processes and their impact on socio-technological systems in frames of CRISMA EU FP7 project. His particular activity is devoted to using GNSS observations for meteorological purposes, for supporting monitoring of climate change and NWP. He is also working on implementation of GNSS-techniques for a national project - Estonian Radiation Climate. He is a co-chair of the GRUAN GNSS-PW Task Team, and MC member of COST ES1206 GNSS4SWEC. Dr. Rannat has participated in different international scientific and technology projects. Kalev Rannat coordinates TUT contributions in the proposed project and participates in developing/testing the tools and methods for ECV uncertainties analysis. | | |
| ***Dr. Merik Meriste (male***) is a senior research scientist at Tallinn University of Technology. , Laboratory for Proactive Technologies. His research interests are in cyber-physical and system of systems modeling and simulation methods - agent-based modeling and simulation of situation-aware proactive systems and systems of systems, foundations of interactive computing, formal models of interactive computations. Focus of the current work is in the research and development of shared situation awareness by adaptive communities of situation aware agents providing services for collecting, fusion, and redistribution of situational information for adequate decision support. He has developed a novel approach of self-organizing dynamic maps, applied for knowledge based decision support systems in various projects and prototype applications (in EDA projects Athena, Cardinal, in FR7 project CRISMA). He has 42 years of experience in computer science and software systems research, software development (compiler construction), defense research (NATO RTO Modeling and Simulation Group member, NATO RTO workgroups) and, teaching in Universities of Tartu, Helsinki, Turku and Kuopio and in Tallinn University of Technology. He is member of the COST ICT Domain Committee.  Merik Meriste contributes in conceptual and architectural issues in developing the “virtual observatory”. | | |
| ***Dr. Peep Miidla* (male)**, is an Associate Professor of the Institute of Mathematics of UT and will be subcontracted by TUT for this project. The main scientific interests are connected with differential equations (ODE and PDE), dynamical systems, numerical modelling and computer simulations in operational research. He is a member of ECMI (European Consortium for Mathematics in Industry, http://www.ecmi-indmath.org/) Council, representative of Estonia at EURO (<http://www.euro-online.org/>) and IFORS (<http://ifors.org/web/>). Experiences in modelling of monitoring GNSS sensor networks, numerical solution of systems of differential equations, application of optimization methods, included heuristic methods. Peep Miidla contributes and participates in developing/testing the tools and methods for ECV uncertainties analysis. | | |
| **Publications**  H.Keernik, H. Ohvril, E. Jakobson, K. Rannat, A. Luhamaa, Column water vapour: An intertechnique comparison of estimation methods in Estonia (2014, in Press).  Rannat, K.; Meriste, M.; Mõtus, L.; Preden, J.-S. (2012). On Dynamic Models for Wind Farms as Systems of Systems. In: Proceedings of 2012 7th International Conference on System of Systems Engineering : SoSE in Cooperative and Competitive Distributed Decision Making for Complex Dynamic systems : IEEE SoSE2012, Genoa, Italy, July 16-19, 2012. IEEE, 2012.  Miidla, Peep (2011). Data Envelopment Analysis in Environmental Technologies. Environmental Modeling for Sustainable Regional Development: System Approaches and Advanced Methods (242 - 259). IGI Publishing.  Miidla, P.; Rannat, K.; Uba, P. (2009). A Mathematical Model of Troposphere Water Vapor Tomography. Proceedings of the Second International Conference on Environmental and Computer Science (183 - 187). IEEE Computer Society  Miidla, P.; Rannat, K. (2009). Integrated model of double-diffusive convection: numerical stability. INTERNATIONAL JOURNAL OF MATHEMATICAL MODELS AND METHODS IN APPLIED SCIENCES, 2(4), 455 - 462. | | |
| **Previous Projects**  **International:**  ITEA project – Gene-Auto: Automatic software code generation for real-time embedded systems (partners Airbus, EADS Astrium, Thales-Alenia, Continental, and others); ARTEMIS Joint Undertaking project SIMPLE: Self-organising intelligent middleware platform for manufacturing and logistics enterprises (partners CAEN RFID, Hellenic Aerospace Industry, Philips Consumer Lifestyle, UNINOVA, Gorenje, and others); NATO RTO, task groups SCI-TG-181 (Design considerations and technologies for air defence systems), and SCI-TG 206 (System Design Considerations and Technologies For Safe High tempo operations in degraded environments); EDA Athena (Asymmetric THreat ENvironment/ENgagement Analysis) project; FP7 CRISMA; IN4STARS.  **National:**  Tomographical Surveillance of the Trophosphere; Nonlinear dynamics and stress analysis; Proactivity and situation-awareness; Spatial and temporal variability of the Baltic Sea wave fields in changing climatic conditions; Multi-agent systems in heterogeneous environment with dynamic structure, Ontologies of interactivity, multi-agent systems and time; Structural Problems in Analysis, Algebra, and Geometry, with Applications to Numerical Analysis. | | |

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| **No** | **Name** | **Country** |
| **12** | **Global Climate Observing System (GCOS)** | **UN** |
| **Expertise and experience of the organization**  GCOS is a joint undertaking of the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP) and the International Council for Science (ICSU). Its goal is to provide comprehensive information on the total climate system, involving a multidisciplinary range of physical, chemical and biological properties, and atmospheric, oceanic, hydrological, cryospheric and terrestrial processes. It is built on the WMO Integrated Global Observing System (WIGOS), the IOC-WMO-UNEP-ICSU Global Ocean Observing System (GOOS), the UN Food and Agriculture Organization (FAO)-UNEP-UNESCO-ICSU Global Terrestrial Observing System (GTOS) and a number of other domain-based and cross-domain research and operational observing systems. It includes both in situ and remote sensing components, with its space based components coordinated by the Committee on Earth Observation Satellites (CEOS) and the Coordination Group for Meteorological Satellites (CGMS). GCOS is intended to meet the full range of national and international requirements for climate and climate-related observations. As a system of climate-relevant observing systems, it constitutes, in aggregate, the climate observing component of the Global Earth Observation System of Systems (GEOSS).  GCOS is a long-term, user-driven operational system capable of providing the comprehensive observations required for monitoring the climate system, for detecting and attributing climate change, for assessing the impacts of climate variability and change, and for supporting research toward improved understanding, modelling and prediction of the climate system. GCOS addresses the total climate system including physical, chemical and biological properties, and atmospheric, oceanic, terrestrial hydrologic, and cryospheric components.  The GCOS programme stimulates, encourages, coordinates and otherwise facilitates the taking of the needed observations by national or international organizations in support of their own requirements as well as of common goals. It provides an operational framework for integrating, and enhancing as needed, observational systems of participating countries and organizations into a comprehensive system focussed on the requirements for climate issues. The GCOS programme does not directly make observations nor generate data products.  GCOS builds upon, and works in partnership with, other existing and developing observing systems such as the WMO Global Observing System and Global Atmosphere Watch, the Global Ocean Observing System, and the Global Terrestrial Observing System. It includes *in situ*, airborne and space-based observational components.  GCOS is directed by a Steering Committee which provides guidance, coordination and oversight to the programme. Three science panels, reporting to the Steering Committee, have been established to define the observations needed in each of the main global domains (atmosphere, oceans, and land), to prepare specific programme elements and to make recommendations for implementation:   * Atmospheric Observation Panel for Climate (AOPC) * Ocean Observations Panel for Climate (OOPC) * Terrestrial Observation Panel for Climate (TOPC)   The GCOS Secretariat located at the WMO headquarters in Geneva, Switzerland, supports the activities of the Steering Committee, the panels and the GCOS programme as a whole. | | |
| **Role in the project**  GCOS will contribute to the deliverables in WP1 (and ultimately WP6) with its expertise on global observing systems capability and its operational performance monitoring of these networks. GCOS also has good links to the different global regions and countries themselves, in terms of both the observing stations and equipment (metadata) and the measurements.  GCOS will provide a link to its own Steering Committee and the Atmospheric Observation Panel for Climate (AOPC). | | |
| **Key personnel CVs**  **Tim Oakley (male),** GCOS Implementation Manager.  I am employed by, and based at, the UK Met Office but work full-time for GCOS under a secondment agreement. My background is working for 24 years at the Met Office in the Observations branch, primarily in the Research and Development of Upper-Air Instrumentation but more recently as a network manager responsible for the operational delivery for a number of UK observing networks. As such I have experience in instrument and network design, procurement and specifications, network quality monitoring, financial management and capacity development. All very much focused on the end to end delivery of observational data and providing a reliable and sustainable future. I have also worked extensively in Europe where we collaborate both in the exchange and management of our observing systems, with a focus on efficiency and a sharing of technical expertise which is becoming increasingly finite. Since 2012, I have been working for programmes in WMO (Geneva), initially for WIGOS (WMO Integrated Global Observing System) and more recently GCOS. I see myself as an international network manager, linking funding from our sponsors to priority areas, both in terms of the uniqueness of measurement (i.e. location, content) and the financial challenges for the host organisation in operating the equipment. GCOS does not own any of the observing equipment but through the GCM (GCOS Cooperation Mechanism) it aims to support National services and institutes, in the design, installation and operational management of their systems. | | |
| **Publications**  WMO Intercomparison of High Quality Radiosonde Systems Yangjiang, China, 12 July - 3 August 2010  J. Nash, T. Oakley, H. Vömel, LI Wei  Systematic Observation Requirements for Satellite-based Products for Climate Supplemental details to the satellite-based component of the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC - 2011 Update, December 2011, GCOS-154  Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update), August 2010, GCOS-138 | | |
| **Previous Projects**  ESA Climate Change Initiative, 2009 - 2016 and consist of three stages: requirement analysis, algorithm development and prototype ECV building; ECV production and system development; and user analysis and feedback. - SC Chair GCOS is member of the Advisory BodyQA4EC. The ESA CCI programme is not a FP 7 project per se, but will make full use of existing bi-lateral cooperation mechanisms with the relevant EC services, notably DG-Enterprise and Industry for GMES, and DG-Research for Climate and Environment, to ensure coordinated action within Europe.  Quality Assurance for multi-decadal ECVs, is a 4-year European Union Framework 7 project, led by KNMI - D/GCOS is member of the Advisory Body. | | |

