

ESA CLIMATE CHANGE INITIATIVE PHASE 1

SCIENTIFIC USER CONSULTATION AND DETAILED SPECIFICATION

STATEMENT OF WORK

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1 DOCUMENT SCOPE

This Statement of Work (SoW) specifies the tasks to be performed by the Contractor under the first phase of ESA's 6 year Climate Change Initiative. It will serve as a contractually applicable document for all contracts awarded by ESA as a result of this Invitation to Tender.

The tasks to be undertaken by the Contractor, the deliverables to be generated, the technical and performance requirements to be met, and the project schedule and milestones to be achieved are defined herein.

During execution of the project the Contractor shall comply with the requirements set out in this document, including all Annexes.

This document is organized as follows:

Section 1: Defines the document scope, terminology, applicable and reference documents

Section 2: Presents the background to the CCI programme and identifies resulting requirements for the CCI projects to be implemented

Section 3: Specifies the tasks to be executed in each CCI project, and describes the associated workflow

Section 4: Specifies the management requirements, deliverable items, schedule and milestones, applicable to all CCI projects

Appendix 1 Provides a list of Acronyms and Abbreviations

Appendix 2 Describes the content of the main documents to be produced

Annexes A-K Define specific technical requirements applicable to each individual ECV

1.1 Terminology

Terms used in this document are to be understood as follows:

FCDR (Fundamental Climate Data Record): is used to denote a long-term data record, involving a series of satellites from different Space Agencies, different sensors, each with different performance characteristics, most notably, different spatial and temporal sampling, different time extents, and different stability, but with overlaps and calibrations sufficient to allow the generation

of homogeneous and well characterised global products that are accurate and stable enough for climate monitoring [RD-1].

For “one-off” research spacecraft the principles of continuity obviously do not apply, but as many of the other principles as possible (e.g. those for rigorous pre-launch characterisation and calibration, on-board calibration, complementary surface-based observations etc.) are applicable [RD-2].

The generation of FCDRs will require consistency across multiple platforms with respect to calibration, algorithms, spatial and temporal resolution, quantification of errors and biases, and data format. FCDRs include the ancillary data used to calibrate them.

ECV (Essential Climate Variable): The Essential Climate Variables are those that are required to support the work of the Convention [UNFCCC] and that are technically and economically feasible for systematic observation. It is these variables for which international exchange is required for both current and historical observations. Additional variables required for research purposes are not included in this listing [RD-3].

Domain	Essential Climate Variables
Atmospheric (over land, sea and ice)	Precipitation, Earth radiation budget (including solar irradiance), Upper-air temperature, Wind speed and direction, Water vapour; Cloud properties, Carbon dioxide, Ozone, Aerosol properties.
Oceanic	Sea-surface temperature, Sea level, Sea ice, Ocean colour (for biological activity), Sea state, Ocean salinity.
Terrestrial	Lakes, Snow cover, Glaciers and ice caps, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI), Biomass, Fire disturbance, Soil moisture.

Table 1: Essential Climate Variables (ECVs) largely dependent upon satellite observations [RD-1].

1.2 Reference Documents

[RD-1]	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 (GCOS-92)”,
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	GCOS-107, September 2006 (WMO/TD No.1338) Available online at http://www.wmo.int/pages/prog/gcos/index.php
[RD-2]	Satellite Observation of the Climate System: The Committee on Earth Observation Satellites (CEOS) Response to the Global Climate Observing System (GCOS) Implementation Plan Available online at http://www.ceos.org/pages/CEOSResponse_1010A.pdf
[RD-3]	The Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC, GCOS – 82, April 2003 (WMO/TD No. 1143) Available online at http://www.wmo.int/pages/prog/gcos/index.php
[RD-4]	IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp. All 4 documents contributing to the Fourth Assessment Report are available online at http://www.ipcc.ch/publications_and_data/publications_and_data_reports.htm
[RD-5]	UNFCCC, 2008, Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007: Addendum Part Two: Action taken by the Conference of the Parties at its thirteenth session, FCCC/CP/2007/6/Add.1, 14 March 2008 Available online at http://unfccc.int/meetings/cop_13/items/4049.php
[RD-6]	The ESA Climate Change Initiative – Description issue 1 revision 0 - 30/09/09 EOP-SEP/TN/0030-09/SP Available online at: http://earth.esa.int/workshops/esa_cci/ESA_CCI_Description.pdf
[RD-7]	GCOS Climate Monitoring Implementation Principles, November 1999 Available online at: http://www.wmo.int/pages/prog/gcos/documents/GCOS_Climate_Monitoring_Principles.pdf
[RD-8]	Guideline for the Generation of Satellite-based Datasets and Products meeting GCOS Requirements, GCOS Secretariat, GCOS-128, March 2009 (WMO/TD No. 1488) Available online at: http://www.wmo.int/pages/prog/gcos/index.php
[RD-9]	The European Commission 7 th Framework Programme: http://cordis.europa.eu/fp7/
[RD-10]	Implementation Plan for the Global Observing System for Climate in support of the UNFCCC, GCOS-92, October 2004 (WMO/TD No.1219) Available online at http://www.wmo.int/pages/prog/gcos/index.php
[RD-11]	Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC, GCOS-82, April 2003 (WMO/TD No. 1143) Available online at http://www.wmo.int/pages/prog/gcos/index.php
[RD-12]	The ESA Data User Element: http://www.esa.int/duel
[RD-13]	Information on Essential Climate Variable (ECV) related products to be delivered by FP7 Space projects Geoland-2, MyOcean, MACC and three new projects planned to start up following successful negotiations, can be found at: http://ec.europa.eu/enterprise/policies/space/research/fp7-call-for-proposals/climate_change_en.htm

2 CCI PROGRAMME BACKGROUND

2.1 CCI Programme Scope and Context

The ESA Climate Change Initiative was approved by ESA member states at the Ministerial Council in November 2008, as a new element of the existing European Earth Watch Programme. This underlines the high political importance given by European nations to climate policy in general, and to the fourth IPCC assessment report [RD-4] and the resolutions of the 2007 Bali Climate Conference [RD-5], in particular.

This programme capitalizes on previous investments in the space and ground segment by ESA, its Member states and its European partners.

A comprehensive description of the scope and context of the CCI is given in [RD-6], and is not repeated herein.

⇒ *Any adequate response to this statement of work will require all project participants to be fully informed on the scope and international context of this program: Read RD-6.*

2.2 CCI Programme Objectives

The objective of the CCI, as laid out in the programme declaration approved by ESA Member States is:

To realize the full potential of the long-term global Earth Observation archives that ESA together with its Member states have established over the last thirty years, as a significant and timely contribution to the ECV databases required by United Nations Framework Convention on Climate Change (UNFCCC).

CCI will ensure that full capital is derived from ongoing and planned ESA missions for climate purposes, including ERS, Envisat, the Earth Explorer missions, relevant ESA managed archives of Third-Party Mission data and, in due course, the GMES Space Component.

[R-1]	⇒ <i>Each CCI project (the contractor) shall focus on the contribution of ESA EO missions, but not to the exclusion of non-ESA missions</i>
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An essential feature of CCI will be to implement a coherent and continuous suite of actions that encompasses all steps necessary for the systematic generation of relevant Essential Climate Variables (ECVs), and ensures their regular updating on timescales corresponding to the increasingly urgent needs of the international climate change community

[R-2]	<p>⇒ <i>Each CCI project (the contractor) shall bring continuity of action and coherent scientific progress, to relevant existing research efforts, especially those constrained by start-stop funding conditions</i></p>
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This demands a major sustained, and coordinated scientific effort to review, improve, and in some cases to develop new underlying processing, retrieval and validation methods.

⇒ *This is the primary scope of the present statement of work.*

The users of the ECV data products, as specified by GCOS, are the scientific, research, and (in a limited number of cases) operational organizations from the UNFCCC countries responsible for climate research, modelling, assessment and prediction within nationally and internationally funded research programmes. Some, but not all, of these scientists, organizations and programmes are already users of ESA EO data products. Consequently:

[R-3]	<p>⇒ <i>Each CCI project team (the contractor) shall engage key international scientific user communities and climate research programmes to guide their activity and to independently validate their results</i></p>
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2.3 CCI Programme Outputs

ESA member states have assigned resources to this programme so that it will, in the course of the next six years, generate a well defined, comprehensive set of outputs. The programme deliverables are listed in [RD-6]. They include global data sets, associated meta data, software systems, scientific reports, technical documentation, all complying with:

- GCOS Climate Monitoring Implementation Principles [RD-7]
- Guideline for the Generation of Satellite-based Datasets and Products meeting GCOS Requirements [RD-8]

⇒ *Each CCI project will, for one ECV, produce and validate a subset of the programme deliverables, as specified in this statement of work.*

CCI is intended to significantly advance scientific understanding of the climate system and of climate change, in support to the IPCC process (see <http://www.ipcc.ch>). Thus it must result in **world class scientific results**.

[R-4]	⇒ <i>Each CCI project team (the contractor) shall publish its results in world class peer-reviewed scientific journals that are cited by the IPCC assessment reports</i>
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2.4 International Scientific Cooperation

To succeed, the CCI programme must meet the needs of international Climate Research community and contribute effectively to the collective international response to GCOS, via CEOS and GEO. Consequently:

[R-5]	⇒ <i>Each CCI project (the contractor) shall meet the specific needs of a well identified, specialized climate research community by addressing the corresponding GCOS requirements</i>
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Key elements of the international framework for this programme are:

- **GCOS:** which represents the scientific and technical requirements of the Global Climate Observing System on behalf of **UNFCCC and IPCC**.
- **International Climate Research Programmes**, which represent the collective interests and priorities of the worldwide climate research communities
- **CEOS:** which serves as a focal point for Earth Observation related activities of Space Agencies in the **GEO** framework
- **Individual Partner Space Agencies** with whom ESA cooperates bilaterally
- **EC and National Research Programmes** which establish research priorities and provide resources for climate research community within Europe
- **Individual end-user organizations** in ESA member states and worldwide, climate research, monitoring and modelling practitioners who are active in the IPCC processes

The ESA executive will ensure the necessary international coordination at programme level.

Each CCI project team must implement the necessary international scientific coordination at project level. In practice, this means that

Each CCI project team (the contractor):

[R-6]	⇒ <i>Within Europe: shall take full advantage of existing results, on-going projects, and future funding opportunities from national research programmes, from EUMETSAT and from the EC 7th Framework Programme, when planning, implementing and reviewing the progress of their CCI project.</i>
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[R-7]	⇒ <i>On the international scene: shall coordinate activities with non-European teams, and seek independent scientific review of methods and validation of results, under the auspices of the authoritative international scientific bod(ies), most appropriate for each ECV.</i>
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2.5 CCI Programme Implementation

Phased programme implementation

The CCI programme will [RD-6] be progressively built up, and contracted, in three major phases during the six years of the programme:

- **Phase 1:** Requirements analysis and specifications, algorithm development, ECV prototyping and validation
- **Phase 2:** Systems development and ECV production
- **Phase 3:** User assessment, assimilation and feedback

Phase 1 will be implemented via two closely related lines of action:

- A series of parallel, 3-year projects (one per ECV), each led and executed by the relevant EO science community in collaboration with the climate research community - [*CCI Projects*].
- A single project, to provide integrated analysis from a dedicated “Climate Modelling User Group” for all eleven ECVs being addressed in phase 1 of the CCI programme [*CMUG*]

ESA intends, as a result of this ITT, to place eleven parallel contract actions, each of duration three years. This statement of work addresses the first line of action above and specifies the requirements for these CCI projects.

