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1 CCI PROGRAMME OVERVIEW

1.1 Scope

This document presents the status of the ESA Climate Change Initiative (formally referred to as the "Global Monitoring of Essential Climate Variables Element of the European Earthwatch Programme") as of September 2012. This is a public version of the official report submitted to ESA member states as part of the programme mid-term review in September 2012. The plan for implementing the next (3-year) phase of the programme will be based on the outcome of this review.

The intended audience for this document includes all participants and stakeholders in the CCI programme, the individual project teams, their international partners and cooperating projects, as well as other Space Agencies, research programmes and projects that are also contributing to the Global Climate Observing System.

1.2 Programme Objectives and Status

The programme objective 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).***
>
> *It 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.*
>
> *Its essential feature 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.*

To meet these objectives, the programme is being coordinated within the framework for international cooperation between Space Agencies and the climate community, i.e. the Global Climate Observing System (GCOS) and the Committee on Earth Observation Satellites (CEOS).

In particular, the latest GCOS implementation plan with its satellite supplement is taken as the primary source of requirements, and the CEOS Response to GCOS

provides the overall framework for international cooperation. The programme has already enabled ESA and European scientists to contribute significantly to coordinated international action on Climate Observations from Space.

The programme was approved by ESA Member States at the Ministerial council in November 2008, and programme implementation started in January 2009. From a total of 21 ECVs falling within its scope, a reduced number of ECVs were prioritized for action at the start of the programme, to match available programme resources.

A series of ten parallel three-year projects were awarded in 2010 to ten specialist teams. Each project brings together leading research and industry experts from ESA Member States to work on a given ECV. A Climate Modelling User Group (CMUG) project was awarded in March 2010, to provide a common gateway for all CCI teams to the international climate modelling community. A further three ECV projects were started in January 2012, when additional resources became available via the ESA Strategic Initiative.

Thus, within phase 1 of the programme, a total of fourteen three-year CCI projects have been started. Thirteen are addressing the following ECVs, and one is providing the working-level interface to the climate modelling community:

- Cloud Properties; Greenhouse Gases; Ozone; Aerosol Properties
- Sea Surface Temperature; Sea Level; Sea Ice; Ocean Colour
- Glaciers and Ice Caps; Ice Sheets; Land Cover; Fire; Soil Moisture

Coordination and scientific exchanges between these teams is assured by a series of internal programme-level mechanisms. Cooperation with international partners and projects is similarly assured at project level, through established international scientific working groups and forums.

To ensure openness and traceability, as specifically called for by GCOS and WCRP, all CCI teams make their project documentation publicly available on their respective project web sites: http://www.esa-cci.org

To promote free and open access to climate data records, all ECV data products generated within CCI will be made freely accessible, on-line, with associated documents and metadata.

1.2.1 Scientific Advice for the Programme

A dedicated Climate Science Advisory Body (CSAB) was established for CCI in 2009, to provide independent expert scientific advice at the level of the programme, and to assure high-level scientific liaison with GCOS and the climate research community. CSAB has convened three times (~annually) to date, and its advice has been reported to the Earth Observation Programme Board (PBEO) to inform their decisions during programme implementation. The ESA Earth Science Advisory Committee (ESAC) has also been kept regularly informed, its advice sought and reported to PBEO. The combined expert guidance of CSAB and ESAC has proven

vital for programme implementation, keeping the ESA executive authoritatively informed of the evolving state-of-art, user needs and expectations of the international earth science and climate research communities.

The major recommendation from both ESAC and CSAB, namely that the programme should be implemented in an integrated manner and enable project teams to work together across different disciplines, to address the inter-dependencies of the ECVs and thereby deliver scientifically consistent data products, has had significant beneficial influence on the programme organization.

At its third meeting on May 12th 2012, CSAB received an up to date briefing on the status of the programme. This focussed on the ECV products from phase 1 of the programme, the associated improvements over state-of-the art, and some early science results. This was positively received by CSAB who provided clear guidance on the medium and long-term evolution of the programme.

The CSAB advice from its third meeting is attached in Annex 1.