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| **No** | **Name** | **Country** |
| **13** | **National Physical Laboratory (NPL)** | **UK** |
| **Expertise and experience of the organization**  The National Physical Laboratory (NPL) is the UK’s national measurement institute and is a world-leading centre of excellence in developing and applying the most accurate measurement standards, science and technology available. For more than a century NPL has developed and maintained the nation’s primary measurement standards. These standards underpin an infrastructure of traceability throughout the UK and the world that ensures accuracy and consistency of measurement.  This proposal brings together the complementary expertise of the Environmental Measurements Group, with their experience of validating field measurement methods for a wide range of atmospheric science, air quality and climate applications and in establishing reliable uncertainties for such methods, and the Optical Measurement Group with expertise in pre-flight and in-flight satellite calibration, the exploitation of vicarious reference sites and the traceability and the development and implication of quality assurance methods and applications for Earth Observation, ECVs and derived satellite products. It will also draw on the expertise of the Temperature and Humidity Group on the traceable measurement of these key climate variables. | | |
| **Role in the project**  Under WP2, NPL will review the methodologies devised in tasks 2.1 & 2.2; consult on best practice in accordance with the GUM, independently verify a few examples within the tasks, feed in the tasks were required (resources allowing) and produce a best practise document from the task 2.1 & 2.2 activities for application by the wider community.  Under WP3 NPL will contribute to Task 3.1 on the quantification of the vertical and seasonal distribution of temporal mismatch uncertainties using high-resolution sonde and model data. NPL will develop the first ever full metrological assessment of the complete uncertainty budget associated with the comparison of ground-based and space-based optical remote sensing measurements of the vertical profile of key atmospheric species, this latter effort is distributed within tasks 3.1-3.3.  Under WP5, NPL will evaluate the Virtual Observatory in terms of the principle of the Quality Assurance service developed in the FP7 project QA4ECV, and address suitability of inclusion into that framework. | | |
| **Key personnel CVs**  **Tom Gardiner (male)** has over twenty years’ experience with NPL. He is a specialist in the development and implementation of advanced trace gas monitoring techniques, and the assessment of the calibration requirements and uncertainty analysis of such measurement methods. He has internationally leading expertise in the development of the complex optical systems required for Differential Absorption Lidar (DIAL) and he leads research with Universities to develop new laser sources for atmospheric sensing. He is a member of the AOPC Working Group on Atmospheric Reference Observations which is the steering body for the GCOS Reference Upper Air Network. Tom will lead the contribution of NPL’s Environmental Measurements Group.  **Paul Green (male)** has a research background in the calibration, characterization and exploitation of field study-based infra-red Fourier transform spectroscopy and the analysis, comparison and homogenisation of meteorological field measurements to allow the study of atmospheric phenomena. More recently he has moved to the UV-VIS-NIR spectral domain working on instrument design and realisation focusing on the development of high accuracy, low uncertainty and traceable solutions for the pre-flight and in-flight calibration of satellite instrument systems. Paul is currently a technical lead on the AIT OGSE provision for the Sentinel 4 UVN instrument. Paul will lead the contribution of NPL’s Optical Measurements Group. | | |
| **Publications**  Willett, K. M., Williams Jr., C. N., Dunn, R. J. H., Thorne, P. W., Bell, S., de Podesta, M., Jones, P. D., and Parker D. E., 2013: An updated land surface specific humidity product for climate monitoring, HadISDH:. Climate of the Past, 9, 657-677, doi:10.5194/cp-9-657-2013.  T. Gardiner, A. Forbes, M. de Maziere, C. Vigouroux, E. Mahieu, P. Demoulin, V. Velazco, J. Notholt, T. Blumenstock, F. Hase, I. Kramer, R. Sussmann, W. Stremme, J. Mellqvist, A. Strandberg, K. Ellingsen, and M. Gauss; Trend analysis of greenhouse gases over Europe measured by a network of ground-based remote FTIR instruments; Atmos. Chem. Phys., 8, 6719–6727, 2008  Immler, F. J., Dykema, J., Gardiner, T., Whiteman, D. N., Thorne, P. W., and Vömel, Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products; H Atmos. Meas. Tech., 3, 1217-1231, doi:10.5194/amt-3-1217-2010, 2010  T. Gardiner, F. Madonna, J. Wang, D. N. Whiteman, J. Dykema, A. Fassò, P. W. Thorne, and G. Bodeker ; Sampling and measurement issues in establishing a climate reference upper air network; AIP Conf. Proc. 1552, pp. 1066-1071; doi:http://dx.doi.org/10.1063/1.4821422, 2013  Ball, C., Marks, A., Green, P.D., MacArthur, A., Maturilli, M, Fox, N., King, M. Hemispherical-directional reflectance of windblown snow-covered Arctic tundra at large solar zenith angles. Submitted to Transactions on Geoscience and Remote Sensing | | |
| **Previous Projects**  EMRP Meteomet (2011-2014) Measurement traceability and uncertainty of ground based and airborne measurements of atmospheric ECVs principally temperature, humidity, and air flow.  EMPIR MetEOC (2011-2014) Pre-flight and inflight satellite calibration. | | |