The second line of action on the Climate Modelling User Group (CMUG) is addressed in a separate ITT and statement of work.

CCI Phase 1 provides a unique opportunity for the European EO science community to define and validate innovative approaches for continuously generating and updating a comprehensive and consistent set of set of ECV global satellite based data products in the long term – i.e. *decades hence*. The science community is thus invited - not only to define *what* is to be implemented in the subsequent stages of the CCI– but also to determine *how* it can most effectively be implemented – with regard to both system architecture and system operations. It is thus essential that, *from the outset*, scientists, systems experts, and prospective operators work side by side in CCI to identify

modern, adaptive and cost effective implementation and operational approaches that will remain science driven throughout their entire life-cycle. Full advantage must be taken of the latest developments in computing architectures, data management and communications technologies. Innovative structures for large-scale data sharing, data (re)processing and user access, need to be investigated and traded off alongside the associated cost models. The main criteria for such trade-offs are 1) Openness to science-driven evolution 2) Cost effectiveness for operations.

CCI Phase-2 will implement ‘operational’ systems, based on complete requirements *specified and thoroughly validated by the competent science communities during phase 1*. These operational systems must meet industry-level standards for operations, maintenance, evolution and configuration control and will operate in an environment that provides computing performance and data access adequate for frequent cyclical reprocessing and improvement of ECV products. *They must also be cost-effective as a whole*. It is foreseen that Phase 2 will follow an iterative life-cycle, of concurrent development and operations – not a waterfall approach. Phase 2 must continue to be driven by climate science and engage the relevant science communities, working side-by-side with industry and data centres in Europe.

CCI Phase 3 will provide a framework within which the international climate research community can provide comprehensive feedback on the overall impact of the CCI programme results, and offer guidance on future evolution. Although such comprehensive feedback can only occur when complete programme results are available, climate research and modelling user communities will be fully engaged, *and should drive*, all CCI projects throughout phases 1 and 2.

Longer term continuity

CCI phases 1,2 and 3 should lay the basis for integrating the operational systems, developed and validated in the CCI R&D programme, into operational European framework(s), managed and funded by organizations that have the mandate, expertise, infrastructure and funding mechanisms necessary to sustain long-term generation and cyclical updating of ECVs for GCOS and UNFCCC.

⇒ *Therefore all CCI project teams should, from the outset, address the technical issue related to future integration within an operational context. They should actively prepare future opportunities for doing so within operational structures in Europe, both those existing and those planned, particularly GMES and, if appropriate, operational meteorology.*

2.6 Cardinal Requirements

Each CCI project (the contractor) **shall** meet the following “Cardinal Requirements”:

[CR-1]	<ul style="list-style-type: none"> • <i>Develop and validate algorithms to meet GCOS ECV requirements for (consistent, stable, error-characterized) global satellite data products from multi-sensor data archives</i>
[CR-2]	<ul style="list-style-type: none"> • <i>Produce and validate, within an R&D context, the most complete and consistent possible time series of multi-sensor global satellite data products for climate research and modelling</i>
[CR-3]	<ul style="list-style-type: none"> • <i>Optimize the impact of ESA EO missions data on climate data records</i>
[CR-4]	<ul style="list-style-type: none"> • <i>Generate complete specifications for an operational production system</i>
[CR-5]	<ul style="list-style-type: none"> • <i>Strengthen inter-disciplinary cooperation between international earth observation, climate research and modelling communities, in pursuit of scientific excellence</i>

The Cardinal Requirements are derived directly from the programme objectives and programme implementation plan approved by ESA Member States. They constitute the top level objectives for each CCI project. They determine the measures by which ESA will formally assess the progress, success, or failure of each CCI project.

All other requirements, defined herein, are derived from them.

In addressing these cardinal requirements each CCI project team will:

- Pursue scientific advances, innovation and international excellence to achieve the significant performance improvements required by GCOS for specific ECVs.
- Adhere to the GCOS guidelines for the generation of global satellite data products [RD-8].

- Build on lessons from previous projects and existing global data sets.
- Bring together several leading research groups expert in EO data analysis along with relevant engaged climate research groups (evaluation and feedback).
- Collaborate with the main worldwide groups developing and producing climate relevant products from satellite observations to develop the ECV products through exchange of experience, inter-comparison exercises and merging approaches.
- Work with the appropriate international research communities that ultimately will use the data.
- Liaise with other consortia producing ECV products under the CCI to ensure consistency is assured.
- Liaise with the CMUG to ensure the ECV products developed are compatible with the needs of the CMUG and wider Climate Research Community.
- Go as far as possible – in a research context – to generate consistent, long-term global data sets, improved with respect to those presently available.
- Provide public information and project documents on a open website that is easily accessible by the Climate Research Community so that it can be informed and participate in the review process.

2.7 *ECVs to be addressed*

[R-8]	<i>Each CCI project (the contractor) shall address one of the 11 ECVs listed in table 1.</i>
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	ECV	GCOS-107 (September 2006)		Project Name	Annex to this SOW
		Product Number	Chapter		
Atmosphere	Cloud properties	A.4	3.1.4	Cloud_cci	Annex A
	Ozone	A.7	3.1.7	Ozone_cci	Annex B
	Aerosol properties	A.8	3.1.8	Aerosol_cci	Annex C
	Greenhouse Gases	A.9	3.1.9	GHG_cci	Annex D
Ocean	Sea Ice	O.1	3.2.1	Sea_Ice_cci	Annex E
	Sea Level	O.2	3.2.2	Sea_Level_cci	Annex F
	Sea Surface Temperature	O.3	3.2.3	SST_cci	Annex G
	Ocean Colour	O.4	3.2.4	Ocean_Colour_cci	Annex H

Terrestrial	Glaciers and Ice Caps	T.2.1	3.3.2	Glaciers_cci	Annex I
	Land Cover	T.5.1	3.3.5	Land_Cover_cci	Annex J
	Fire Disturbance	T.9	3.3.9	Fire_cci	Annex K

Table 1: ECVs within scope of this statement of work

2.8 Technical Constraints

[R-9]	<i>Each CCI project team (the contractor) shall take full account of the following key technical constraints when planning and implementing the CCI project:</i>
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- Need for scientific consensus on detailed ECV Product and performance specifications
- Availability and quality input data from EO Archives (ESA and non-ESA)
- Availability and quality of associated meta data, cal/val data, and documentation
- Compatibility of data from different missions and sensors
- Trade-offs between cost, complexity and impact of new algorithms to be developed and validated during the project
- Advance planning for data from new missions to be integrated during the project
- End-to-end throughput of ECV production systems
- Re-use of existing capabilities within Europe
- Compliance to applicable ESA standards
- Availability of external validation data
- No duplication of activities covered by projects or programmes (e.g. FP7, National funding)

2.9 Project Timescales

Three-stage implementation

[R-10]	<i>Each CCI project shall be executed within 36 months, in three consecutive stages, each of duration 12 months, as follows:</i>
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- **Stage 1:** *focused on* Scientific requirements analysis and specification, algorithm development, inter-comparison and selection
- **Stage 2:** *focused on* System prototyping and ECV production
- **Stage 3:** *focused on* product validation and user assessment

A major annual progress review will be held at the end of each stage.

2.10 *Link to the Global Climate Modelling Community*

ESA, through a separate ITT, will ensure that the CMUG project team is in place at the start of the CCI projects.

All CCI project teams and CMUG will conduct a structured dialogue during the next three years. The primary goal is to ensure integrated feedback between the “EO data community” and the global climate modelling community, dedicated to the CCI programme.

[R-11]	<p><i>Each CCI project team (the contractor) shall cooperate with the CMUG team for:</i></p> <ul style="list-style-type: none"> • <i>bi-annual working meetings involving all CCI_projects, convened by CMUG</i> • <i>open review of key documents (user reqts, product specs, validation reports)</i> • <i>joint error characterization of satellite data products from each CCI_project</i> • <i>confronting climate quality satellite data products and climate models</i> • <i>generating systematic user feedback for annual planning of CCI projects</i>
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It should be noted that each CCI project team will include climate research groups with domain-specific expertise and capabilities for each ECV. These will, as appropriate, include data analysis, in-situ observations, data assimilation and modelling capabilities. The climate research group within each CCI project team should identify specific user needs and priorities that elaborate upon the high-level requirements set by GCOS for each ECV. It should provide independent, critical user reviews of product definitions, algorithm performance, consistency and quality of data products generated by the EO science group. It should ensure that validation is both independent and comprehensive from a user perspective. It is expected that these specialized climate research teams will be active in, or lead, the interaction between each CCI project and CMUG.

The CMUG is intended as a structured forum, dedicated to CCI, through which all CCI actors can iteratively identify achievable performance targets for each ECV, discuss and inter-compare assessment methods, agree best practices and common standards, and conduct multi-disciplinary assessments of the consistency, error characteristics and impacts of the global data products generated by CCI.

It is foreseen that the following four organizations will organize the CMUG:

- UK Met Office Hadley Centre
- Max Plank Institute for Meteorology
- Meteo France
- ECMWF

The CMUG will establish working links and information exchange between the CCI programme and the global climate modelling community at large, coordinating with relevant WCRP activities

and projects, and with existing climate modelling networks such as ENES and related international projects, in particular those supported by EC FP7 [RD-9].

3 TASKS TO BE EXECUTED

There are five discrete technical tasks and one management task to be executed under each ECV development contract:

- 1) Requirements Analysis and Product Specifications
- 2) Algorithm Development, Inter-comparison (Round-Robin) and Selection
- 3) System Prototyping and ECV Production
- 4) Final Product Validation and User Assessment
- 5) System Specification
- 6) Project Management

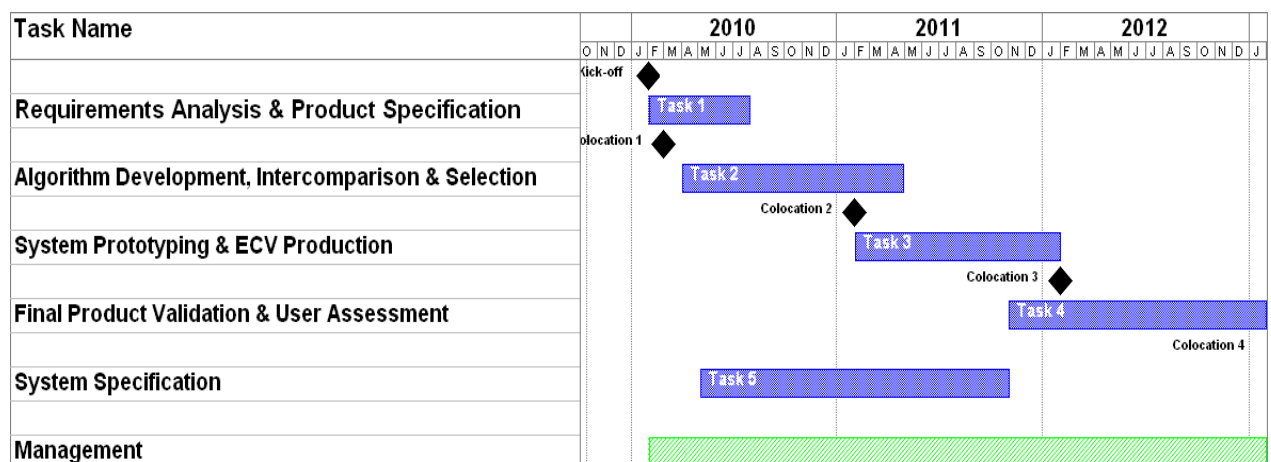
[R-12]	<i>Each CCI project team (the contractor) shall execute all tasks as specified herein</i>
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Each task consolidates a major activity and produces deliverables that the Contractor will need to maintain throughout the contract.