1.3 Phase 1 Projects Status

1.3.1 Climate Modelling User Group (CMUG Project)

The "Climate Modelling User Group" project was set-up to put the integrated climate perspective recommended by CSAB and ESAC into practise. CMUG interacts directly with all ECV project teams and acts as a central gateway to the international climate modelling community. The CMUG project was set up before the other ECV projects started, and its first activity was a user consultation on the specific needs of the climate modelling community, which covered the first ECVs addressed. This established a unified climate perspective, from the outset of the programme. CMUG has subsequently reviewed and provided collective feedback on the product specifications of all ECV teams. CMUG will confront the ECV data products delivered by all ECV projects with global and regional climate models, with climate re-analysis data, and will provide coherent feedback across all ECV projects. CMUG thus ensures a critical capability for independent assessment and user feedback, from a climate system perspective, throughout the programme.

1.3.2 ECV Projects

During the first phase of the programme, all ECV projects have been addressing the following cardinal requirements, derived from the programme objectives, for their specific ECV:

- *Develop and validate algorithms to meet GCOS ECV requirements for (consistent, stable, error-characterized) global satellite data products from multi-sensor data archives*
- *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 modeling*

- *Optimize the impact of ESA EO missions data on climate data records*
- *Generate complete specifications for an operational production system*
- *Strengthen inter-disciplinary cooperation between international earth observation, climate research and modeling communities, in pursuit of scientific excellence*

To achieve this all projects are executing a set of standard tasks, as listed below. Each team adapts the scope and schedule of these tasks to suit the needs of their particular ECV:

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

Each ECV project team will deliver two major data sets during their phase 1 projects:

- A Round Robin Data Package: *test data set for inter-comparing and evaluating different candidate algorithms for processing their ECV.*
- Climate Research Data Package: *The global data products generated with the selected algorithms for each ECV.*

All CCI teams deliver a standard set of scientific, technical and system reports that document information needed by co-workers and users, which then form the basis for progress reviews with the Agency, and establish specifications for the next phase of the programme. The ECV projects that started in 2010 have progressed consistently towards their project objectives and maintained their schedules and quality of deliverables, with only minor deviations. Each team has by now completed a comprehensive user requirements analysis and has specified a set of global data products to meet these requirements. Throughout the last 18-24 months they have been assembling the global input EO data sets (mostly Level 1B or Level 2) needed for production and arranged access to the in-situ and re-analysis data needed for validation.

At this the stage of the programme, most teams have completed a major 'round-robin' algorithm inter-comparison exercise. This puts them in a position to make a well-informed assessment of the extent to which their final ECV data products will satisfy the user requirements, and the improvements they expect to achieve, compared to already existing data sets.

Such improvements, although specific to each ECV, fall into general categories:

- *Improved internal consistency* within individual ECV products.
- *Improved consistency* between different ECV products.
- *Extended temporal coverage* of decadal ECV data records derived from multiple-sensors via harmonized retrieval schemes, algorithms and

reference data applied to all sensors.

- *More complete geographic coverage* for specific ECVs, by use of algorithms adapted for dealing with various observation conditions (e.g. cloud-clearing, glitter).
- *Product content better adapted* to the needs of specific climate research communities (e.g. climate modellers).
- *Improved characterization of uncertainties* of the observed climate variables.
- *Unique* new data sets of quality not previously available.

1.3.3 Interaction between CCI Project Teams

Acting upon the CSAB and ESAC recommendations, a range of mechanisms have been put in place to facilitate cooperation and information exchange between project teams on issues of common interest:

- **CCI Collocation Meetings**: *Annual, 3-days duration, 3-5 participants per team (total ~70), organized by ESA, discussions on scientific, technical, system and organizational issues of common interest to all teams.*
- **CMUG Integration Meetings**: *Annual, 3-days duration, 2-3 participants from each team, organized by CMUG, to foster broad dialogue on confronting climate observations, models, re-analysis and the impact of ECV products.*
- **Data Standards Working Group:** *Coordinated by ESA; one representative from each project; quarterly teleconferences; on-line wiki; discussions via a dedicated mailing list; annual sessions at collocation.*
- **System Engineering Working Group:** *Bi-monthly teleconferences; one representative from each project; annual session at collocation; shares information on prototype ECV production systems, system engineering issues and system requirements.*
- **Cross-team participation to project progress meetings**: *Ad-hoc basis, most frequent is CMUG participant to ECV project reviews.*
- **Inter-project workshops**: *Ad-hoc basis; organized bi-laterally between teams, e.g. Cloud-Aerosol algorithm workshop.*
- **Joint Scientific Publications**: *Initiative of science leaders: e.g. Joint BAMs paper on CCI (co-authorship from all 14 teams), Preparation of a journal special issue on CCI Round Robin Results.*

CCI project teams have interacted with the Quality Working Groups for the ESA Missions, to ensure coherence with work on Calibration/Validation and re-processing in the ground segment.