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| **No** | **Name** | **Country** |
| **14** | **University of Bergamo (UniBergamo)** | **Italy** |
| **Expertise and experience of the organization**  The University of Bergamo is an Italian State University with about 16,000 students, and more than 300 PhD students. With 6 departments and a staff of 656 members (331 permanent professors and researchers, 95 assisting academic staff, 230 administrative and technical staff) it provides a dynamic scientific and teaching environment open to innovations.  In particular, the twenty year old Department of Engineering has 84 people among permanent professors and researchers and another 90 people among PhD students and research assistants. It contributes to national and European research projects. Moreover it collaborates in many Industrial funded research projects.  The Department of Engineering of the University of Bergamo has a twenty year experience in statistical methods for space-time and environmental data.  The group lead by Prof. A. Fassò and composed by Francesco Finazzi and Michela Cameletti published a number of peer reviewed papers on space-time statistical modelling of atmospheric variables, including ECVs, atmospheric gases and aerosols.  Various papers have been dedicated to space-time statistical models merging multiple sources of data, e.g. satellite and ground level data.  UniBergamo participates in GRUAN research activity (WG-GRUAN and GATNDOR) since 2011. | | |
| **Role in the project**  UniBergamo will contribute to WP1. In particular it will lead the task on statistical modelling and data analysis for mapping network uncertainty and network gaps.  UniBergamo will contribute to WP3. In particular it will contribute to the task on statistical modelling and data analysis of collocation uncertainty, in particular humidity, pressure and temperature Statistical modelling of space-time atmospheric data merging satellite and radiosondes. | | |
| **Key personnel CVs**  **Alessandro Fassò (male)** is professor of Statistics at Department of Engineering of the University of Bergamo since 1998. Coordinator of GRASPA the permanent working group of the Italian Statistical Society (SIS) on environmetrics. Member of the Council of the International Statistical Institute (ISI) 2013-2017. Member and past Secretary (2008-2011) of The International Environmetrics Society (TIES). Member of WG-GRUAN, the Working Group on Global Climate Observing System (GCOS) Atmospheric Reference Observations.  He is author of more than 100 papers and, in the last twenty years its research activity has been mainly concentrated on environmetrics. In particular he developed statistical methods and models for space-time data with applications to ECV’s atmospheric profiles and air quality meso scale problems, handling heterogeneous and heterotopic networks for ground level data, model outputs, satellite observations and missing values (cloudy days).  Since 2011 he is member of GRUAN Working group contributing his statistical modelling and data analysis expertise to understanding vertical profiles of climate variables, collocation uncertainty and space-time variability.  He will lead UniBG group contributing to statistical modelling and data analysis for mapping network uncertainty and network gaps (WP1) and statistical modelling and data analysis of collocation uncertainty (WP3). | | |
| **Francesco Finazzi (male)** is a researcher at the Department of Management, Economics and Quantitative Methods of the University of Bergamo, where he is currently working at the research programme "Statistical modeling of environmental phenomena".  In October 2009, he received his Ph.D. in Applied Statistics at the Department of Quantitative Methods, University of Milan-Bicocca. He received his M.Sc. degree in Computer Engineering at the University of Bergamo in September 2005.  His research interests are in space-time stochastic models, geostatistics, remote sensing data, environmetrics, image analysis, artificial vision and distributed computing. He is an expert in Matlab, R language and parallel computing for large datasets.  He is research affiliate at the School of Mathematics and Statistics of the University of Glasgow, member of the International Environmental Society (TIES) and member of GRASPA, the permanent working group of the Italian Statistical Society (SIS) on environmetrics.  He will contribute his expertise on space-time modelling of large dataset for mapping network gaps in WP1. | | |
| **Michela Cameletti (female)** is assistant professor in Statistics at the Department of Management, Economics and Quantitative Methods, University of Bergamo since 2008.  At the University of Milan-Bicocca, she had Summa cum Laude M.Sc. in Statistics in 2001 and Ph.D. in Statistics in 2007, with a dissertation on “Spatio- temporal models for environmental data”.  Her current research interests include: spatio-temporal models for environmental data, computer intensive methods for parameter estimation and mapping, Bayesian modelling of exposure to air pollutants, integration of atmospheric variables from different sources, Bayesian hierarchical models for combining individual and ecological data in space-time studies. She is an expert in R language and parallel computing.  She is local principal investigator for the FIRB2012 project “Statistical modeling of environmental phenomena” (http://stephiproject.it/).  She is a member of The International Environmetrics Society (TIES), of the Italian Statistical Society (SIS), of the International Society for Bayesian Analysis (ISBA) and of GRASPA, the permanent working group of the Italian Statistical Society (SIS) on environmetrics.  She will contribute her expertise on Bayesian space-time modelling and R language for collocation uncertainty in WP3. | | |
| **Publications**  Fassò A, Finazzi F. (2013) A varying coefficients space-time model for ground and satellite air quality data over Europe. Statistica and Applicazioni. Special Issue. 45-56. (http://www.vponline.it/riviste/statisticaeapplicazioni/2013/2/).  Gardiner T, Madonna F, Wang J, Whiteman DN, Dykema J, Fassò A, Thorne P, Bodeker G. (2013) Sampling and Measurement Issues in Establishing a Climate Reference Upper Air Network. AIP Conf. Proc. 1552, pp. 1066-1071; doi:http://dx.doi.org/10.1063/1.4821422  Fassò, A, Ignaccolo, R, Madonna, F, and Demoz, B. (2013) Statistical modelling of collocation uncertainty in atmospheric thermodynamic profiles, Atmos. Meas. Tech. Discuss, 6, 7505-7533, doi:10.5194/amtd-6-7505-2013.  Finazzi F, Scott M.E, Fassò A. (2013). A model based framework for air quality indices and population risk evaluation. With an application to the analysis of Scottish air quality data. Journal of the Royal Statistical Society, series C. Vol.62(2): 287-308. DOI: 10.1111/rssc.12001.  Fassò A, Finazzi F, (2011) Maximum likelihood estimation of the dynamic coregionalization model with heterotopic data. Environmetrics. Vol. 22:6, 735-748. Online ISSN: 1099-095X. Published Online. DOI:10.1002/env.1123. | | |
| **Previous Projects**  Period: 2013-. Funding: Italian Research and University Ministry  Project: Future in Research (FIRB-2012).  General Subject: Statistical modeling of environmental phenomena (http://stephiproject.it).  Period: 2011-2012. Funding: Regione Lombardia  Project: AQ2009-EN17  Subject: Methods for the integration of renewable energy sources and satellite monitoring of the environmental impact (http://wwwdata.unibg.it/dati/bacheca/224/47381.pdf)  Period: 2007-2009 Funding: Italian Research and University Ministry  Project: Relevant National Project (PRIN-2006).  Subject: Statistical analysis and modelling of impact and risk for environmental phenomena in space and time  (http://www.ricercaitaliana.it/prin/dettaglio\_completo\_prin\_en-2006131039.htm). | | |