Concurrent engineering and management practices shall be adopted whenever possible to maintain continuous project activity in tasks which can be carried out in parallel to avoid unproductive latency times.

Feedback on algorithm performance obtained e.g. during system prototyping or from users after dissemination shall be immediately analysed by the groups working on product specification and algorithm development for preparation of upgrades and re-processing cycles.

The indicative overall schedule of all tasks is shown in the Gantt chart below:



The above schedule is a template that each CCI team can adapt in accordance with the effort, and time needed for the different tasks on each specific ECV. For example, it may be preferable, for a given ECV, to start certain tasks sooner than identified in the template, or to continue work on certain tasks for longer. This adaptation should reflect the current state of art, maturity of algorithms, diversity of input data sources, and present operational readiness for each ECV.

CCI Project teams should note that:

- **Task 1** is intended to engage the climate research community as end users, to understand and document their needs and priorities at the start of the project, and make sure than all other tasks respond to and are continuously assessed against these documented user needs of the appropriate climate research community.

- **Task 2** is intended to encourage innovative approaches at the start of the programme by establishing a transparent framework for independent evaluation of innovative algorithms and diverse data sources - without imposing inappropriate, restrictive or costly requirements for lengthy formal documentation at an early stage of the project

- **Task 3** is intended to progressively invest greater efforts on the most promising methods, by applying them to more representative large time series, by scrutinizing and verifying the quality and consistency of the results, by documenting them to a level suitable for external scientific peer review (and for later operational implementation), prior to making them available to a large end user community

Task 4 aims to actively engage end users who can provide high quality external (in situ) measurements and tools to independently validate the ECV data products, contribute to comprehensive error characterisation and provide authoritative feedback on the suitability and impact of the ECV data products for climate research

Task 5 provides a unique opportunity for the science community to work with system experts and industry, to evaluate new computing environments and architectures, early in the CCI, and to determine how the most effective and responsive 'operational' ECV production systems possible can be implemented and operated within Europe in the coming decades. This task will require substantial cooperation between all 11 CCI project teams, on fundamental issues such as: "one operational system, three operational systems, or eleven?" and "at what total cost"

It is to be noted that the system prototype described herein is considered as a research tool, to be used by scientists, in a research context, within each CCI project. Since heritage processing systems already exist for most of the individual EO sensors, both in industry and in research organizations, it is expected that CCI project teams will be able to rapidly assemble prototypes by re-using, adapting and integrating existing scientific software and pre-operational components. The data products to be generated during CCI phase 1 are considered as scientific data sets that are urgently needed and will be of high value to the climate science community in the next 3-4 years, at least

3.1 Task 1: Requirements Analysis and Product Specification

3.1.1 Objectives

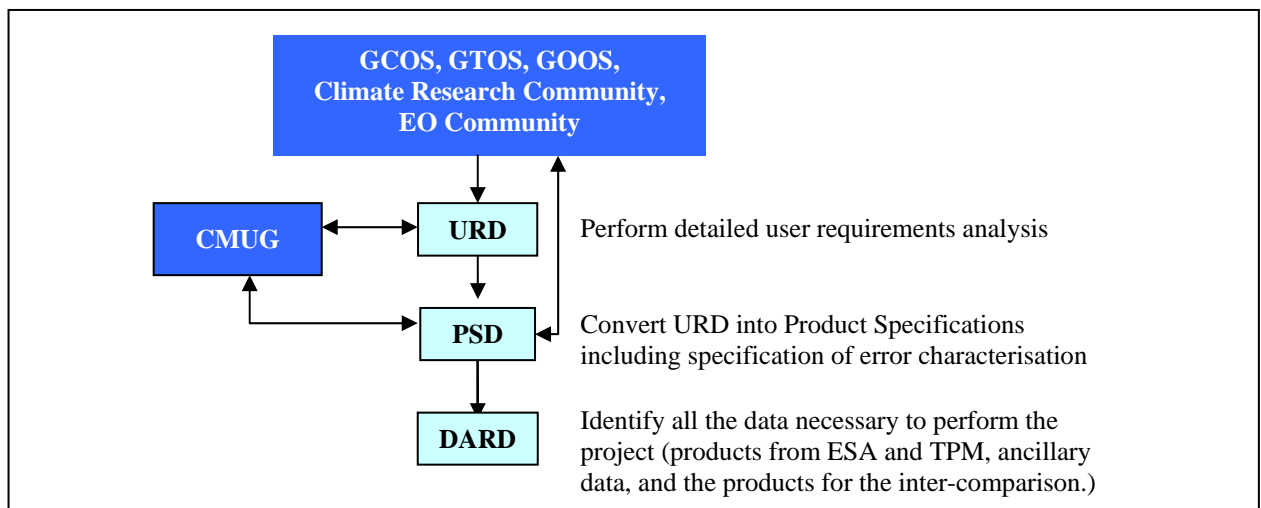
The objective of this task is to perform in consultation with the wider Climate Research Community a detailed and complete user requirements analysis to understand which products are needed to improve climate model outputs. The extent it is necessary to undertake climate model development to achieve this shall also be evaluated and a detailed plan formulated.

The assessment shall include identification of the extent the GCOS requirements are achievable with the currently available multi-satellite data records and shall include assessment of access and quality requirements for all the data necessary to perform the project. It shall also establish the plans and methods for validation and product and algorithm inter-comparison.

This task shall include a complete assessment of the error characteristics that are required to allow the detection of climate change impacts over and above natural variability and a full error budget analysis for the translation of the input baseline datasets to the ECV product. The error budget analysis shall make reference to the error characteristics

The outputs from the user requirements analysis shall be converted into detailed product technical specifications agreed through community consensus on the relevant ECV product.

3.1.2 Work logic of Task 1



3.1.3 Inputs

This task requires extensive interaction between the contractor, EO community and the Climate Research Community including review of material from the scientific literature as well as consultation with experts on organisations such as GCOS, relevant projects (past and present) both within and external to ESA and consultation with the relevant modelling community. As start points the following shall be consulted:

- This SoW complete with its Annexes
- GCOS-107: Systematic Observation Requirements for Satellite-based Products for Climate [RD-1]
- GCOS-92: Implementation Plan for the Global Observing System for Climate in support of the UNFCCC [RD-10]
- GCOS-82: The Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC [RD-11]
- Satellite Observation of the Climate System: The Committee on Earth Observation Satellites (CEOS) Response to GCOS Implementation Plan [RD-2]
- GCOS Global Climate Monitoring Principles [RD-7]
- GCOS Guideline for the Generation of Satellite-based Datasets and Products meeting GCOS Requirements [RD-8]
- Lessons from relevant projects and existing global data sets, including DUE projects [RD-12]
- Lessons from assimilation of existing global data products in numerical climate models

3.1.4 Activities

- In consultation with the CMUG and the Climate Research Group engaged in the project consolidate / refine the GCOS requirements and generate a **User Requirements Document (URD)** establishing a complete, structured set of individual end-user requirements for the ECV products and the FCDRs required to achieve them. User requirements shall be clarified through open review and based on the experience of products from existing algorithms and processors. Identification of the error characteristics that permit the detection of climate change over and above natural variability is a fundamental component of this document.
- Transform the URD into a complete and consistent set of product specifications and generate the **Product Specification Document (PSD)**. This document will naturally evolve as the project progresses through the different stages of the ECV development process. This document shall describe in a fully traceable manner the accumulation of error in the process of moving from the baseline datasets to the ECV product.
- Generate a detailed **Data Access Requirement Document (DARD)**.

3.1.5 Deliverables

- D1.1 User Requirement Document (URD)
- D1.2 ECV Product Specification Document (PSD)
- D1.3 Data Access Requirements Document (DARD)

3.2 *Task 2: Algorithm Development, Inter-comparison and Selection*

3.2.1 Objectives

The objective of this task is to develop, test and select the necessary algorithms to generate the high quality (multi-sensor) FCDRs and the derived ECV data products required by the end-users. This process shall respond to the performance requirements identified in the URD and PSD.

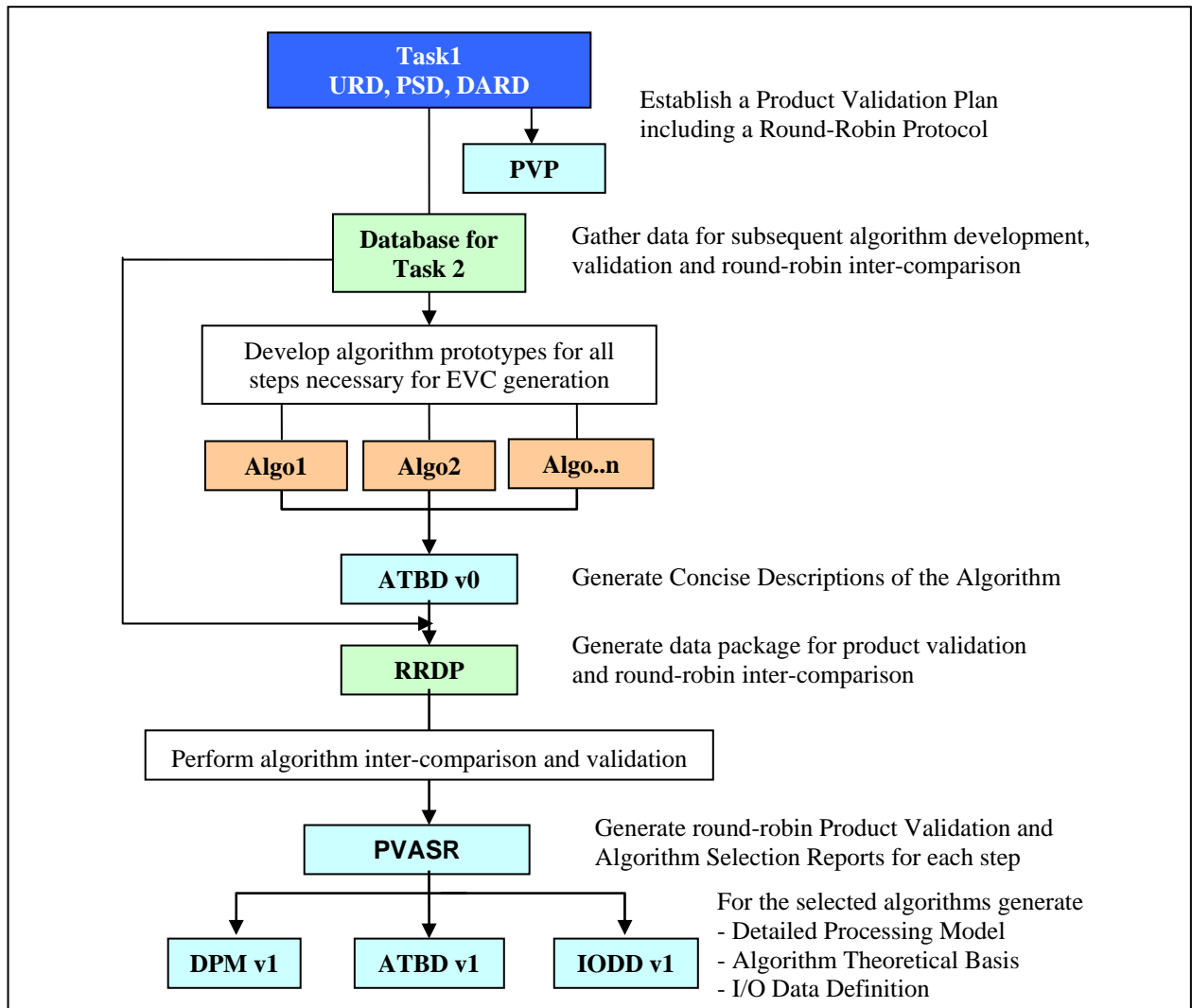
Major sustained, and coordinated scientific effort shall be undertaken to review, improve, and re-invent the underlying processing and retrieval algorithms. This includes the prototyping of scientifically improved algorithms for FCDR and ECV processing, as well as aggregation and multi-sensor data merging.