1.3.4 Data Standards

A key outcome of the first CCI collocation meeting was the recognition that common data standards are needed for the CCI data products and thus a CCI Data Standards Working Group was formed. Such standards are essential to achieve maximum uptake of the data by users. They define the formats the data are produced in, and

requirements for additional information about the data (metadata). Well-defined data standards are already widely in use within the climate modelling community and CCI aims to adopt them where possible.

The CCI Data Standards Working Group has defined a file format and metadata standard for CCI data products, fixing on netCDF-4 classic format (or netCDF-3 if tools for netCDF-4 are not yet in place) and the CF (Climate and Forecasting) convention for metadata with CF standard names for the main variables. A minimum set of metadata attributes required to describe a CCI dataset has been defined ("CCI Guidelines for Data Producers"). An update is planned for July 2012.

1.4 International Cooperation

1.4.1 Committee on Earth Observing Satellites (CEOS)

CEOS Agencies decided at their 24th plenary meeting, in October 2010, to establish a dedicated working group on climate (WG Climate). Its goal is to facilitate the implementation and exploitation of Essential Climate Variable (ECV) time-series through coordination of activities by CEOS member agencies. ESA strongly advocated the creation of the working group and hosted its first meeting. WGClimate is co-chaired by the European Commission (specifically, the Directorate General of the Joint Research Centre) and NOAA.

The initial activities of WG Climate include: a meta-analysis to identify the current capability for producing ECVs within CEOS agencies; building a link to the IPCC modelling community to facilitate the inter-comparison of model outputs and data; and developing an ECV-by-ECV implementation strategy. Since the CCI is already paving the way on all of these activities within Europe, the ESA executive is cooperating actively in this WG to maximise the impact of ESA and European observations via the CCI, and to ensure a consistent and collaborative contribution from CEOS Agencies to the Global Climate Observing System.

1.4.2 Global Climate Observing System (GCOS)

ESA has maintained close cooperation with the GCOS secretariat and the GCOS scientific committees. ESA staff, and CCI project teams have participated in meetings of related GCOS science panels, while the director of the GCOS secretariat has participated in both CCI collocation meetings and interacted directly with the CCI project teams.

The requirements analysis performed by the CCI teams has generated a wealth of information related to the use of satellite data for a wide range of climate-related applications. A summary report of the overall CCI user requirements analysis was provided to GCOS as feedback from the programme. This documented coordinated feedback from the CCI teams and their users as input for the 2011 update of the GCOS Satellite Supplement. It thus represents a substantial contribution to the international cooperative response by CEOS agencies to GCOS.

1.4.3 Climate Monitoring Architecture

ESA has contributed to the drafting of the "Strategy Towards an Architecture for Climate Monitoring from Space" in a joint team, drawn from CEOS, WMO and CGMS agencies. This describes a high-level strategy for an international architecture that could ensure long-term delivery of climate observations from space. This is a preliminary step towards a physical architecture, for an internationally inclusive end-to-end system. ESA has channelled experience and outputs from CCI into this cooperative activity. The report recognizes CCI is as an example of an “Initial Operational Capability” for delivering ECVs, and cites CMUG as a source of generic requirements related to climate modelling.

1.4.4 Cooperation within Europe

ESA has ensured it is coordinated with European partners and programmes that are also involved in responding to GCOS. Representatives of EUMETSAT, EC participated in the CCI Tender evaluation process and have also attended CCI collocation meetings. These, and other European organizations including ECMWF, contributed to the joint report, ‘European capacity for monitoring and assimilating space based climate change observations’ published by the JRC in 2010. A technical coordination group for climate observations was established between ESA-EUMESAT-EC. This group, along with other European actors, interact frequently with the global coordination framework (CEOS, GEO, GCOS, WMO, WCRP) and meet periodically for specific coordination actions. In this capacity, ESA contributed to the preparation of EU-US dialogue on climate and space in 2011. ESA also participated in preparatory discussions on scoping the GMES Climate Change Service and the Helsinki workshop in June 2011. A seconded JRC staff member was hosted at ESRIN to facilitate close technical coordination.