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| **No** | **Name** | **Country** |
| **15** | **EUMETSAT** | **International** |
| **Expertise and experience of the organization**  The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) is an international organisation, founded in 1986, currently with 29 European Member States (Austria, Belgium, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom) and 2 Co-operating States (Bulgaria and Serbia). The main purpose of EUMETSAT is to deliver weather and climate-related satellite data, images and products, 24 hours a day, 365 days a year. This information is supplied to the National Meteorological Services of the organisation’s Member and Cooperating States in Europe, as well as other users world-wide.  Regarding climate variability and change studies, EUMETSAT’s mission is to provide satellite-based Climate Data Records over decades with the highest possible level of accuracy, reliability and stability as approved by a Council Resolution in June 2009. EUMETSAT has a more than 25 year long history of ensuring best product quality and timeliness for their users.  EUMETSAT has developed dedicated operating systems for sustained offline satellite data processing including instrument cross-calibration and evaluation capabilities that is currently used within the EU FP7 ERA-CLIM2 and QA4ECV projects to provide improved satellite data records for the 20th century reanalysis and for climate model related studies. EUMETSAT is also a partner in the EU FP7 project CORE-CLIMAX that coordinates Earth observation data for the validation of reanalysis. Within this project EUMETSAT has developed the system maturity matrix and application performance metric that are used to assess European capacity for the generation of GCOS ECV climate data records. | | |
| **Role in the project**  Scientists from Climate Services Section of EUMETSAT will lead and deliver WP5 in conjunction with the partners of the work package. The major deliverable of WP 5 is the Virtual Observatory that integrates collocated satellite and in situ measurements as well as data from reanalysis inclusive their respective traceable estimates of uncertainty. The data of the Virtual Observatory contain radiance data, retrieved geophysical quantities and some selected geographical maps for the geographical quantities. EUMETSAT will develop diagnostic graphical output for several satellite missions on the Virtual Observatory and will use it to demonstrate its usefulness for the monitoring of instrument quality.  In addition EUMETSAT will be active in WP 1 with further developments of the process oriented quality assessment tools such as the maturity matrix developed in the FP7 project CORE CLIMAX. EUMETSAT will also use its international contacts to support the outreach activities of the project in several forums of science and satellite agencies. | | |
| **Key personnel CVs**  **Jörg Schulz, PhD** **(male)**, is the Head of the Climate Services Section at EUMETSAT and will be responsible for EUMETSAT’s contribution to GAIA-CLIM. He has more than 25 years experience in retrieval of various atmospheric and oceanic parameters using observations in the visible, infrared and microwave spectral range, radiative transfer and satellite instrument calibration and inter-calibration. He is Vice-chair of the GEWEX Data and Assessment Panel, a member of the WCRP Data Advisory Council, the CEOS-CGMS Working Group Climate, the Executive Panel of WMO Space Programme Sustained Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM) initiative, and serves as a co-chair of the climate working group of the IRC/CGMS-TOVS Working Group. He is also co-author of the document describing the architecture for space-based climate monitoring. | | |
| **Marie Doutriaux-Boucher (female)**, PhD, works as Climate Product Evaluation Expert at EUMETSAT where she is responsible for the evaluation of Climate Data Records generated at EUMETSAT. She has more than 15 years experience with EUMETSAT satellite data, retrieval systems, and data products. In her time at the UK Met Office she also achieved deep knowledge about climate modelling and the use of satellite data in that context. She is member of the CGMS International Winds Working Group and leads the SCOPE-CM Secretariat on behalf of CMA, JMA, EUMETSAT and NOAA: She will be the scientific and technical lead for the GAIA-CLIM work at EUMETSAT | | |
| **Rob Roebeling (male)**, PhD, works as Climate Product Expert at EUMETSAT where he is responsible for the generation of climate data records. In particular he is developing and implementing the inter-satellite calibration for both generations of the Meteosat satellites. Rob Roebeling also leads some international activities in the framework of the Global Space-based Inter-Calibration System (GSICS). He has more than 20 years experience in Cloud Properties Retrievals from satellite observations including radiative transfer of the cloudy atmosphere as well as in the field of boundary layer meteorology, crop growth modelling, and multi-sensor remote sensing. | | |
| **Drs. Alessio Lattanzio (male), Roger Huckle (male) and Viju John (male)** are senior scientists working in the Climate Services Section at EUMETSAT. Collectively their experience covers a wide range of aspects relevant to the proposal such as collocations of data and the determination of the associated uncertainty budgets. | | |
| **Publications**  Lockhoff, M., O. Zolina, C. Simmer, J. Schulz: Evaluation of Satellite-Retrieved Extreme Precipitation over Europe using Gauge Observations. *J. Climate*, **27**, 607–623. doi: <http://dx.doi.org/10.1175/JCLI-D-13-00194.1>, 2014.  Hamann, U., Walther, A., Baum, B., Bennartz, R., Bugliaro, L., Derrien, M., Francis, P., Heidinger, A., Joro, S., Kniffka, A., Le Gléau, H., Lockhoff, M., Lutz, H.-J., Meirink, J. F., Minnis, P., Palikonda, R., Roebeling, R., Thoss, A., Platnick, S., Watts, P., and Wind, G.: Remote sensing of cloud top pressure/height from SEVIRI, 2014: analysis of ten current retrieval algorithms, *Atmos. Meas. Tech. Discuss*., **7,** 401-473, doi:10.5194/amtd-7-401-2014.  Borde R., M. Doutriaux-Boucher, G. Dew, and M. Carranza, A direct link between feature tracking and height assignment of operational EUMETSAT atmospheric motion vectors, *Journal of Atmospheric and Oceanic Technology*, **31, 1** 33-46, doi: <http://dx.doi.org/10.1175/JTECH-D-13-00126.1>, 2014.  Lattanzio A, J. Schulz, J. Matthews, A. Okuyama, B. Theodore, J.J. Bates, K.R. Knapp, Y. Kosaka, L. Schüller: Land Surface Albedo from Geostationary Satellites: a multi-agency collaboration within SCOPE-CM, *Bulletin of the American Meteorological Society*, DOI:10.1175/BAMS-D-11-00230.1, 2013. | | |
| **Previous Projects**   * FP7 ERA-CLIM and FP7 ERA-CLIM 2 global reanalysis projects where EUMETSAT provides high quality input data to ECMWF; * FP7 QA4ECV project where EUMETSAT is responsible for the generation and evaluation of land surface property Climate Data Record; * FP7 CORE-CLIMAX project where EUMETSAT led the development of the maturity matrix tools and conducted a European capacity assessment for the generation of Climate Data Records; * Several projects within the global SCOPE-CM initiative inter-satellite calibration of geostationary satellites, surface albedo CDRs, Atmospheric Motion Vectors and Radio Occultation data climatology. | | |

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| **No** | **Name** | **Country** |
| **16** | **National Atmospheric and Oceanic Administration (NOAA)** | **USA** |
| **Expertise and experience of the organization**  The National Oceanic and Atmospheric Administration (NOAA) have the primary mission to understand and predict changes in climate, weather and oceans. This is largely achieved through NOAA’s National Environmental Satellite Data and Information Service (NESDIS) which operates and manages NOAA earth orbiting environmental satellites and associated data processing. The Center for Satellite Applications and Research (STAR) is the science arm of NOAA NESDIS which acquires and manages the scientific processing of environmental satellite data from the research and development stage to routine operations, enabling their dissemination and application, for example, in weather forecast and climate change detection applications. Of primary interest to STAR is atmospheric data validation. The NOAA Products Validation System (NPROVS), operated at STAR since April, 2008, provides daily compilation and archive of collocated RAOB and satellite atmospheric data which has served as a baseline for satellite validation both internally and abroad (ie by EUMETSAT). NPROVS+, deployed in July 2013, performs a similar function focused on designated reference (ie GRUAN) and dedicated RAOB sites with infrastructures to store additional observations (both satellite and ground) required for scientific research in weather and climate. The collocation strategy and dataset compilation have evolved to provide complete, well managed sets of available satellite data anchored to the ground targets. This includes graphical data display and analysis tools providing users with robust capability for data interrogation. NPROVS+ operates routinely and directly contributes to the GRUAN Working Group (WG) providing feedback on the utility of GRUAN observations in satellite validation and research. | | |
| **Role in the project**  NOAA plans to leverage the NOAA Products Validation System + (NPROVS+) to serve as a baseline for WP 5. Work will focus on expansions to include satellites, observations and analytical capabilities required by the proposed project which are not currently resident in NPROVS+. These have the objective to improve the quality of atmospheric products retrieved from satellite data through a better understanding of the retrieval process and underlying data sets through comparison with well-characterized ground-based (GRUAN) observations. This also serves to provide useful feedback to GRUAN concerning data utility, continuity and consistency across the network and the respective satellites. Providing such a baseline for the routine compilation of collocation datasets and associated graphical analysis is seen as highly cost effective and scientifically beneficial to both NOAA and European partners. | | |
| **Key personnel CVs**  **Mr Anthony Reale (male)** has been a Physical Scientist at NOAA National Environmental and Satellite Data Information Service (NESDIS) Center for Satellite Applications and Research (STAR) for over 30 years. His responsibilities include technical guidance for the development and implementation of the NOAA Products Validation System (NPROVS) and most recently the NPROVS+ operated at STAR and proposed as baseline for WP5 activities. Mr Reale has authored or (co-) authored over 20 peer-reviewed articles in the fields of remote sensing, atmospheric sounding products and validation. He currently serves as co-chair of the GRUAN Task Team on Ancillary Observations with the goal to facilitate their optimal integration from a given site into NPROVS+ for use in weather and climate monitoring. Mr Reale is a graduate of State University of New York where he received BS degrees in meteorology and physics and from the University of Nevada, Reno with an MS in Atmospheric Physics. | | |
| **Dr Bomin Sun (male)** received his Ph.D. in Atmospheric Sciences from the University of Massachusetts-Amherst and was awarded a two-year Postdoctoral Fellowship with the Department of Oceanography, Woods Hole Oceanographic Institution. He is currently a Senior Research Scientist with IMSG, Inc., where he develops and operates the radiosonde and satellite collocation system, NOAA Products Validation System (NPROVS) and its expansion (NPROVS+), onsite at NOAA / STAR. His primary area of expertise include atmospheric sounding validation, development of enhanced validation strategies using reference RAOB, respective weather and climate change detection applications, impacts of cloud and associated instrument / measurement analysis including feedback to ground based upper air (climate )observing networks. Dr Sun’s most recent contributions include the analysis of global RAOB collocations with COSMIC GPSRO to quantify RAOB radiation induced errors with potential application in NOAA operational forecasts. | | |
| **Dr. Nicholas Nalli (male)** received B.S and M.S. degrees in Education from the State University of New York, College at Oneonta, M.S. and Ph.D. degrees in Atmospheric and Oceanic Sciences from the University of Wisconsin-Madison, and was awarded a four-year Postdoctoral Fellowship with the Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University. He is currently a Senior Research Scientist with IMSG, Inc., where he performs basic and applied research onsite at NOAA/STAR. His primary research specialty is in environmental satellite remote sensing, radiative transfer and validation, with focus on oceanic and atmospheric applications. Other research interests include atmospheric aerosols, air-sea interactions, boundary layer and marine meteorology, and global climate change applications. Dr. Nalli collaborates with the Howard University NOAA Center for Atmospheric Sciences (NCAS) and has served as a Principle Investigator (PI) including ship-board participation on NOAA Aerosols and Ocean Science Expeditions (AEROSE), a series of trans-Atlantic intensive atmospheric field research campaigns that have obtained large quantities of truth data over open-ocean in support of satellite data calibration/validation efforts at STAR. | | |
| **Mr. Michael Pettey (male)** received a B.S. degree in Computer Science from the University of Maryland, College Park and a M.S. degree in Computer Science from The Johns Hopkins University. He is currently a Senior Research Analyst with IMSG, Inc., where he performs computer and system support at NOAA/NESDIS/STAR. Mr. Pettey has supported work at STAR for 24 years. During that time he has evolved as the primary person responsible for the design, development and maintenance of graphical programs to view and analyze satellite data with a focus on collocated satellite and ground truth (mainly RAOB) observations. Referred to as the Environmental Data Graphical Evaluation (EDGE) analytical interface, these provide the underlying graphical analysis tools for interrogating the baseline NPROVS+ collocation datasets proposed for WP5. Mr. Pettey has extensive experience and knowledge of multiple computer languages including Java, C, Fortran, Perl and a variety of human-computer interaction and artificial intelligence areas. Having worked primarily with NOAA scientists he is well equipped to meet the need and requirements associated with the proposed work. | | |
| **Publications**  Reale, A., B. Sun, F. Tilley, and M. Pettey, 2012: The NOAA Products Validation System (NPROVS). *Journal of Atmospheric and Oceanic Technology*, **29**, DOI:10.1175/JTECH-D-11-00072.1.  Sun, B., A.L. Reale, D.J. Seidel, and D. Hunt, 2010: Comparing radiosonde and COSMIC atmospheric profiles data to quantify differences among radiosonde types and the effects of imperfect collocation on comparison statistics. *Journal of Geophysical Research,* **115**, D23104, doi:10.1029/2010JD01445  Sun, B., A. Reale, S. Schrieder, D.J. Seidel, and B. Ballish, 2013: Toward improved corrections for radiation-induced biases in radiosonde temperature observations, *Journal of Geophysical Research,* **118**, 1–13, doi:10.1002/jgrd.50369.  Nalli, N. R., C. D. Barnet, A. Reale, D. Tobin, A. Gambacorta, E. S. Maddy, E. Joseph, B. Sun, L. Borg, A. K. Mollner, V. R. Morris,X. Liu, M. Divakarla, P. J. Minnett, R. O. Knuteson, T. S. King, and W. W. Wolf, 2013: Validation of satellite sounder Environmental Data Records: Application to the Cross-track Infrared Microwave Sounder Suite, *J. Geophys. Res. Atmos.,* **118**, doi:10.1002/2013JD020436.  Nalli, N. R.,et al., 2011: Multi-year observations of the tropical Atlantic atmosphere: Multidisciplinary applications of the NOAA Aerosols and Ocean Science Expeditions (AEROSE), *Bull. Amer. Meteorol. Soc.,* **92**, 765-789, doi: 10.1175/2011BAMS2997.1. | | |
| **Previous Projects**  Core funded | | |