The best performing algorithm(s) or combinations of algorithms shall be selected following an open round-robin algorithm inter-comparison and product validation exercise following the protocols developed and agreed on by the relevant key science bodies in the initial steps of this task.

Following the algorithm selection a detailed description of the algorithms will be generated as the basis for subsequent implementation in an end-to-end system to be used for the generation of a sufficient quantity of test ECV products to allow their effective assessment.

Data analysis software tools to permit the effective assessment of all algorithms and visualisation software for transmission of results to the wider community shall be designed and implemented for all products developed within the CCI projects.

3.2.2 Work logic of Task 2



3.2.3 Inputs

- User Requirements Document (URD)
- ECV Product Specification Document (PSD)
- Data Access Requirements Document (DARD)

3.2.4 Activities

- Establish a **Product Validation Plan (PVP)** for the validation of all algorithms to be developed and tested and the products generated. This shall include a formal round-robin protocol for inter-comparison of improved L1, L2 and data merging algorithms. The plan shall cover the time windows and regions of interest of the Climate Research Group.

- Establish a **Database for task 2** containing all necessary Level 1 products from ESA and non-ESA archives, auxiliary data files and sufficient inter-comparison and validation data sets to ensure that quantitative conclusions can be drawn on algorithm performance from the Round-Robin and Validation activities in task 2.
- Using the Database for Task 2, develop, test and validate the necessary algorithms, starting from the Level 1b, to generate the required FCDRs and ECV products. It is the responsibility of the contractor in this process to ensure both scientific rigour and undertake all steps required to meet the specifications in the PSD. The following issues shall be considered in this process:
 - improvements of existing algorithms
 - use of combinations of algorithms, where this improves on the performance of any single algorithm
 - multi-sensor data merging algorithms
 - prototyping of new and innovative algorithms to address existing limitations.
 - Provision of quantitative per-pixel error estimates as well as measures of confidence on each final product as defined in the PSD.

The scientific background to an algorithm and a functional description of what the algorithm does shall be provided in a “light” version of an **Algorithm Theoretical Basis Document (ATBD version 0)**.

- Generate a **Round-Robin Data Package (RRDP)** for algorithm inter-comparison and product validation. This data package must include the Database for Task 2 enabling external participants to use their algorithms, generated test products from each algorithm, product user guides and instructions for production, formatting and submission of the results. The RRDP shall be made available via internet to all round-robin participants and the participation from the wider scientific community shall be actively encouraged.
- Perform round-robin algorithm inter-comparisons and product validation exercises for all processing steps using the round-robin data package and following the methods and protocols detailed in the RRP. Based on the result from the round-robin identify the best performing algorithm(s) to be implemented for all relevant steps and contributing missions. Full justification must be given for decisions to select or reject algorithms. The selected algorithms shall be globally applicable and function across the full temporal range for the relevant ESA and Third Party EO missions which contribute to the production of the relevant ECV unless a detailed explanation is provided for circumstances where it is necessary to adopt regional approaches. The results from this activity shall be documented in a **Round-Robin Product Validation and Algorithm Selection Report (PVASR)**.
- Generate a full and detailed version of the **Algorithm Theoretical Basis Document (ATBD version 1)**, **Detailed Processing Model (DPM version 1)** and the **Input Output Data Definition (IODD version 1)** covering all necessary steps to generate the required quality relevant ECV data products. These documents are expected to evolve as improved algorithms become available and are tested and shown quantitatively via the RRDP to produce better results. The period for algorithm improvement once the first version of the ATBD, DPM and IODD have been produced is 6 months. A final version of these documents shall be developed in Task 3.

3.2.5 Deliverables

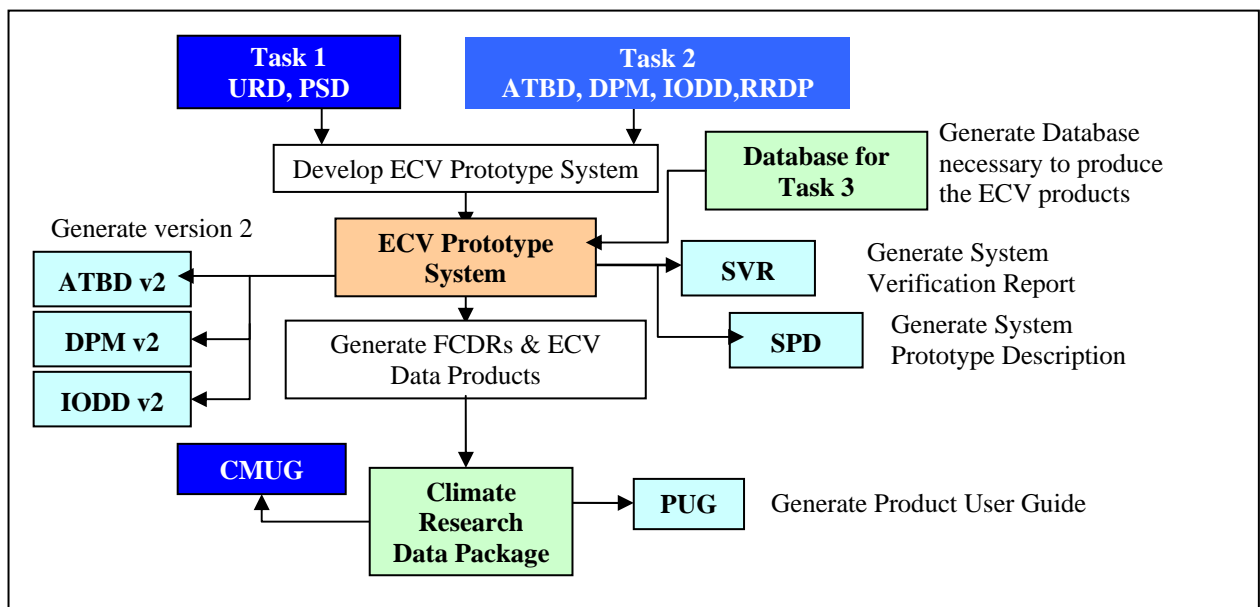
- D2.1 Product Validation Plan (PVP)
- D2.2 Database for Task 2
- D2.3 Algorithm Theoretical Basis Document (ATBD), version 0
- D2.4 Round-Robin Data Package (RRDP) for Inter-comparison and Validation
- D2.5 Product Validation and Algorithm Selection Report (PVASR)
- D2.6 Algorithm Theoretical Basis Documents (ATBD), version 1
- D2.7 Detailed Processing Models (DPM) (Pseudo code), version 1
- D2.8 Input Output Data Definition (IODD), version 1

3.3 Task 3: System Prototyping and ECV Production

3.3.1 Objectives

Given selection of the algorithm(s) in task 2 this task comprises the full-scale development of the software prototype end-to-end system and its use to generate a sufficient quantity of ECV test products necessary for Task 4. The Contractor shall go as far as possible in actually generating high quality long-time series of ECV products.

3.3.2 Work logic of Task 3



3.3.3 Inputs

- ATBD v.1
- DPM v.1
- IOOD v.1
- Round-Robin Data Package (from Task 2)
- User Requirements Document (from Task 1)
- Product Specification Document (from Task 1)

3.3.4 Activities

- Develop a working end-to-end **Prototype ECV Production System** for generation of the **Climate Research Data Package**. The Prototype System shall be developed using commonly available platforms and programming languages and dependence on COTS and IPR protected

elements shall be avoided. Special emphasis shall be put on software modularity with sufficient annotation to allow its analysis by software engineers. The system shall include all steps necessary to generate the ECV outputs from the original multi-sensor data inputs as described in the PSD. It will be based on the DPM and IOOD and terminology and structure shall reflect and be traceable back to these documents. While, the Prototype ECV Production System is not a formal deliverable to ESA it shall be maintained by the Contractor until the end of the CCI Programme. The maintenance shall cover installation and configuration on clean hardware outside the development environment. Since the CCI Programme is fundamentally based on international collaboration and open exchange of documents and data, the Prototype ECV Production System shall be accessible to other research groups on request.

- Verify the correct implementation of the prototype system against the algorithms developed in Task 2 and compile a **System Verification Report (SVR)**. The contractor shall ensure scientific rigour in this process and issues raised shall be addressed.
- Acquire all satellite, ancillary, and in-situ data necessary for the generation, validation and inter-comparison of the ECV products (**Database for Task 3**). This is a larger dataset than the **Database for Task 2** in Task 2. Where necessary this also includes generation of validation data.
- Process and deliver the **Climate Research Data Package** to the end users engaged in the project according to the requirements established in the URD and PSD. Strict quality control procedures shall be followed during processing: the production will be interrupted if the resulting products do not meet previously agreed (scientific) quality standards and the issues raised shall be addressed.
- Write a **Product User Guide (PUG)** for the ECV data products to provide the end user with practical information regarding the use of these products.
- Write a **System Prototype Description (SPD)** containing an overview of the system and its components, functionality of the system and its subsystems, inputs, outputs, resource key interfaces, and resource requirements.
- Establish version 2 of the **ATBD, DPM, IOOD**

3.3.5 Deliverables

- D3.1 System Prototype Description (SPD)
- D3.2 System Verification Report (SVR)
- D3.3 Database for Task 3
- D3.4 Product User Guide (PUG)
- D3.5 Climate Research Data Package
- D3.6 ATBD, version 2
- D3.7 DPM, version 2
- D3.8 IOOD, version 2