Close bilateral cooperation has been pursued with EUMESAT on ECVs of relevance for its climate data reprocessing. This is notably the case with regards to the Climate Monitoring Satellite Application Facility (CM SAF) and the Ozone SAF. EUMETSAT is providing several CCI teams with access to reprocessed Fundamental Climate Data Records (FDCR) from its archives. Coordination with the WMO SCOPE-CM (Sustained, coordinated processing of environmental satellite data for climate monitoring) project has also been maintained through participation of ESA members to its technical meetings.

1.4.5 Bilateral cooperation with NASA

In response to a need identified at the user consultation meeting to prepare the *Ice_sheets_cci* project in March 2011, ESA and NASA brought together experts from more than 20 European and US research organizations to discuss differences in the measurements of ice sheet mass balance. This was an ad-hoc, highly demanding and time constrained exercise, to be completed in advance of the publication deadline for the 5th IPCC Assessment Report. In the course of the last year this group compared and combined estimates of ice sheet mass balance using three different satellite geodetic techniques, altimetry (radar and laser), gravimetry and input-output-method (imaging and models), to investigate the extent to which the

different approaches concur and to produce a reconciled estimate of mass balance for the Antarctic and Greenland ice sheets.

1.4.6 Scientific Cooperation at project level

Scientific and technical cooperation between the CCI project teams and relevant national and European funded projects is particularly strong. Each CCI team has put in place effective working links with the related projects. This includes large FP7 climate research projects such as ICE2Sea; Earth system modelling infrastructure projects such as IS-ENES; GMES core service projects such as MACC and MyOcean; climate re-analysis projects such as ERACLIM; as well as projects such as Monarch-A and Cryoland. Many of these projects will be users of the CCI data products and will thus contribute to their assessment, validation and exploitation.

The CCI project teams also benefit from long established cooperation with international science teams outside of Europe, notably USA, Canada and Japan. In most projects this is facilitated via international expert working groups and networks such as OSTWG, IOCCG, GHRSST, WGMS, AERONET, TCCON and the CEOS Virtual constellations

1.5 Programme Promotion and Communication

A series of actions have been undertaken to promote the CCI programme, to highlight the European contribution to Global Climate monitoring from space, and to raise awareness of the benefits for stakeholders in member states and internationally.

- At the outset of the programme ESA made numerous presentations and organized dedicated sessions at international scientific conferences to encourage the widest possible participation and scientific excellence within the programme (eg OceanObs 2009, EGU, AGU).

- ESA co-hosted a series of workshops in cooperation with international partners, in order to facilitate cross-disciplinary scientific cooperation between the CCI teams and relevant international programmes. (eg WOAP workshop on ECVs, MARCDAT III, JCOMM, Carbon from Space Workshop).

- Each of the CCI project teams has presented their project and results at the relevant major international scientific forums, and working groups (e.g. SPARC, WCRP Open Science Conference, Planet under Pressure, IGARSS, Living Planet Symposium).

CCI scientists have already started reporting the initial results of CCI-supported research in the scientific literature. This includes papers in prestigious publications such as Nature, Science and other high impact-factor journals citied in IPCC Assessment Reports.

1.6 Completion of Phase 1

During the coming 6-9 month the teams will start to produce the full set of ECV data products to be generated in phase 1 of the programme and deliver them to their validation partners, the Climate Research Groups, to CMUG and other users who will evaluate and exploit them. A comprehensive assessment of all ECV products from the first ten projects will thus be available by end 2013.

The three additional project teams, who started work in early 2012, have taken advantage of lessons learned from the other teams, established robust project plans and schedules, and are on track to achieve their phase I project objectives within the foreseen three-year time-scale.

1.7 Preliminary Outline of Phase 2

The approach for implementation of second phase of CCI programme will be decided by ESA Member states on the basis of the mid-term progress review being held in September 2012. A preliminary outline for the potential scope of phase 2, follows hereafter, as input for the review.