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| **No** | **Name** | **Country** |
| **17** | **Helsingin yliopisto (UH)** | **Finland** |
| **Expertise and experience of the organization**  The Department of Physics at the University of Helsinki has over 25 years of experience in atmospheric research, and 125 scientists and PhD students are currently engaged in this area. The main research subjects are aerosol dynamics, atmospheric chemistry, climate change, dynamic and radar meteorology, forest-atmosphere interactions, aerosol-cloud-climate interactions, and urban air quality. The iLEAPS/IGBP project office and Pan Eurasian Experiment (PEEX) head office is at UH. The computational resources cover detailed computer codes from the nanoscale to a global scale. The basic experimental resources consist of three field stations and state-of-the-art aerosol laboratory. In last five years major efforts has been put on developments in in-situ aerosol characterization via atmospheric mass spectrometry and cluster spectrometers. | | |
| **Role in the project**  UH participates in the project with the objective to improve the quality of atmospheric composition products retrieved form satellite data that are consistent with the ground-based data. UH acts as a focal point for Pan Eurasian Experiment (PEEX) initiative providing in-situ, ground based and satellite remote sensing data from the Pan Eurasian region. UH is co-located with Integrated Carbon Observation System (ICOS) headquarters providing a link from the ground based GHG observations and the satellite community. Contribution to WP 1. | | |
| **Key personnel CVs**  **Prof Tuukka Petäjä (male)** is the leader of atmospheric aerosol observations in University of Helsinki field stations. He has 156 published or accepted peer-reviewed journal articles, 6 in Science, 4 in Nature. Total citations: 4008, h = 32, Vaisala Award 2013, FAAR Award in Excellent aerosol science. Participated in 8 EU projects, research income over 2 M€; supervised 8 PhD theses. PI for Biogenic Aerosols – Effects on Clouds and Climate AMF2 deployment supported by US DoE. | | |
| **Prof. Markku Kulmala** **(male)** is the world leading scientist in the area of atmospheric nucleation and related biosphere-atmosphere interactions. Prof Kulmala has published over 800 peer-review papers (10 in Nature, 12 in Science and 7 in Phys. Rev. Lett.). He is 1st in the Citation Rankings in Geosciences (ISI Web of Knowledge, since 1.5.2011), h= 74 (>23000 citations). He is an ERC grant holder. He is one of the founders of “terrestrial ecosystem meteorology”. His works cover theoretical and experimental physics, atmospheric chemistry, observational chemical meteorology, biophysics and, in particular, biosphere-aerosol-cloud-climate interactions. He was WP leader in ESA-ALANIS-Aerosols project. He has received many international and national prizes and awards. | | |
| **Prof Veli-Matti Kerminen** is expert in the formation and transformation of atmospheric aerosols and aerosol cloud interactions, covering both experimental and modelling approaches. He has published 180 (3 in Science, 1 in Nature, h-index=38) peer-reviewed research articles and reviewed >200 articles in 25 different journals. He has participated in 5 EU projects, produced >1.5 M€ in research income, and supervised 10 PhD theses. Editor in Atmospheric Chemistry and Physics, Boreal Environment Research. Received the Marian Smoluchowski Award for Aerosol Research in 2007. | | |
| **Asst. Prof. Dmitri Moisseev** leads the University of Helsinki Radar Meteorology Laboratory. He has extensive experience of various types of dual-polarization radars in Europe and in the USA. PhD from Delft University of Technology, A research associate at Colorado State University in Prof. Chandrasekar's group. Local organizer of Light Precipitation Validation Experiment. Supervising 8 PhD students on radar observations and precipitation microphysics. | | |
| **Prof. Heikki Järvinen** is an expert in data assimilation of observations into numerical models of the atmosphere and estimating parametric uncertainties of these models. He is a member and former chair of the Scientific Advisory Committee of the ECMWF, Member of Finland in COST Domain Committee for Earth System Science, former Co-Chair of the COSMOS Earth system modeling network. Has supervised 10 PhD students, earned about 2.5 Meur research funding, and has 60 peer-reviewed papers in various aspects of numerical modeling of the atmosphere, the most highly sited being the 4D-Var data assimilation implementation paper of ECMWF with over 300 citations. | | |
| **Publications**  Kulmala, M., et al., Direct observations of atmospheric aerosol nucleation, Science, 2013.  Kerminen, V.-M., et al., Cloud condensation nuclei production associated with atmospheric nucleation: a synthesis based on existing literature and new results, ACP, 12, 12037-12059, 2012.  Ehn, M. et al. A large source of low-volatility secondary organic aerosol, Nature, 506, 476-479.  Paasonen, P. et al. Warming-induced increase in aerosol number concentration likely to moderate climate change, Nature Geosci. 6, 438–442.  Kulmala, M. et al. (2011) The first estimates of global nucleation mode aerosol concentrations based on satellite measurements, Atmos. Chem. Phys. 11, 10791–10801. | | |
| **Previous Projects**  EC: BACCHUS, PEGASOS, ICOS, ACTRIS, EUCAARI, QUEST, OSOA, BOND, MC-ITN CLOUDTRAIN, CLOUD, HEXACOMM, Finnish Center of Excellence (Academy of Finland), Nordic center of Excellence in cryosphere-atmosphere interactions (CRAICC), ESA-ALANIS  US DOE: BAECC | | |