3.4 Task 4: Final Product Validation and User Assessment

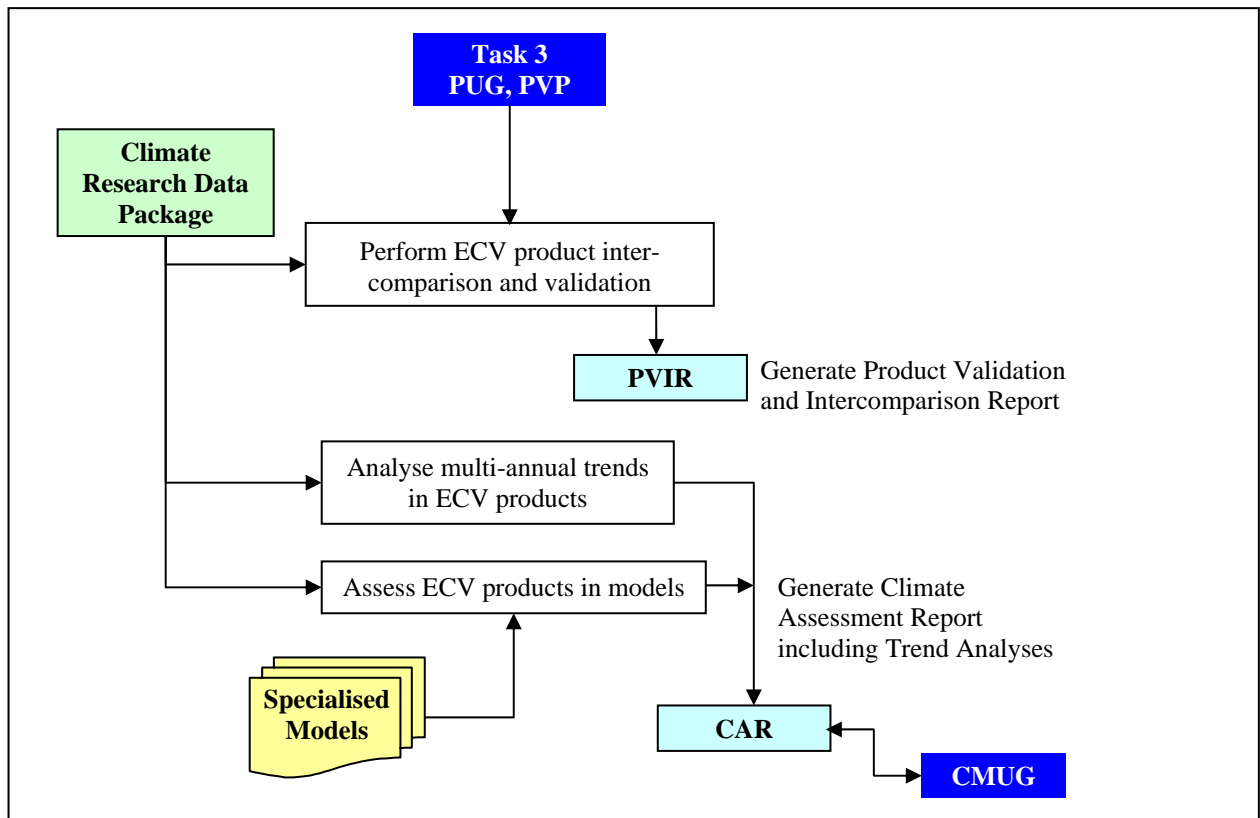
3.4.1 Objectives

The derived ECV prototype products shall be fully validated against independent data such as ground based measurements and alternative estimates of climate variables from other projects and other sensors. The products shall be used to analyse multi-annual trends and confronted with models to assess the sensitivity of the models and their resulting outputs to the ECV products.

The validation shall determine observation uncertainties by confronting independent observations and the prototype products, taking account of uncertainties in the independent data. Trends and model sensitivity analysis shall be used to determine the degree to which climate change impacts can be identified over and above natural variability, by accumulation of errors due to observations and those due to models. This shall be achieved by confronting models and ECV data products.

Validation work shall be conducted by the EO Science Team in cooperation e.g. with relevant international partners while the prototype ECV products shall be released to the CMUG and the engaged Specialized Climate Research Groups for evaluation and assessment of trends and consistency of the ECV records in the context of climate models and assimilation schemes.

3.4.2 Work Logic of Task 4



3.4.3 Inputs

- Product Validation Plan (PVP)
- Product User Guide (PUG)
- Climate Research Data Package

3.4.4 Activities

Members of the **Science Team** not directly associated with the ECV product generation shall perform the following activities:

- Assess the ECV prototype products, using the **Climate Research Data Package**, following the methods detailed in the PVP.
- Inter-compare the ECV prototype products with products from other missions and other R&D initiatives, using the **Climate Research Data Package**, as a collaborative effort with key external projects.
- Generate a **Product Validation and Inter-comparison Report (PVIR)** from the results from the validation and inter-comparison exercises. The analysis shall quantify the accuracy of the derived products against the validation data and comparable alternative satellite-based products generated by international projects.

The **Climate Research Group** shall perform the following activities, in association with the CMUG:

- Analyse multi-annual trends in the derived ECV products, using the **Climate Research Data Package**, and report the assessment in a **Climate Assessment Report (CAR)**.
- Conduct a comprehensive analysis of the sensitivity of models to ECV products based on the **Climate Research Data Package** and report this analysis in the **Climate Assessment Report (CAR)**.

3.4.5 Deliverables

- D4.1 Product Validation and Inter-comparison Report (PVIR)
- D4.2 Climate Assessment Report (CAR)

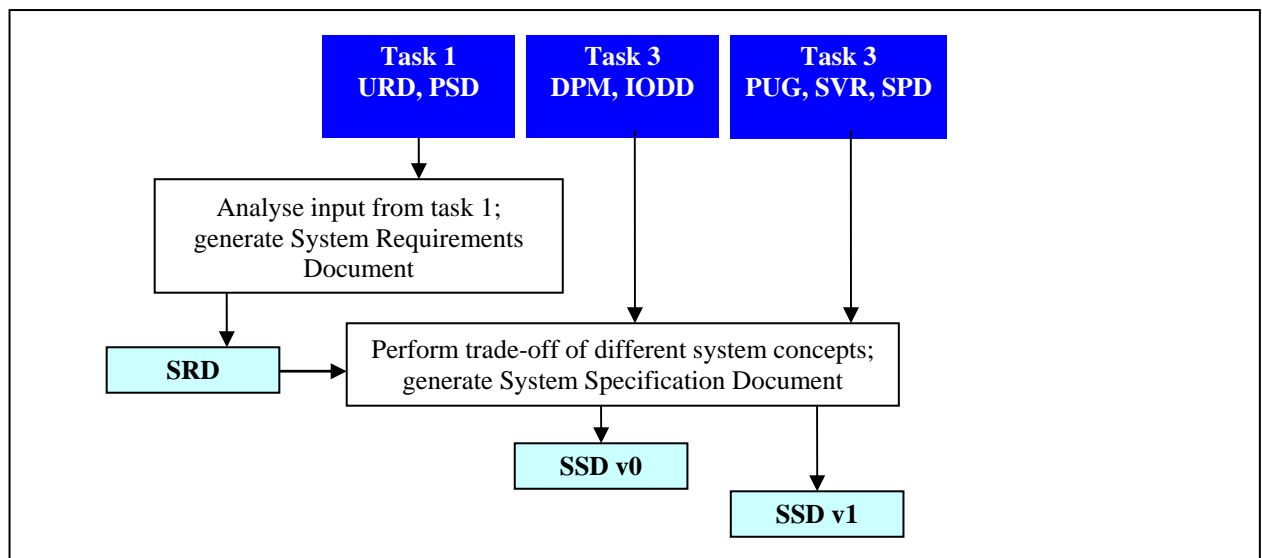
3.5 Task 5: System Specifications

3.5.1 Objectives

This task is the preparation for Phase 2 of the CCI Programme and involves:

- analysis of the requirements for, and definition of, an **operational** production system
- evaluation of the effectiveness of alternative system concepts e.g. discrete standalone approaches, GRID processing and CLOUD processing.

3.5.2 Work Logic of Task 5



3.5.3 Inputs

- User Requirements Document (from Task 1)
- Product Specification Document (from Task 1)
- Detailed Processing Model (DPM) (from Task 3)
- Input Output Data Definition (IOOD) (from Task 3)
- Product User Guide (PUG) (from Task 3)
- System Verification Report (SVR) (from Task 3)
- System Prototype Description (SPD) (from Task 3)

3.5.4 Activities

- Analyse all the relevant outputs from Task 1 to 3 and generate a **System Requirements Document (SRD)** providing a structured definition of the characteristics of the complete end-

to-end processor in an operational context. This task shall also address the need for establishing data service systems that ensure ongoing accessibility to the Climate Data Sets into the future as well as the required capacity to update these data sets periodically by addition of new data or by reprocessing complete records when calibration improves or ECV generation methods evolve.

System sizing metrics, and requirements for their future evolution shall be identified, taking due account of relevant historical archives, current EO missions in orbit and planned for the next 15 years. Requirements for input and output data throughputs, processing complexity and processing power shall be specified, taking due account of the present state of the art in algorithms and the improvements that will be needed to meet GCOS requirements.

- Perform a critical review and trade-off analysis of potential technical solutions including methods such as standalone approaches, GRID processing, CLOUD processing as well as alternative methods to these and generate a **System Specification Document (SSD)** defining a system concept most appropriate to achieve the ECV product generation. This shall address in particular the following priority issues in the assessment:
 - Modularity: most open to broad scientific participatory inputs
 - Re-processing Capability: most amenable to rapid updating and re-processing of data from all contributing sensors
 - Alternative (re)processing system architectures
 - One (re)processing system per ECV
 - One (re)processing system per ECV domain (eg land, atmosphere, ocean)
 - A single integrated (re)processing system (for all ECVs)
 - Ease of user access to, and dissemination of global ECV data products
 - Maintenance and user access to associated Meta Data and documentation
 - System (and algorithm) Development life-cycles and latency times
 - Associated cost models
 - Achieving low operational cost

3.5.5 Deliverables

- D5.1 System Requirements Document (SRD)
- D5.2 System Specification Document (SSD version 0)
- D5.3 System Specification Document (SSD version 1)

3.6 Task 6: Project Management

3.6.1 Objectives

The objective of this task is to ensure that all activities of each ECV contract are carried out according to the agreed schedule and quality. For each contract a single Project Manager shall manage and control all project activities of all sub-contractors. The Project Manager shall identify any departure from planned performance and schedule and take corrective action necessary to recover schedule and quality of deliverables.

3.6.2 Inputs

- ITT & signed contract
- Project Proposal

3.6.3 Activities to be executed

The Project Manager shall manage all activities of the consortium. A detailed description of his task is provided in Section 4.4.

3.6.4 Deliverables

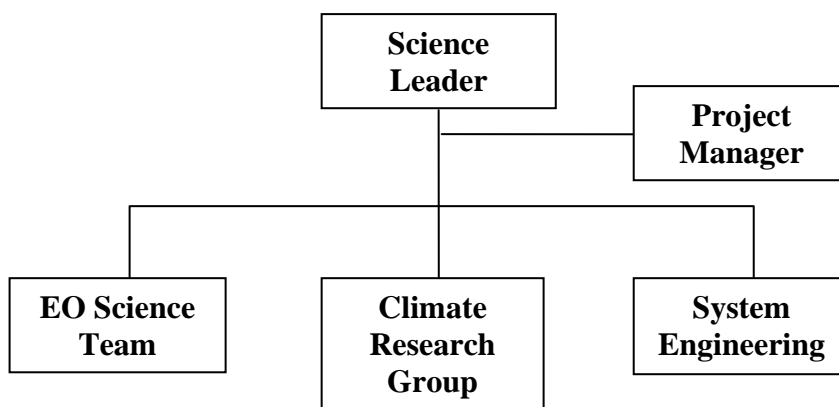
- Project Management Plan (PMP)
- Monthly Progress Reports (MPR)
- Quarterly Progress Reports (QPR)
- Project Website

These items are detailed in section 4.7.2 and 4.7.3.