In line with the overall CCI programme objective, the second phase of the programme should ensure continuity and further development of the actions initiated on ECVs so far, in order to provide the most complete and robust European response possible to the GCOS requirements by the end of the programme

CCI Phase 2 should take into account:

- Publication of 5th IPCC Assessment Report (2014) and the initiation of a sixth Assessment cycle (typically 5-6 years).
- Launch and initial operations and availability of data from of Sentinels 1, 2 and 3.
- Initial implementations of Global Framework for Climate Service and GMES Climate Change Service.

The major activities should:

- Extend the temporal and geographic coverage of the prototype ECV data products, generated in Phase 1.
- Improve their quality and consistency by enhancing the processing algorithms and incorporating data from additional sensors.
- Take steps to bridge the gap in the ECV records, between the end of the ENVISAT mission, and the Sentinel Missions.
- Ensure free, open, unrestricted and easy online data access to the CCI Data products.
- Stimulate widest possible use of the CCI Data products, and enlarge their user base.
- Maximise the scientific impact of exploitation of the CCI data products, in particular via publications in high impact scientific journals.
- Evolve the prototype ECV production systems set-up in phase 1, towards a

more operational and sustainable configuration.

These activities should:

- Build directly on the results of phase 1 projects.
- Continue to be closely coordinated within the GCOS-CEOS-GEO framework for international cooperation, notably with CEOS WG Climate.
- Continue to be closely coordinated with related activities conducted within Europe, in particular: Member States national programmes, EU programmes (GMES, Horizon 2020), and EUMETSAT programmes.

This should deliver, by programme completion:

- An up-to-date, comprehensive, consistent set of climate quality, global ECV data products for the period 1991 – 2016.
- A quasi-operational network of research institutes, data centres and companies capable to re-generate and upgrade the ECV data product.

1.8 Mid Term Programme Review

The **scope** of the mid-term programme review is twofold:

1. Address the status and results of activities carried out so far.
2. Provide an overview of actions for further implementation of the programme.

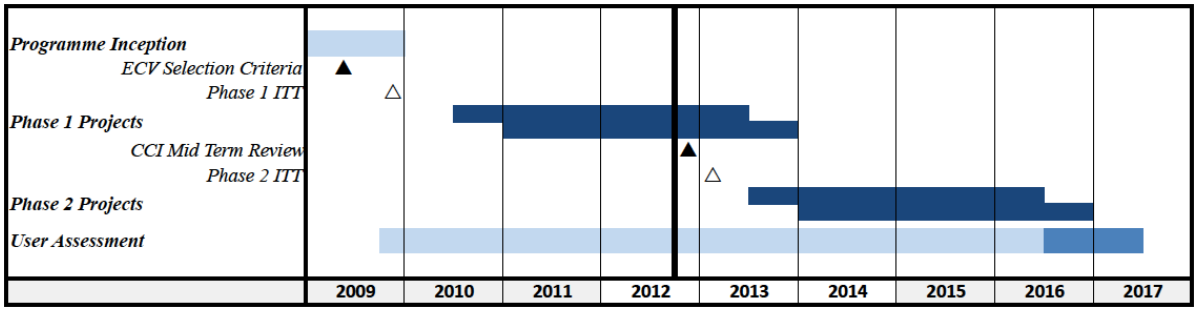
The review will thus address the following **key questions,** derived from the **programme objectives:**

- *Is CCI adequately connected and responsive to the needs of the international climate research programmes and communities?*
- *Is independent scientific advice being adequately sought and factored-in to programme implementation?*
- *Is CCI providing an adequate and timely response to GCOS requirements?*
- *Is CCI sufficiently engaged with GCOS communities and processes?*
- *Is it realising the full potential contribution of ESA and European EO missions to climate records?*
- *Is it capitalising on multi-disciplinary expertise within Europe to achieve scientific impact of the required excellence?*
- *Is it bringing a significant contribution, adequately coordinated with other international actions on Climate Records?*
- *Is there sufficient connection with non-space, in situ observation networks?*
- *Is overall progress adequate for preparing the next stage of the programme and is the approach outlined for the next 3-4 years appropriate?*

The Agenda for the mid-term review workshop is attached in Annex 1.