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| **No** | **Name** | **Country** |
| **18** | **Lille University** | **France** |
| **Expertise and experience of the organization**  The ICARE Data and Services Center at the University of Lille is a facility jointly administrated by CNRS, CNES and the University of Lille. It is the main component of the ICARE (Cloud-Aerosol-Water-Radiation Interactions) Thematic Centre that was created in 2003 by CNES, CNRS, the Nord-Pas-De-Calais Regional Concil, and the University of Lille. ICARE provides various services to support the research community in fields related to atmospheric physics, such as aerosols, clouds, radiation, water cycle, and their interactions. ICARE's initial emphasis is the production and distribution of remote sensing data derived from Earth observation missions from CNES, NASA, EUMETSAT, ESA, and various other space agencies. The ICARE Data and Services Center develops science algorithms and production codes, building on the expertise from a number of partner Science Computing Facilities, and distributes products to the user community.  ICARE has a lot of experience with the processing and analysis of large amounts of EO data in support of research activities such as climate change monitoring. ICARE contributes to many collaborative projects to provide custom data services, including visualization, subsetting, reprojection, collocation, reformatting, and satellite vs. ground-based observations comparisons. | | |
| **Role in the project**  University of Lille / ICARE will provide collocation datasets and contribute to building the match-up database under WP5. ICARE will also provide various collocation, mapping and extraction services for the project partners, and will provide specific expertise with aerosol products. | | |
| **Key personnel CVs**  **Dr. Jacques Descloitres (male)** has been the Director of the ICARE Data and Services Center since 2005. He leads a team of a dozen developers and technicians who process satellite observations and develop tools to support data analysis. Dr. Jacques Descloitres holds a Ph.D. in Physics for Remote Sensing from the University of Paris 7. His field of expertise is radiative transfer in the atmosphere and land remote sensing. Prior to joining the ICARE project in 2005, he worked as a Quality Assurance lead scientist for the MODIS Land Science Team during 1997-2000. He led the MODIS Rapid Response System at NASA Goddard Space Flight Center during 2001-2004 and was a MODIS Science Team member. | | |
| **Dr. Anne Vermeulen (female)** holds a Ph.D. in Atmospheric Physics from University of Lille. She has extensive experience in radiative transfer, atmospheric correction, and aerosol ground-based and spaceborne observations. She was responsible for the quality assurance of the MODIS surface reflectance product with the University of Maryland during 1996-1999. She worked with the AERONET group at NASA Goddard Space Flight Center during 1999-2005. She joined the ICARE Data and Services Center in 2006. | | |
| **Dr. Bruno Six (male)** holds a Ph. D. in Mathematics. He has been a senior developer with the ICARE Data and Services Center since 2004. He has extensive experience in data processing and code development, including development of operational processing codes for the Megha-Tropiques mission and other ICARE projects. | | |
| **Publications**  Bréon, F.-M., A. Vermeulen, J. Descloitres, 2011: An evaluation of satellite aerosol products against sunphotometer measurements. *Remote Sens. Environ.*, 115, 3102-3111, doi:10.1016/j.rse.2011.06.017  Descloitres, J., D. P. Roy, and P. Couvert, 2000: Evidence and implications of solar eclipses in short wavelength global remotely sensed data. *Int. J. Remote Sensing*, 21, 1961-1967.  Vermeulen A.,  C.Devaux, and M. Herman, 2000**:**Retrieval of the scattering and microphysical properties of aerosols from ground-based measurements including polarization. 1 : Method, *Applied Optics*, Vol. 39, No 33, pp 6207-6220  Descloitres, J., J. C. Buriez, F. Parol, and Y. Fouquart, 1998: POLDER observations of cloud bidirectional reflectances compared to a plane-parallel model using the ISCCP cloud phase functions. *J. Geophys. Res.*, 103, 11411-11418. | | |
| **Previous Projects**  MACC (2008-2011), MACC-II (2011-2014), MACC-III (2014-2015): Provision of NRT SEVIRI aerosol products  Aerosol-CCI-I (2011-2014), Aerosol-CCI-II (2014-2017): Provision of PARASOL and MERIS aerosol products, provision of a validation environment for the project, development of match-up capabilities for validation against AERONET  ACTRIS (2011-2015): National data center (data collection, database, processing, visualization) for French ACTRIS participants  CHARMEX (2009-2014): Provision of aerosol satellite data sets, visualization and analysis tools  GEOmon (2007-2010): Provision of aerosol satellite products, intercomparison of products and comparison to AERONET observations | | |

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| **No** | **Name** | **Country** |
| **19** | **Karlsruhe Institute of Technology (KIT)** | **Germany** |
| **Expertise and experience of the organization**  Karlsruhe Institute of Technology (KIT) is a higher education and research organisation with about 10.000 employees, 25.000 students, and a total annual budget of about 750 million Euro. It bundles the missions of a university of the state of Baden-Wuerttemberg and of a large-scale research institution of the Helmholtz Association. Within these missions, KIT is operating along the three strategic fields of action of research, teaching, and innovation. In establishing innovative research structures, KIT is pursuing joint strategies and visions. KIT is devoted to top research and excellent academic education as well as to being a prominent location of academic life, life-long learning, comprehensive advanced training, exchange of know-how, and sustainable innovation culture.  KIT’s Institute for Meteorology and Climate Research plays an active role in the research of chemistry climate interactions by remote sensing and in situ observations from ground-based, aircraft, balloon and satellite platforms as well as modelling activities. | | |
| **Role in the project**  1. KIT will perform and provide chemistry climate model calculations for the model based assessment of gaps in the observing system. (WP1)  2. KIT will contribute to the characterization and error analysis of FTS data as part of the NDACC and TCCON networks. (WP 2) | | |
| **Key personnel CVs**  **Dr. Björn-Martin Sinnhuber (male)** has 20 years of expertise in atmospheric physics, chemistry and remote sensing. He published more than 40 peer reviewed scientific papers and was a coauthor on the WMO/UNEP Scientific Assessments of Ozone Depletion in 2006 and 2010. In 2008 he received the Dobson Award of the International Ozone Commission. His current work focuses on chemistry-climate modelling. He was member of the steering group of the EU FP7 project SHIVA. B.-M. Sinnhuber is member of the Scientific Steering Committee of the Network for the Detection of Atmospheric Composition Change (NDACC) and co-chair of the NDACC Theory and Analysis working group. | | |
| **Dr. Matthias Schneider (male)** studied Physics at the University of Heidelberg, Germany. He received his PhD from the University of Karlsruhe in 2002, working on the "Continuous Observations of Atmospheric Trace Gases by Ground-based FTIR Spectroscopy at Izana Observatory, Tenerife Island". Dr. Schneider is an expert for high resolution infrared remote sensing retrieval characterization. He has made various detailed studies about the optimisation and theoretical and empirical validation of ground-based FTIR and space-based METOP/IASI retrieval products. Since 2011 he has been the head of the MUSICA (MUlti-platform remote Sensing of Isotopologues for investigating the Cycle of Atmospheric Water) research group at KIT, IMK-ASF. MUSICA is an European Research Council Starting Grant project that integrates infrared remote sensing observation (from ground and space) and in-situ observation (from the surface and research aircraft) of tropospheric water vapour isotopologues. | | |
| **Dr. Frank Hase (male)** studied Physics at the University of Karlsruhe, Germany. He received his PhD from the University of Karlsruhe in 2000, working on the "Inversion of trace gas profiles from ground-based solar absorption FTIR measurements". Dr. Hase is an expert for FTIR spectroscopy, e.g. in the characterisation of the instrumental line shape (ILS) of FTIR spectrometers. His software LINEFIT for ILS-retrieval from lab gas-cell measurements is used by FTIR groups all over the world. Dr. Hase was involved in the coding of the radiative transfer code KOPRA which is used at IMK-ASF for the analysis of MIPAS-Envisat spectra and is the author of the PROFFIT radiative transfer and retrieval code, which is used for the analysis of ground-based FTIR spectra at IMK-ASF and is also used by several other FTIR working groups in Spain, Belgium, France and Russia. He was involved in various studies on applied infrared spectroscopy, e.g. he lead an international collaboration to construct an accurate empirical model of the infrared solar spectrum. He is a member of the MUSICA team, an ERC project to investigate water isotologues by remote sensing measurements. From 2010 to 2013 he served as Applied Optics topical editor. Recently, Dr. Hase was significantly involved in the development of a low-resolution FTIR spectrometer in cooperation with Bruker Optics, Ettlingen. Dr. Hase is with the KIT, IMK-ASF. | | |
| **Publications**  **Hase, F.**: Improved instrumental line shape monitoring for the ground-based, high-resolution FTIR spectrometers of the Network for the Detection of Atmospheric Composition Change, Atmos. Meas. Tech., 5, 603-610, doi:10.5194/amt-5-603-2012 , 2012 .  Kohlhepp, R., R. Ruhnke, M. P. Chipperfield, M. De Mazière, J. Notholt, S. Barthlott, R. L. Batchelor, R. D. Blatherwick, Th. Blumenstock, M. T. Coffey, P. Demoulin, H. Fast, W. Feng, A. Goldman, D. W. T. Griffith, K. Hamann, J. W. Hannigan, **F. Hase**, N. B. Jones, A. Kagawa, I. Kaiser, Y. Kasai, O. Kirner, W. Kouker, R. Lindenmaier, E. Mahieu, R. L. Mittermeier, B. Monge-Sanz, I. Morino, I. Murata, H. Nakajima, M. Palm, C. Paton-Walsh, U. Raffalski, Th. Reddmann, M. Rettinger, C. P. Rinsland, E. Rozanov, **M. Schneider**, C. Senten, C. Servais, **B.-M. Sinnhuber**, D. Smale, K. Strong, R. Sussmann, J. R. Taylor, G. Vanhaelewyn, T. Warneke, C. Whaley, M. Wiehle, and S. W. Wood: Observed and simulated time evolution of HCl, ClONO2, and HF total column abundances, Atmos. Chem. Phys., 12, 3527-3556, doi:10.5194/acp-12-3527-2012, 2012 .  **Schneider, M.**, S. Barthlott, **F. Hase**, Y. González, K. Yoshimura, O. E. García, E. Sepúlveda, A. Gomez-Pelaez, M. Gisi, R. Kohlhepp, S. Dohe, T. Blumenstock, A. Wiegele, E. Christner, K. Strong, D. Weaver, M. Palm, N. M. Deutscher, T. Warneke, J. Notholt, B. Lejeune, P. Demoulin, N. Jones, D. W. T. Griffith, D. Smale, and J. Robinson: Ground-based remote sensing of tropospheric water vapour isotopologues within the project MUSICA, Atmos. Meas. Tech., 5, 3007-3027, doi:10.5194/amt-5-3007-2012, 2012 .  **Schneider, M.** and **F. Hase**: Technical Note: Recipe for monitoring of total ozone with a precision of around 1 DU applying mid-infrared solar absorption spectra, Atmos. Chem. Phys., 8, 63-71, SRef-ID: 1680-7324/acp/2008-8-63, 2008 .  **B.-M. Sinnhuber**, G. Stiller, R. Ruhnke, T. von Clarmann, S. Kellmann, and J. Aschmann, Arctic winter 2010/2011 at the brink of an ozone hole, Geophys. Res. Lett., 38, L24814, doi:10.1029/2011GL049784, 2011 | | |
| **Previous Projects**  **EU:** NORS, InGOS, HYMN, GeoMON, UFTIR, SCOUT-O3, SHIVA, StratoClim, MUSICA (ERC)  **ESA:** TASTE, Multi-TASTE | | |