4 MANAGEMENT REQUIREMENTS

[R-13]	<i>Each CCI project team (the contractor) shall comply with all management requirements specified herein</i>
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4.1 Organisation



4.2 Prime Contractor

Each Consortium working on an ECV shall be led by a single Prime Contractor. The Prime Contractor shall appoint a Science Leader who shall lead the Consortium and be the interface to ESA and a Project Manager who shall provide the necessary administrative support to the Science Leader to ensure the project remains within schedule, within budget and achieves its objectives.

4.3 Science Leader

The Science Leader shall be an internationally recognised expert from the EO science community with a proven track record on research activities relevant for the concerned ECV and with expertise in coordinating large scale research projects.

The Science Leader of each ECV **is the interface to ESA for all issues**. They shall be responsible for setting-up the project in a manner that facilitates interaction, exchange and coordination. The Science Leader shall:

- Participate in activities carried out by the EO Science Team
- Manage the science interface with research groups, networks and relevant scientific bodies including the interface to the engaged Climate Research Groups.

- Manage the interface with the System Engineers such that the system specifications are driven by the scientific objectives and an effective exchange of ideas is established with the Climate Research Group and the EO Science Team.
- Actively link to and interact with the climate modelling experts engaged in the ESA Climate Modelling User Group (CMUG) project and with the other ECV project teams
- Build interfaces and linkages with relevant actors and community consensus groups (e.g. GHRSSST, GOFC-GOLD, IOCCG/IOCCP) and ensure efficient coordination and collaboration with all relevant partners and external activities of the wider community
- Ensure feedback mechanisms with the wider Climate Research Community
- Establish coordination and efficient cooperation with relevant on-going external activities and projects inside Europe (e.g., funded nationally, by EC or by EUMETSAT) and outside of Europe (e.g., NASA, NOAA, JAXA), particularly for the purposes of validation and inter-comparison.
- Work closely with the Project Manager to achieve all milestones and ensure the timely delivery and quality of all documents and data sets.

4.4 Project Manager

The Project Manager shall support the Science Leader in the overall management of the project and ensure that all tasks are executed in a coherent, consistent and efficient manner. They shall have **a proven track record on managing large scale international projects and an understanding of the scientific issues being tackled** in the project.

The Project Manager shall:

- Provide at Kick-Off and implement the Project Management Plan to achieve the objectives of the ECV project set out in this SOW
- Monitor progress of each task and identify, follow-up and close-out all problems or under-performance
- Set up and maintain a project actions database
- Organise internal quality review and ensure timeliness in submission of all deliverables
- Compile monthly progress reports and minutes of meetings
- Compile quarterly progress reports for a technically literate but non-expert audience.
- Organize and attend progress meetings and ensure attendance by all necessary project team members
- Manage the entire organisation of the round robin exercises with the support of the EO Science Team
- Support the Science Leader in the interface with other ECV project teams and ensure that specifications, data definitions, reference data sets, output products, algorithms, and documentation are exchanged.
- Support the coordination of project activities with other relevant on-going national, EC funded and international projects.
- Set up and regularly update the project website. The website shall be easily recognisable to the international Earth observation and Climate Research Communities.

4.5 *Working Teams*

Three working teams shall support the Science Leader:

- EO Science Team
- Climate Research Group
- System Engineers

4.5.1 EO Science Team

The EO Science Team shall comprise key experts who:

- are at the forefront of developing methodologies and next generation algorithms required for generating high quality climate relevant data sets
- have already developed, demonstrated and validated pre-cursor systems
- will orient their future research activities to support the CCI initiative

The role of the EO Science Team shall be to:

- Review and improve existing, and implement new high-performance, algorithms necessary to produce long term data products meeting, or approaching the specific GCOS performance requirements for each ECV.
- Develop formal scientific specification of algorithms, prototype software, and reference data products, which can be passed, in a second programme phase, to industry for integration within operational systems.
- Generate data products demonstrating the feasibility of achieving GCOS performance requirements
- Validate the derived products and provide recommendations for future algorithm developments to meet the GCOS performance requirements.
- Develop a formal protocol for the Round-Robin algorithm inter-comparison and validation exercise
- Actively participate in the Round-Robin inter-comparison and validation exercises and provide a conclusive Round-Robin Report.
- Select the best performing and most suitable algorithms in agreement with the wider EO science community.
- Publish the results of the project in internationally recognised, peer-reviewed scientific journals and through community newsletters

4.5.2 Climate Research Group

Each ECV project shall engage internationally recognized experts involved in understanding climate dynamics specifically related to the concerned EVC. These experts shall:

- Ensure that the ESA CCI meets the requirements of the Climate Research Community, e.g. gather requirements from the wider community in terms of observational climate data and contribute to the preparation of a detailed User Requirements Document.
- Review and comment from an end-user and modeller perspective key project deliverables.
- Liaise with the wider international research community in the exploitation and integration of ECV products within specialised models.
- Undertake necessary steps to integrate ECVs within specialised models.
- Assess the trends and consistency of these products, examine the impact of such datasets on results from specialised models and provide the necessary feedback.
- Publish the results of the project in internationally recognised, peer-reviewed scientific journals and through specialised community newsletters

4.5.3 System Engineer(s)

The System Engineer(s) shall have previous expertise in requirement definition and specification of large EO data processing and product delivery systems, in terms of software, hardware, archiving and throughput. Knowledge of the latest related technologies like GRID or CLOUD computing is an asset.

The System Engineers shall:

- identify the requirements and the technical specifications for a complete end-to-end ECV processing chain by analysing the system prototype in an operational context.
- interact closely with the EO Science Team and Climate Research Group to ensure that any specification is 'fit for purpose'.
- conduct trade-off analysis between different system concepts based on the priorities of:
 - Low operational cost
 - Reprocessing capability
 - Modularity
- address the need for establishing data service systems that ensure ongoing accessibility to the Climate Data Sets into the future as well as the required capacity to update these data sets periodically.

4.6 Meetings

Four types of meeting shall be organised during the duration of the project:

- Contract progress meetings
- Annual review meetings
- Co-location working periods with the other CCI projects
- Co-location meetings with the CMUG

Indicative time-lines for these meetings are provided in 4.8.1

4.6.1 Contract Progress Meetings

Progress review meetings with ESA shall be held every three months.

The Contractor shall make all organisational arrangements to prepare these progress meetings and shall circulate a draft agenda and meeting logistical information at least two weeks in advance. Choice of date, venue and agenda shall be subject to approval by ESA.

The Contractor shall chair all progress meetings, shall be responsible for all minutes and shall ensure all actions raised during the meetings are promptly recorded in the Actions Database.

4.6.2 Annual Review Meetings

The annual review **shall** cover:

- Progress status of the work in the current phase and reporting of achievements
- Completion status of the deliverables
- Management effectiveness and efficiency
- Identification of current and potential problems
- Consolidation of action plans for the next project phase

Where progress is deemed by ESA to be unsatisfactory, recovery actions **shall** be identified and implemented.

Based on the outcome of this review, the consortium **shall** revise its annual work-plan for the following year with the objective to return to the original project schedule.

4.6.3 Co-location Working Periods

Co-location working periods are an important means to firmly establish the scientific coherency between the ECV projects, ensure inter-consortia coordination, consolidate common approaches, and mobilize the multi-disciplinary scientific expertise available within the various teams.

Key personnel from all ECV consortia including the EO Science Teams and the engaged Climate Research Groups shall participate in four co-location working periods:

Co-location 1: three months after KO (Jul-2010)

This shall focus on examining and ensuring consistency in requirements and specifications

Co-location 2: KO+15 (Jul-2011)

Assessment of potential and actual performance with existing algorithms and discussion and consolidation of algorithm selection

Co-location 3: KO+27 (Jul-2012)

Assessment of the quality and consistency of ECV data products across the CCI projects

Co-location 4: KO+34 (Feb-2013)

Assessment of climate trends and model outputs

Each collocation shall last 3 days comprising one Information Day for the ESA delegations and invited external experts and 2 full working days focusing on the interface between CCI projects.

Co-location 1, 2, 3 shall be combined with PM1, PM4, PM7.

4.6.4 Co-location meetings with the CMUG

Key representatives of the EO Science Team and the engaged Climate Research Group shall participate in co-location meetings of one day with, and organised by, the CMUG. These will take place two times a year in order to discuss issues from a climate model perspective.

4.6.5 Meeting Locations

The contract kick-off meeting, the annual review meetings and the co-location meetings shall be held at ESRIN.

Contract progress meetings shall alternate between the premises of the EO Science Team partners or the Climate Research Group. They shall normally last two full days.

The Contractor and consortium members shall use video-conferencing, tele-conferencing, and internet-based-meeting facilities for regular working meetings with partners to minimise travel and the project carbon footprint.

Co-location meetings with the CMUG shall be held at CMUG premises.

4.7 Deliverables

This section defines the minimum set of items to be provided to the Agency within the frame of the whole project.

The deliverable items are:

- Data sets
- Documents
- Project monitoring elements
- ECV Project Web site

[R-14]	<i>Each CCI project team (the contractor) shall produce and deliver all deliverable items specified herein, in accordance with the defined schedule</i>
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It should be noted that progress payments will be linked to project milestones that are denoted by final acceptance of deliverable items (e.g. data products, technical and scientific documents).

4.7.1 Data Sets

D2.2 Database for Task 2

The *Database for Task 2* is the baseline dataset for the generation of the round-robin data package. It contains all necessary products from ESA and non-ESA archives including all auxiliary data files necessary for the algorithm development, validation and inter-comparison activities in Task 2. In particular it shall contain sufficient inter-comparison and validation data sets ensuring that quantitative conclusions can be drawn on algorithm performance from the round-robin activities in task 2. All data entering the Database shall be quality controlled by the EO Science Team.

Responsible: EO Science Team
 International Interface: Science Leader

D2.4 Round-Robin Data Package (RRDP)

The *Round-Robin Data Package* shall be used for algorithm inter-comparison and product validation and shall be made available via internet to all round-robin participants and interested parties subject to licence agreement. The licence agreement will be generated by the consortium and approved by ESA and the Key Science Bodies. It includes:

- all source data used for product generation
- generated test data products
- auxiliary data
- product user guides
- product evaluation and analysis tools
- common set of well characterized field-based validation datasets
- validation protocols
- instructions for production, formatting and submission of the results.

This data package shall be hosted on the project website with the necessary links to the data providers, the key science bodies and the external EO science community with an open read access.

Responsible: EO Science Team
International Interface: Science Leader

D3.3 Database for Task 3

Acquire all satellite, ancillary, and in-situ data necessary for the generation of the ECV products. This is a larger dataset than the well-characterised round-robin data package in Task 2. It shall be globally comprehensive and representative of the appropriate temporal cycles of the ECV product as agreed with the engaged Climate Research Community. Where necessary this also includes acquisition of all data required for the generation of validation data in collaboration with international partners. It shall include acquisition of the necessary validation data from external sources. It shall also include the acquisition of the necessary data for inter-comparison of the ECV products, obtained through international collaboration.