1.9 Programme Schedule

The master schedule for CCI programme remains as follows:



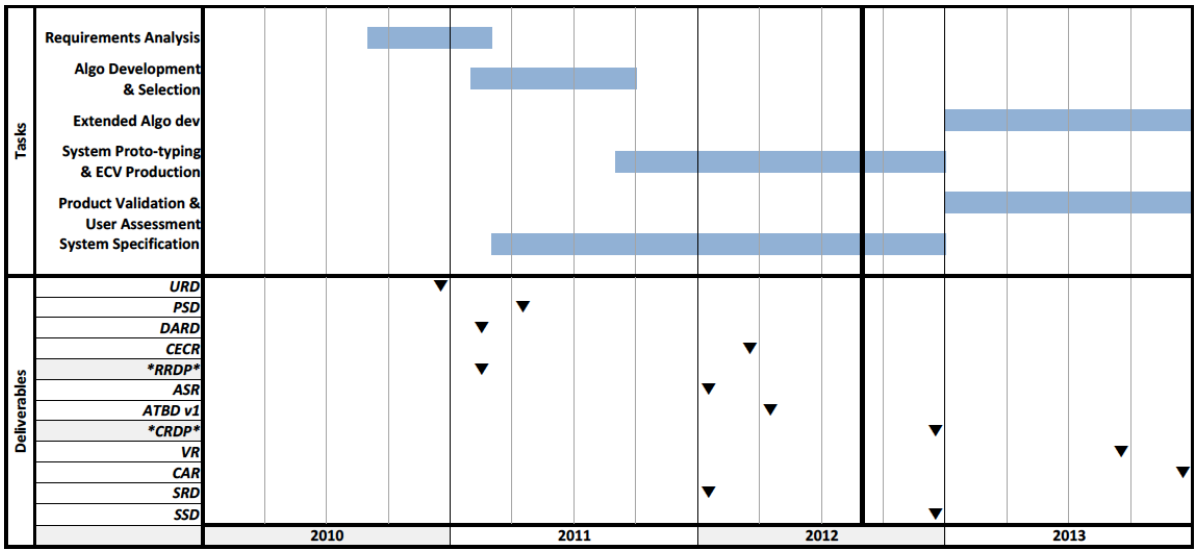
2 CLOUD_CCI *(GCOS A.4)*

2.1 Overall Project Status

Summary of Overall Progress to date

The *Cloud_cci* project combines, for the first time, observations from both European and US missions and instruments for cloud property retrievals. The resulting data products have novel character and applicability that complement existing cloud property datasets. The project has progressed according to schedule and plan. Two optimal estimation schemes have been selected and further developed as result of the round robin exercise. The implementation of corresponding prototype processors has been the main focus recently. Large efforts have gone into improving the algorithms, making them generic for different sensors, and preparing them for an operational environment on different platforms. The project work plan has been revised to recover a 3-4 month delay in data access.

Overall Schedule



Team Composition

Prime Contractor/ Scientific Lead	DWD - (Germany)
Project Management	DWD - (Germany)
EO Science Team Algorithm Development	RAL - (**lead**), (United Kingdom) Univ. Oxford - (United Kingdom) FUB - (Germany) Univ. Bremen - (Germany) Univ. Valencia - (Spain)

	DWD - (Germany), KNMI - (The Netherlands) SMHI - (Sweden)
EO Science Team Validation	DWD - (**lead**), (Germany) DLR - (Germany) MeteoSwiss - (Switzerland) – Since June 2012.
Climate Research Group	SMHI - (**lead**), (Sweden) CNRS-LMD - (France) ETH, (Switzerland).
System Engineering Team	DWD - (**lead**) (Germany) FUB - (Germany) RAL - (United Kingdom)

2.2 Requirements Analysis and Product Specification

User Consultation

The user requirement analysis mainly builds on GCOS's requirements from 2006. Furthermore, the collected requirements of WMO and those of WCRP, CMUG and the *Cloud_cci* climate research group were considered. All CCI project teams were contacted and corresponding across-ECV requirements inferred. The *Cloud_cci* products specification were directly derived from these requirements, also considering the capabilities of the available EO missions, aiming to close the gap between the requirements of the scientific community and the existing state-of-the-art cloud property datasets.