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| --- | --- | --- |
| **No** | **Name** | **Country** |
| **20** | **California Institute of Technology, Jet Propulsion Laboratory (NASA-JPL/Caltech)** | **USA** |
| **Expertise and experience of the organization**  The NASA Jet Propulsion Laboratory (JPL) Atmospheric Lidar Group based at the Table Mountain Facility in Southern California has a long history of designing and operating ground-based lidars for long-term measurements of atmospheric profiles of ozone, temperature, water vapor and aerosols. Measurements from ground-based stations represent important components in the NASA Earth Science Research Program (ESRP) for addressing the issues of variability, forcing, response, consequences, and prediction within the Atmospheric Composition focus area. Consistent, accurate, long-term lidar measurements of water vapour, together with temperature, ozone, and aerosol profiles provide important contribution to all fundamental questions such as changes and trends in atmospheric composition.  In support of the demanding task of producing high quality long-term datasets, the JPL/TMF Lidar Group activities is specifically engaged in the development of an integrated framework for the consistent and traceable processing of ozone, temperature and water vapour lidar measurement within two major long-term monitoring networks: NDACC and GRUAN. One critical aspect of this data processing is the consistent and accurate reporting of measurement and retrieval uncertainties. In this framework, a group of lidar experts, the ISSI (International Space Science Institute) Team on NDACC Lidar Algorithms has developed tools and issued recommendations on the consistent use of uncertainty and vertical resolution definitions, and their application to a comprehensive uncertainty budget for all NDACC and GRUAN ozone, temperature, and water vapor lidar datasets. | | |
| **Role in the project**  The JPL/TMF Atmospheric Lidar Group will provide key expertise and technical tools taken from the ISSI Team on Lidar Algorithms Recommendations and Guidelines (2014). Comprehensive and fully-quantified measurement and algorithm uncertainty budgets for lidar, as well as consistent NDACC-standardized definitions of vertical resolution will be delivered. These standardized definitions will be implemented in the GRUAN Lidar Analysis Software Suite (GLASS), the centralized data processing software for GRUAN water vapour, ozone and temperature lidars currently under development. The GLASS can be used as the cost effective means to collect and process the data and send on to virtual observatory. Providing standardized tools as well as consistent definitions is scientifically beneficial to all monitoring networks, and therefore both NASA/JPL and European partners who widely contribute to these networks. | | |
| **Key personnel CVs**  **Dr. Thierry Leblanc (male)** is a Research Scientist at the Jet Propulsion Laboratory since 1999. He is currently Head of the JPL-Table Mountain Science Group (Div. 32, Sect. 3287). He is the Principal Investigator of the JPL Long-Term Ozone Lidar Monitoring Program, and Principal Investigator of the JPL Water Vapor Raman Lidar Program. He is responsible for the direction and oversight of all JPL lidar projects at TMF and Mauna Loa Observatory, Hawaii. He is responsible for the data processing and all science investigations associated with the ozone, temperature, and water vapor lidars at TMF and Mauna Loa, as well as multiple radiosonde datasets obtained from the TMF balloon launch facility. Dr. Leblanc is responsible for monitoring data quality, and for the data processing, dissemination, and archiving, including NDACC and TOLNet. He is responsible for the coordination of inter-comparison and validation campaigns deployed at TMF every 4 years in average (last campaign named MOHAVE-2009, in October 2009).  Dr. Leblanc’s science interest ranges from the free-troposphere to the mesosphere, including troposphere/stratosphere exchanges, stratospheric dynamics and chemistry, upper tropospheric water vapor trends, deep stratospheric intrusions and long-range transport of ozone in the troposphere. | | |
| **Publications**  Eckert, E., von Clarmann, T., Kiefer, M., Stiller, G. P., Lossow, S., Glatthor, N., Degenstein, D. A., Froidevaux, L., Godin-Beekmann, S., Leblanc, T., McDermid, S., Pastel, M., Steinbrecht, W., Swart, D. P. J., Walker, K. A., and Bernath, P. F.: Drift-corrected trends and periodic variations in MIPAS IMK/IAA ozone measurements, Atmos. Chem. Phys., 14, 2571-2589, 10.5194/acp-14-2571-2014, 2014.  Kirgis, G., Leblanc, T., McDermid, I. S., and Walsh, T. D.: Stratospheric ozone interannual variability (1995–2011) as observed by lidar and satellite at Mauna Loa Observatory, HI and Table Mountain Facility, CA, Atmos. Chem. Phys., 13, 5033-5047, 10.5194/acp-13-5033-2013, 2013.  Leblanc, T., McDermid, I. S., and Walsh, T. D.: Ground-based water vapor Raman lidar measurements up to the upper troposphere and lower stratosphere for long-term monitoring, *Atmos. Meas. Tech*., 5, 17-36, 10.5194/amt-5-17-2012, 2012**.**  Leblanc, T., et al., A.: Measurements of Humidity in the Atmosphere and Validation Experiments (MOHAVE)-2009: overview of campaign operations and results, *Atmos. Meas. Tech*., 4, 2579-2605, 10.5194/amt-4-2579-2011, 2011.  Cooper, O. R., Parrish, D. D., Stohl, A., Trainer, M., Nedelec, P., Thouret, V., Cammas, J. P., Oltmans, S. J., Johnson, B. J., Tarasick, D., Leblanc, T., McDermid, I. S., Jaffe, D., Gao, R., Stith, J., Ryerson, T., Aikin, K., Campos, T., Weinheimer, A., and Avery, M. A.: Increasing springtime ozone mixing ratios in the free troposphere over western North America, *Nature*, 463, 344-348, http://www.nature.com/nature/journal/v463/n7279/suppinfo/nature08708\_S1.html, 2010 | | |
| **Previous Projects** | | |

## THIRD PARTIES INVOLVED IN THE PROJECT

No third parties involved except through USTL as shown below.

|  |  |  |
| --- | --- | --- |
| **Partner No: 18** | **Partner: USTL** | |
| Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be subcontracted)? | | N |
| *If yes, please describe and justify the tasks to be subcontracted* | | |
| Does the participant envisage that part of the work is performed by linked third parties? | | Y |
| There is one third party for University of Lille (USTL): the “Centre National de la Recherche Scientifique” (CNRS).  The ICARE Data and Services Center is a Joint Service Unit (JSU) with CNRS, University of Lille, and CNES (Centre National d'Etudes Spatiales). The Joint Service Units (UMS in French for Unité Mixte de Service) are structures which are administrated and supported by CNRS and one or more other organizations, most of the time by one or more universities. CNRS will be a third party for USTL that will provide part of the human resources involved in GAIA-Clim.  The number of person-months for this third party is 6 out of a total of 24 for University of Lille. Total direct eligible costs for the linked third party: 38400€. It corresponds to permanent personnels: Jacques Descloitres (3 PM) and Loredana Focsa (3 PM). | | |
| Does the participant envisage the use of contributions in kind provided by third parties (articles 11 and 12 of the General Model Grant Agreement)? | | N |
| *If yes, please describe the third party and their contribution* | | |

# ETHICS AND SECURITY

## ETHICS

Not applicable.