Responsible: EO Science Team
International Interface: Science Leader

D3.5 Climate Research Data Package

The *Climate Research Data Package* contains all the data products necessary to perform the steps in Task 4, namely the validation of the output products, their inter-comparison with alternatives, trend analysis of the ECV products and the use of the products in specialised models generated by the engaged Climate Research Group. It shall contain sufficient test and validation data to allow comprehensive assessment of results both globally and temporally. The ECV products shall be traceable in format and content to the Product User Guide and will match the Product Specifications detailed in the PSD. The inter-comparison data obtained in D3.3 shall be converted into this format for subsequent inter-comparison. Similarly the validation datasets shall be generated and/or converted into standard compatible format following the PVP. No subsequent data reformatting shall be necessary in Task 4.

This data package shall be hosted on the project website with the necessary links to the data providers, the key science bodies and the external climate research community with an open read access subject to licence agreement. The licence agreement will be generated by the consortium and approved by ESA and the Key Science Bodies.

Responsible: EO Science Team
International Interface: Science Leader

4.7.2 Documents

All documents shall be delivered to ESA in Microsoft Word and Portable Document Format (PDF) electronic format and on physical media (2 copies on CD-ROM or DVD).

All documents shall be reviewed, before delivery to ESA, for:

- Scope, Completeness, Configuration control
- Clarity, consistency, grammar, spelling
- Scientific rigour

Where there is an international interface a formal review shall be performed by the Science Leader. These are indicated in the document descriptions (see Appendix 2).

All documents delivered to ESA shall bear the following information:

- Document title; issue & version number; issue date
- Author(s) name & signature
- Reviewer(s) name & Signature
- Approver(s) name, organisation & signature
- Issuing Authority name & signature

All documents shall contain:

- Table of contents
- Executive Summary
- Change Record

All documents shall refer to a single bibliography list that uniquely identifies each reference document.

All text revisions shall be recorded in change logs that provide information on the reason for the change, the issue number, revision number, date and pages and paragraphs affected.

All documents shall be clear, self-explanatory and self-contained.

No two documents shall contain the same information – neither verbatim, nor paraphrased.

All diagrams and illustrations shall be clear, easily legible and provided to ESA on request as high resolution TIFF files for promotion and publication purposes.

All documents shall be made publicly available via the ECV Project Web Site.

4.7.3 Project Monitoring

Project monitoring is conducted through the generation and updating of the Project Management Plan and the delivery of Monthly and Quarterly Progress Reports.

4.7.3.1 Project Management Plan

The Project Management Plan describes the:

- project organisation
- resource breakdown
- travel plan and budget,
- communications,
- the tables of contents of each document deliverable,
- document review cycle,
- analysis of risk factors and mitigation strategies.

It also contains:

- work breakdown structure
- Gantt charts,
- work package descriptions
- identification of task leaders
- level of effort per work package

A full and revised version of this plan shall be prepared and presented at each progress meeting.

Responsible: Project Manager

4.7.3.2 Monthly Progress Report

This describes the project achievements in the last month, current status, problems encountered and solutions adopted. It should be approximately 2 pages.

Responsible: Project Manager

4.7.3.3 *Quarterly Progress Report*

Quarterly progress reports shall be provided by the 15th day of the month before the end of each calendar quarter.

It shall describe:

- the project achievements in the previous three months
- major planned project activities in the coming three months,
- cooperation with international partners, European and national projects,
- major problems encountered and solutions adopted.

It shall be written for a technically literate but non-expert audience and shall be approximately 3 pages.

Responsible: Project Manager

4.7.4 ECV Project Web Site

Each ECV project shall be supported by a web site that shall be used in particular to:

- Present the project
- Publish all technical documentation (e.g. ATBD, IODD, Product Specs, PUG, Validation Report, etc)
- Host ECV prototype software for download (executables and source) on request
- Host all test data in a repository
- Track issues
- Monitor usage and provide statistics
- Provide discussion forum and FAQ
- Provide regularly updated information via newsletters

The web site is expected to evolve during the duration of the project and shall be maintained and regularly updated. It shall be hosted on contractor premises.

Documents shall first be delivered to ESA for approval before being published on the web site.

4.8 Schedule

4.8.1 Meetings Schedule

Month	Date	Type	Purpose	days	Review	PM	Colocation
Apr-2010	KO	Kick-off	Contract kick-offs with Consortia	1			
May-2010							
Jun-2010							
Jul-2010	KO+3	Co-location 1/PM1	Consistency in requirements and specifications	4		●	●
Aug-2010							
Sep-2010	KO+5	PM2		2		●	
Oct-2010	KO+6	CMUG1		1			●
Nov-2010							
Dec-2010							
Jan-2011	KO+9	PM3		2		●	
Feb-2011							
Mar-2011	KO+11	CMUG2		1			●
Apr-2011	KO+12	Review	first annual review	2	●		
May-2011							
Jun-2011							
Jul-2011	KO+15	Co-location 2/PM4	Achievable performance with existing algorithms and algorithm selection	4		●	●
Aug-2011							
Sep-2011	KO+17	PM5		2		●	
Oct-2011	KO+18	CMUG3		1			●
Nov-2011							
Dec-2011	KO+20	PM6		2		●	
Jan-2012	KO+21	CMUG4		1			●
Feb-2012							
Mar-2012							
Apr-2012	KO+24	Review	second annual review	2	●		
May-2012							
Jun-2012	KO+26	CMUG5		1			●
Jul-2012	KO+27	Co-location 3/PM7	Assessment of performance of ECV data products	4		●	●
Aug-2012							
Sep-2012							
Oct-2012	KO+30	PM8		2		●	
Nov-2012							
Dec-2012							
Jan-2013	KO+33	PM9		2		●	
Feb-2013	KO+34	Co-location 4	Assessment of climate trends and model outputs	3			●
Mar-2013	KO+35	CMUG6		1			
Apr-2013	KO+36	Review	final project review	2	●		

4.8.2 Deliverables Schedule

Task	Code	Deliverable	Stage 1 Requirements analysis & specs, algo development, inter-comparison & selection				Stage 2 System prototyping and ECV production				Stage 3 Final product validation & user assessment			
			Year 1				Year 2				Year 3			
			Title	KO +3	KO +6	KO +9	KO +12	KO +15	KO +18	KO +21	KO +24	KO +27	KO +30	KO +33
Requirements Analysis & Prod. Specs	D1.1	User Requirements Document	*											
	D1.2	Product. Specification Document		*										
	D1.3	Data Access Requirements Doc.	*											
Algorithm Development, Intercomparis on and Selection	D2.1	Product Validation Plan		*										
	D2.2	Database for Task 2		*										
	D2.3	ATBD v0		*										
	D2.4	Round-Robin Data Package			*									
	D2.5	Prod. Val. & Algo Selection Rep			*									
	D2.6	ATBD v1					*							
	D2.7	DPM v1					*							
	D2.8	IODD v1					*							
System Protoyping & ECV Production	D3.1	System Prototype Description						*						
	D3.2	System Verification Report						*						
	D3.3	Database for Task 3						*						
	D3.4	Product User Guide								*				
	D3.5	Climate Research Data Package								*				
	D3.6	ATBD v2							*					
	D3.7	DPM v2							*					
	D3.8	IODD v2							*					
Final Prod. Val & User Assess.	D4.1	Prod. Val. & Intercomp. Report										*		
	D4.2	Climate Assessment Report											*	
System Specification	D5.1	System Requirements Document			*									
	D5.2	System Specification Doc V0				*								
	D5.3	System Specification Doc V1						*						

4.8.3 Milestones Schedule

Date	Milestone	Milestone description
KO	M1	Contract Kick-off
KO+6	M2	Delivery and acceptance of: <ul style="list-style-type: none"> • URD (D1.1), DARD (D1.3) • PSD (D1.2), , PVP, (D2.1), DBT2 (D2.2), ATBD v0 (D2.3)
KO+9	M3	Delivery and acceptance of: <ul style="list-style-type: none"> • RRDP (D2.4), PVASR (D2.5) • SRD (D5.1)
KO+15	M4	Delivery and acceptance of: <ul style="list-style-type: none"> • SSD v0 (D5.2) • ATBD v1 (D2.6), DPM v1 (D2.7), IOODD v1 (D2.8)
KO+18	M5	Delivery and acceptance of: <ul style="list-style-type: none"> • SPD (D3.1), SVR (D3.2), DBT3 (D3.3)
KO+24	M6	Delivery and acceptance of: <ul style="list-style-type: none"> • ATBD v2 (D3.6), DPM v2 (D3.7), IOODD v2 (D3.8), SSD v1 (D5.3) • PUG (D3.4), CRDP (D3.5)
KO+33	M7	Delivery and acceptance of: <ul style="list-style-type: none"> • PVIR (D4.1)
KO+36	M8	Delivery and acceptance of: <ul style="list-style-type: none"> • CAR (D4.2)

APPENDIX 1: ACRONYMS AND ABBREVIATIONS

ATBD	Algorithm theoretical Basis Document
CCI	Climate Change Initiative
COTS	Commercial Off-The-Shelf software
CMUG	Climate Modelling User Group
DPM	Detailed Processing Model
DUE	Data User Element of ESA's Earth Observation Programme
EC	European Commission
ECV	Essential Climate Variable
EO	Earth Observation
FCDR	Fundamental Climate Data Record
GCOS	Global Climate Observation System
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of Systems
GOOS	Global Ocean Observing System
GTOS	Global Terrestrial Observing System
IODD	Input Output Data Definition
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual Property Rights
ITT	Invitation to tender
KO	Kick-off
PM	Progress meeting
PMP	Project Management Plan
RD	Reference Document

APPENDIX 2: DESCRIPTION OF MAJOR DOCUMENTS

Definition of Terms

- *Commented by:* This process involves invitation to provide feedback on the relevant document. The feedback may be incorporated at the discretion of the authors.
- *Formally reviewed by:* This process involves formal feedback which shall be addressed in the revision of the relevant document.

D1.1 User Requirements Document (URD)

The *User Requirements Document* provides a complete, definitive, structured set of individual requirements and constraints to meet the needs of the Climate Research Community for FCDRs and ECV data products.

For each FCDR and ECV product it shall describe from a modelling perspective

- the geophysical parameters of interest
- their required (and minimum acceptable) accuracy and stability
- error characteristics expressed in terms of the ability to detect climate change over the natural variation in physical terms
- expected and minimum acceptable resolution and coverage in time (observation cycle) and space
- product format
- metadata
- quality flags/indicators
- grid and projection.

The document shall involve a close cooperation with the Climate Research Group engaged in the projects in its generation and shall be reviewed and agreed by this group and the CMUG to achieve community consensus.

Written by: EO Science Team, Climate Research Group

Commented by: CMUG

Formally reviewed by: Key Science Body (+1 month)

Internally approved by: Science Leader

D1.2 Product Specification Document (PSD)

The *Product Specification Document* incorporates the user requirements described in the URD. For each (multi-mission) FCDR and EVC product it contains the most detailed and specific definition of the

- geophysical parameters to be provided

- structure and format of the product
- annotation data sets
- quality flags / indicators
- product grid and projection
- ancillary data used
- error budget in terms of the ability to make the observations, considering each step in the conversion from TOA radiance to the ECV product with reference to the terms expressed in the User Requirements Document.