International Scientific coordination

The project requirements analysis and product definition documents were reviewed and endorsed by international experts (e.g. from the MODIS team, ISCCP, NOAA-NCDC, GDAP co-chair). Colleagues from NOAA/NESDIS/STAR participated in the Round Robin exercise. The algorithms were assessed in the EUMETSAT Cloud Retrieval Evaluation Workshop (CREW), which provided guidance and established methods for interpretation of the results. A strong interaction is taking place with EUMETSAT's CM SAF, also currently releasing cloud data sets. This helped to improve knowledge on AVHRR cloud products. The team participated actively to the 2011 update of GCOS satellite supplement review as well as in the WOAP workshop of ECVs.

Interactions (workshop participation, exchange of data) with the *Aerosol_cci* team lead to joint work packages. During user consultation all CCI project teams provided feedback. CMUG interacted actively with *Cloud_cci* on the detailed definition of products and intended use for global climate modelling. Following intense discussions, *Cloud_cci* agreed to provide Level 2 data for climate model inter-comparison, i.e. process studies. The project was presented at the following

conferences: IRS 2012, WCRP 2011, EGU 2010-2012, EUMETSAT 2012, and ATMOS 2012.

ECV products description

The *Cloud_cci* data products provide multiple derived cloud properties: Cloud mask (for low, mid, high clouds); cloud-top parameters (pressure, height, and temperature); microphysical properties (optical depth, effective radius) and subsequently derived cloud water paths (for water and ice clouds); and combined products (ISCCP-like histograms). Two cloud property product families are defined, with respect to the satellites used:

- The AVHRR-heritage product family, which is based on the cloud parameter retrieval results from AATSR (on-board ENVISAT), MODIS (on-board AQUA and TERRA), and AVHRR (on-board NOAA-15, NOAA-16, NOAA-17, NOAA-18, and MetOp). The inter-sensor retrieval consistency of the data is ensured by the application of an optimal-estimation based retrieval scheme and the limitation to the AVHRR-heritage channels of each considered instrument.
- The second product family is based on the cloud parameter retrieval results from a synergetic retrieval system applied to spatially-collocated AATSR and MERIS (both onboard ENVISAT) measurements. This novel approach makes it feasible to fully exploit the synergetic character of two different instruments on-board the same platform.

These are characterized by a set of technical specifications (see table below) of temporal and spatial resolution, temporal and spatial coverage, sensor (sensor group) and an error estimation for each footprint (level 2 data) and grid box (level 3 data).

The technical specifications derive from the user requirements, which focus on climate research and on combining data from European and US sensors.

ECV Product Name: CCI Cloud						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Cloud cover (high/mid/low-level) Cloud top pressure/height /temperature Effective radius Cloud optical thickness Liquid water path Ice water path	AATSR MODIS AVHRR MERIS & AATSR	Global	L2: swath based, L2b: 10x10km, L3a,b,c: 50x50km	2007-2009	L2, L2P, L3U, C, S	168 TB 48 GB
Explanatory text: All products are available at processing levels: 2, 2P, 3, U, C, S (according to CCI DS-WG, see ESA CCI Filenaming Convention Draft v2.1)						

The level 2 products include: a quality indicator, time of observation, surface type, missing data flag, aerosol flag, multi-layer cloud flag, and further auxiliary information as used for the 1D-Var. In addition to the arithmetic mean of the variable forming the level 3 products, the following information about the set of observations used to create the mean is given per grid box: number, standard deviation and higher moments about the set.

2.3 Algorithm Development, Intercomparison and Selection

Results of Round Robin inter-comparison

Various state-of-the-art cloud property retrieval schemes were applied to consistent radiance datasets for the Round Robin inter-comparison. The corresponding results were collocated to A-Train reference observations, validated and inter-compared.

As a result, two retrieval schemes were selected as a basis for developing community retrieval schemes: 1) ORAC, for the heritage product of AVHRR, MODIS, AATSR and 2) FAME-C, for the synergetic approach for AATSR+MERIS. Both selected schemes showed the largest potential to meet the user requirements. They are optimal-estimation based, thus can retrieve cloud parameters and error margins simultaneously.

The documented results of this exercise include a detailed analysis and a list of potential further developments. This has guided further development of the community schemes and their implementation in the prototype processor chains. They will furthermore be basis for development of advanced retrieval component in the 3rd year of the project.