## SECURITY

**Please indicate if your project will involve:**

* Activities or results raising security issues (NO)
* ‘EU-classified information’ as background or results (NO)

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Yaglom, A. M. (1987), Correlation theory of stationary and related random functions, Springer Verlag.Acronyms

This acronym list is solely for those acronyms used in Sections 1 through 3.

ACE-FTS Atmospheric Chemistry Experiment – Fourier Transform Spectrometer

ACTRIS Aerosols, Clouds, and Trace gases Research Infrastructure Network

AERONET Aerosol Robotic Network

AIUB Astronomical Institute of the University of Bern

AMDAR Aircraft Meteorological Data Relay

AMSR Advanced Microwave Scanning Radiometer

Arctic-ROOS Arctic Regional Ocean Observing System

BASECOE Belgium Assimilation System, for Chemical ObsErvations

BIPM International Bureau of Weights and Measurements

BIRA-IASB Belgium Institute for Space Aeronomy

CCCS Copernicus Climate Change Service

CCI Climate Change Initiative

CEOS Committee on Earth Observation Satellites

CHEOPS CHaracterising ExOPlanet Satellite

C-IFS-TM5-BASCOE Data assimilation system for stratospheric chemistry contributing to MACC II/III.

CIMO Commission for Instruments and Methods of Observation

CMSAF Satellite Application Facility on Climate Monitoring

CORE-CLIMAX COordinating earth observation data validation for RE-analysis for CLIMAte ServiceS

COST Cooperation in Science and Technology

COVE CEOS Visualisation Environment

CRISMA Modelling Crisis Management for Improved Action and Preparedness

CRTM Community Radiative Transfer Model

CTM Chemical Transport Model

DA Data Assimilation

DD Double Difference

DIAL Differential Absorption Lidar

DOAS Differential Optical Absorption Spectroscopy

DWD Deutscher Wetterdienst

EARLINET European Aerosol Research Lidar Network

ECHAM5-HAM Global aerosol climate model from Max Planck-Institut for meteorology

ECVs Essential Climate Variables

EDGE Environmental Data Graphical Evaluation

EO Earth Observation

EPOS Earth Parameter and Orbit System

Envisat Environmental Satellite

ESA European Space Agency

ESRL Earth System Research Laboratory

EUFAR European Facility for Airborne Research

EVOSS European Volcano Observatory Space Service

FTIR Fourier Transform Infrared Spectroscopy

FY-3C Feng-Yung 3 series third flight

FY-3D Feng-Yung 3 series fourth flight

GAID Gaps Assessment and Impacts Document

GAMIT/GLOBK GPS analysis package developed at MIT, the Harvard-Smithsonian Center for Astrophysics (CfA), and the Scripps Institution of Oceanography (SIO) for estimating station coordinates and velocities, stochastic or functional representations of post-seismic deformation, atmospheric delays, satellite orbits, and Earth orientation parameters

GAW Global Atmospheric Watch

GCOM-W Global Change Observation Mission – Water

GCOS Global Climate Observing System

GECA Generic Environment for Calibration/Validation Analysis

GEMS Global and regional Earth-system (atmosphere) Monitoring using Satellite and in-situ data

GEO Group on Earth Observations

GEOmon Global Earth Observation and Monitoring

GEOSS Global Earth Observation System of Systems

GEWEX Global Energy and Water Exchange Project

GFCS Global Framework for Climate Services

GFZ German Research Centre for Geosciences

GLOBEMISSION ESA project on Global Emissions

GNSS Global Navigation Satellite System

GOME Global Ozone Monitoring Experiment

GPS Global Positioning System

GRUAN GCOS Reference Upper Air Network

GSICS Global Space-based Inter-calibration System

GUAN GCOS Upper Air Network

GUM Guide to the expression of Uncertainty in Measurements

HYMN Hydrogen, Methane and Nitrous Oxide project

IAGOS In-Service Aircraft for a Global Observing System

IASI Infrared Atmospheric Sounding Interferometer

ICARE Cloud-Aerosol-Water-Radiation Interactions

ICOS\_inwire Integrated Carbon Observation System

InGOS Integrated non-CO2 Greenhouse gas Observing System

INRiM Istituto Nazionale di Ricerca Metrologica

ISSI International Space Science Institute

JPSS Joint Polar Satellite System

LLGHGs Long Lived Greenhouse Gases

MACC Monitoring Atmospheric Composition and Climate

MAXDOAS Multi-axis Differential Optical Absorption Spectroscopy

MetOp Metrological Operational satellite

MIPAS Michelson Interferometer for passive Atmospheric Sounding

MSU Microwave Sounding Unit

Multi-TASTE Multi-mission Technical Assistance To Envisat

MWHS Microwave Humidity Sounder

MWR Microwave Radiometers

MWRI Microwave Radiation Imager

MWTS Microwave Temperature Sounder

NASA National Aeronautics and Space Administration

NDACC Network for the Detection of Atmospheric Composition Change

NOAA National Oceanic and Atmospheric Administration (USA)

NORS Demonstration Network of Remote sensing observations in support of the Copernicus Atmospheric Service

NPROVS NOAA Product Validation Service

NWP Numerical Weather Prediction

OMI Ozone Monitoring Instrument

OSSE Observing Systems Simulation Experiments

OSSSMOSE Observing System of Systems Simulator for Multi-mission Synergies Exploration

O3M-SAF Satellite Application Facility on Ozone and atmospheric chemistry monitoring

PASODOBLE Promote Air Quailty Serivces Integrating Observations – Development Of Basic Localised Informations for Europe

POLDER Polarization and Directionality of Earths Reflectances

PPP Precise Point Positioning

PROMOTE PROtocol MOniToring for the GMES Service Element

QA4ECV Quality Assurance for Essential Climate Variables

RTTOV Radiative Transfer model for TOVs

SACS Special Areas of Conservation

SAOZ System of Analysis of Observations at Zenith

SCIAMACHY SCanning Imaging Absorption spectrometer for Atmopsheric ChartographY

SIROCCO Development and performance assessment of synergetic retrieval algorithms for near-surface concentrations of CH4 and CO from SWIR and IR passive remote sensing measurements for Earth and Mars atmospheres

SMEAR-II Station for Measuring Forest Ecosystem-Atmosphere Relations

SMOD Stratospheric Modelling

SOAP Simple Object Access Protocol

SPARC Stratospheric Processes and their Role in Climate

SSMIS Special Sensor Microwave Imager/Sounder

TASTE Technical Assistance to Envisat

TCCON Total Carbon Column Observing Network

TCWV Total Column Water Vapour

TMOD Tropospheric Modelling

TOPROF Towards Operational ground based PROFiling

TOVS-9 TIROS Operational Vertical Sounder 9

UAV Unmanned Aerial Vehicle

UFTIR Time series of Upper Free Troposphere observations from a European ground-based FTIR network

UTLS Upper Troposphere – Lower Stratosphere

VC Virtual Constellation

WGCV Working Group on Calibrationa dn Validation

WIGOS WMO Integrated Global Observing System

WMO World Meteorological Organization

WSDL Web Service Description Language

WVSS-II Water Vapour Sensing System version two

ZTD Zenith Total Delay

1. All of WP1 through WP5 include several gap analysis milestones to identify the gaps in their area, which form the internal-to-project basis for the over-arching gap analysis deliverable in WP6. [↑](#footnote-ref-1)