Written by: EO Science Team, engaged Climate Research Group

Commented by: CMUG

Formally reviewed by: Key Science Body (+1 month)

Internally approved: Science Leader

D1.3 Data Access Requirements Document (DARD)

The *Data Access Requirements Document* identifies all the data that are needed as input to perform the project, including

- all required Level 1, and if necessary Level 0, products from ESA and Third Party Missions
- all ancillary data
- all in-situ observation data sources as well as higher-level products needed for product inter-comparison
- historical data archives, currently operational sources and sources due to become operational in next 3 years.

For each data source the DARD includes:

- information about the originating system
- identification of the data class (in-situ, EO, model)
- specification of the sensor type and key technical characteristics
- information about data availability & coverage (times-scale, geographic, temporal),
- source data product name & reference to product technical specification documents
- estimates of the data quantity
- indication of data quality and reliability
- description of the ordering and delivery mechanism
- identification of access conditions & pricing

The DARD shall include detailed requirements for resolving any known data access, calibration, validation and performance issues specific to the satellite ground segment processing and identify potential algorithm upgrades enabling the regeneration of improved and most accurate input products required for each ECV.

The document shall include formal agreement with the data suppliers for delivery of the data to the project.

Written by: EO Science Team

Internally approved: Science Leader

D2.1 Product Validation Plan (PVP)

The *Product Validation Plan* is the top-level definition of the approach, protocols, validation data sets, tools, techniques and methods used for verifying that the results coming from the developed algorithms have geophysical meaning and that the developed climate relevant data products meet the user requirements. The plan shall ensure that the tests performed are representative of the full geophysical data space. It contains

- description of all validation activities including validating new products and re-validating upgrades
- master schedule
- resources summary
- rules and responsibilities to ensure unbiased and independent validation
- validation criteria
- description of the review process and decision sequence
- the geographical and temporal representation and quality of the reference data sources
- requirements for validating reference data sources.
- list of required validation documentation
- access, distribution and availability of validation documents
- definition of the approach for getting endorsement of validation from key external users

The PVP contains a definition of the *Round-Robin Protocol* providing a

- description of the method of product inter-comparison and analysis
- definition of the data to be used and their formats
- description of the tasks to be executed and the responsibilities
- schedule for the round-robin activities
- identification of the criteria for selection of the best performing algorithms

Written by: EO Science Team

Commented by: engaged Climate Research Group, CMUG

Formally reviewed by: Key Science Body

Internally approved by: Science Leader

D2.3 Algorithm Theoretical Basis Document (ATBD) version 0

This document is a “light” version of an Algorithm Theoretical Basis Document providing a high level description of the scientific background to an algorithm and a functional description of what the algorithm does.

In particular it defines

- the scope of the problem that the algorithm addresses
- the scientific background
- the mathematical description of the algorithm
- the expected accuracy and performance gains over other algorithms

- the type, amount, format and accuracy of the input data required
- the output data produced by the algorithm
- error budget estimates
- practical considerations for implementation, e.g. exception handling, algorithm validation, numerical computation considerations

Written by: EO Science Team

Commented by: Key Science Body (+1 month)

External access verified by: Project Manager, Key Science Body

Internally approved by: Science Leader

D2.5 Product Validation and Algorithm Selection Report (PVASR)

The *Product Validation and Algorithm Selection Report* describes any analysis done in the round-robin inter-comparison and discusses the results achieved and the algorithm selections made. It contains

- a description of the protocols, methods, reference data sets and tools used to scientifically assess and inter-compare the performance of the prototype algorithms and to validate the resulting products
- a comparison of the results from the various algorithmic approaches in terms of geophysical consistency and accuracy,
- a statistical analysis of the retrieval errors,
- a discussion of the similarities, differences, problems and limitations of the tested algorithms
- identification of all the algorithm(s) to be implemented for all relevant steps and contributing missions.

Written by: EO Science Team with contributions from external round-robin participants

Formally reviewed by: participants in the round-robin managed by the Science Leader (+1 month)

Internally approved by: EO Science Team

D2.6 Algorithm Theoretical Basis Document (ATBD) version 1

The *Algorithm Theoretical Basis Document* provides a detailed description of the scientific background and theoretical justification for the algorithm developed and implemented. It includes

- a description of the physics of the problem
- a definition of the scope of the algorithm
- a detailed mathematical description of the algorithm including error budget estimates
- the assumptions made for the design of the algorithm, and its limitations
- a definition of the input data required and the outputs generated
- an analysis of the computation resources needed
- practical considerations for algorithm test and validation, quality control and diagnostics,
- approaches for exception handling.

Written by: EO Science Team,

Commented by: System Engineers
Internally approved by: EO Science Team

D2.7 Detailed Processing Model (DPM) version 1

The *Detailed Processing Model* provides a compact and informal but structured high-level description of the computer programming algorithms. The document shall provide an environment-independent description of

- the key principles of the algorithm
- the top-down decomposition of the software into its components
- a detailed list and description of the variables used in the mathematical equations
- the computer program in pseudo-code.

Written by: EO Science Team
Commented by: System Engineers
Internally approved by: EO Science Team

D2.8 Input/Output Data Definition Document (IODD) version 1

The *Input/Output Data Definition Document* provides a complete list and a detailed technical description of all data products used for and generated by the prototype processing system.

It shall describe the format, structure and data ranges of all

- demanded satellite input data,
- auxiliary files
- generated output products
- test and validation data sets

Written by: EO Science Team
Commented by: System Engineers
Internally approved by: EO Science Team

D3.2 System Prototype Description (SPD)

The *System Prototype Description* provides a high level description of the end-to-end Prototype Production System for the generation of the required ECV data products.

It provides a description of

- the components, functions, interfaces and modules that form the prototype ECV processing system
- the input and output dependencies
- the data flow between the processor components
- the data throughput
- the processing demand in terms of CPU load
- the processing volumes

- the time resources

This document, coupled with the software prototype provides an understanding of the prototype system from a system analysis perspective.

Written by: EO Science Team

D3.3 System Verification Report (SVR)

The *System Verification Report* gives a complete report of all activities executed and the results achieved form a technical assessment of the end-to-end prototype system with all its subcomponents to verify that the prototype is compliant to the requirements (PSD) and technical specifications (IODD, DPM) and that it fulfils its intended purpose and replicates the results of the algorithms selected through the round-robin.

It includes

- a description of the objectives and scope of the processor
- a list of all elements and components of the prototype that have been tested including a description of the platform, the network, and the interfaces with other systems
- a description of all test activities carried out and of the criteria on how the prototype was tested to ensure that the requirements are fulfilled and that the system performs as specified
- a summary description of all test cases, test procedures, and test data used
- a record of all test results
- a description of all acceptable and stated limitations in the prototype system and the steps taken to workaround anomalous, inappropriate, or undesired operating conditions.

Written by: EO Science Team

D3.5 Product User Guide (PUG)

The *Product User Guide* describes the FCDR and ECV data products in a manner that is understood by the eventual product user.

This shall include a description of

- the geophysical data product content
- the product flags and metadata
- the data format
- the product grid and geographic projection
- known limitations of the product
- available software tools for decoding and interpreting the data.

Written by: EO Science Team

Commented by: CMUG

Formally reviewed by: engaged Climate Research Group

D3.7 ATBD version 2

See D2.6

D3.8 DPM version 2

See D2.7

D3.9 IODD version 2

See D2.8

D4.1 Product Validation and Inter-comparison Report (PVIR)

The *Product Validation and Inter-comparison Report* gives a complete report of the activities executed to assessment of the quality of the generated ECV prototype products and the results achieved.

The document includes

- a description of all in situ observations used for product validation
- a description of all alternative products from other initiatives used for product inter-comparison
- a description of the quality control procedures applied for the selection of the most appropriate validation data and a characterisation of the errors and biases associated to them
- a detailed analysis of the uncertainty associated to the independent validation data
- a description of the match-up analyses performed on the derived ECV products against the selected spatially and temporally coincident in situ observations
- a detailed analysis of the uncertainty of the ECV products with reference to the independent validation data.
- recommendations for fixing errors and/or improving the overall product quality

Written by: EO Science Team

Commented by: validation and inter-comparison data providers

Formally reviewed by: Key Science Body

Internally approved by: Science Leader

D4.2 Climate Assessment Report (CAR)

The *Climate Assessment Report* describes:

- the feedback of users on the delivered ECV data products in respect of the behaviour globally and regionally of the time series of ECV data.
- includes a comparison against standard measures of circulation patterns e.g. El Nino Southern Oscillation (ENSO).
- the comparison against outputs from other ECV projects.

For ECVs where models are used:

- assessment of the contribution to the improvement of model performance with reference to the representation of observations based on current climate
- the approaches used to introduce the ECV products into the models
- any required model developments
- where changes in the model have been made the impact of such changes on the model outputs independent of the ECV products.
- comparison of the model with and without the ECV product
- the comprehensive error analysis derived through confrontation of the models and ECV products taking into account the inherent errors and uncertainty expressed in the URD, PSD and PVIR.

Written by: engaged Climate Research Group

Commented by: CMUG and the other related ECV producers, EO Science Team

Formally reviewed by: submission to internationally recognised peer-reviewed scientific journal

D5.1 System Requirements Document (SRD)

The *System Requirements Document* is a complete, structured collection of individual requirements of the operational ECV production system from a user's point of view.

It shall include

- a description of the scope and the context of the system
- descriptive operational scenarios for the system
- Specification of key parameters that define the required system size, complexity and growth
- a specification of the number, type and qualification of users/operators and the nature of their use of the system
- a complete list of functional, operational, reliability, maintainability, verification, quality and documentation requirements
- detailed requirements for the processing functions, input-output data sets, resource requirements including disk and memory storage volumes,
- archiving requirements (baseline data and interim products and outputs and their safeguarding to allow for reprocessing)
- processing speed and performance requirements
- requirements for modularisation to allow for algorithm improvement or algorithm change while minimising reprocessing temporal constraints, any fundamental interdependencies with other systems, e.g. hosting platform or infrastructure.

Written by: System Engineers

Commented by: EO Science Team

D5.2 System Specification Document (SSD Version 0)

The *System Specification Document* incorporates the requirements described in the System Requirements Document and specifies the characteristics of an operational ECV production system from a developer's point of view.

It shall include

- a specification of the purpose of an operational ECV production system and its intended use
- an overview of the context of the system, defining all significant interfaces among system components and crossing the system's boundaries
- a definition of the fundamental operations to be performed within the system to accept and process the inputs and to process and generate the outputs
- a description of major constraints of the system
- a description of operational scenarios for the system including data sources, valid ranges of values, timing considerations, operator requirements, and special interfaces
- specification of the environmental characteristics of where the system will be installed
- specification of the growth, expansion, and capability characteristics of the system.
- description of the life cycle sustainment activities to be executed during the life cycle of the system
- a trade-off analysis of different technical solutions for a system concept taking into the account the requirements in the SRD, the prototype development described in the SPD and cost, performance, and operational constraints

Written by: System Engineers

Commented by: EO Science Team

D5.3 System Specification Document (SSD Version 1)

This document is an update of D5.2 to take into account developments in the course of the project. This includes:

- improvements in technology, throughput capacity, storage capacity and read-write exchanges
- improvements in processing flow
- improvements or changes in algorithmic approaches as the prototype system evolves.
- availability of more consistent ancillary data

Written by: System Engineers

Commented by: EO Science Team