Expected Product Improvements

The *Cloud_cci* multi-annual cloud properties products have particular strengths in spectral consistency, uncertainty characterization, and increased temporal resolution. This complements already existing cloud climatologies (ISCCP, MODIS, CLARA-GAC, Patmos-X). The two community retrieval schemes will provide a framework for application to multi-decadal measurement records of passive satellite imagers. They will form a unique and easy way to be prepared for future (or other existing) satellite instruments and missions.

2.4 System Proto-typing and ECV Production

Data Gathering and Data Quality

The main satellite input data sets are AVHRR, MODIS collection 6, AATSR and MERIS radiance and geo-location information for 2007-2009. The MODIS collection 6 (superior quality) was not available until July 2012, resulting in a delay

in products. All other non-European and European satellite data were available in time. Team members from the AATSR and MERIS quality working groups (QWG) attended QWG meetings and reported to consortia on the status of AATSR and MERIS calibration. Thus a close link was established with these calibration groups feeding back *Cloud_cci* calibration results.

Product Generation

The *Cloud_cci* team has implemented advanced prototype processors on high performance computer facilities located at FUB, RAL and ECMWF. A particular challenge for this project is the use the computationally expensive OE-retrieval approach. Here, large efforts have gone into optimizing the code, making the code generic for different sensors, and preparing the code for an operational environment on different platforms. Numerous processing optimizations are being implemented to achieve this within the second year of the project.

2.5 Product Validation and User Assessment

Product Validation (plans)

Product validation will rely on the active satellite sensors (i.e. Cloudsat and CALIOP) as a reference for all cloud products. Data from ground-based networks (e.g. ARM programme, CloudNet, and basic SYNOP observations) will also be used. To complement this, the products are also embedded in the GEWEX cloud assessment framework.

Uncertainty Characterization

One outcome of the GEWEX cloud assessment and further international activities (e.g. the CREW workshops) is that the characterization of the uncertainty for cloud properties remains a major challenge in the coming years.

The *Cloud_cci* uncertainty characterization document identifies 3 categories:

- Uncertainty due assuming a plane parallel single layer homogeneous cloud model
- Uncertainty in the evaluation of the Forward Model
- Uncertainty in the instrument

The type of error (e.g. systematic or random) and its impact (small -> large) are also characterized. The techniques used to evaluate the uncertainty are varied; it is done either by propagation through the model, evaluation performing simulations and sensitivity studies, or by evaluation by compositing. Based on this, pixel level uncertainties are provided for the *Cloud_cci* end products, within the level-2 files.

ECV Data Access and exploitation

It is planned to make the data available via ftp through the ESA CCI website. The data availability will be announced through a newsletter, website and dedicated presentations. It is planned to provide access to the data already in an early stage

during validation in order to be able to get a feedback from the user perspective. Potential external users have already contacted *Cloud_cci*. During the third year the Climate Research group will use the products for evaluating EC-Earth global coupled climate simulations and Arctic climate simulations using the Regional Climate Model RCA. For this, they plan to use the satellite data to investigate the benefits of increased model resolution for cloud simulation using EC-Earth Atmosphere only experiments. This user feedback will lead to specific updates of the prototype towards the end of CCI phase 1 and will therefore support the production of the long-term datasets during CCI phase 2.

2.6 System Specification

The prototype system is based on three distributed sub-systems. These H/W components are either based on super-computing system (e.g. IBM6) or on multi-processor Linux systems.

For the heritage processing system, the major SW components consist of the optimal estimation scheme (ORAC heritage since 10 years) and the pre-processing and post-processing developed for MODIS and AVHRR channels.

For the AATSR-MERIS processing chain, the FAME-C retrieval software is made up of three consecutive steps, namely the synergy pre-processing (heritage from the ESA's SYNERGY project) consisting of merging AATSR and MERIS L1b files and performing the cloud detection, the cloud microphysical retrieval (DCOMP) and cloud height retrieval (new development).

The DCOMP microphysical retrieval, operating on AATSR data, is a heritage retrieval algorithm developed for GOES-AB, AVHRR. The nature of optimal estimation code means that the computational requirements are significant. However, the benefits of the scheme outweigh this cost. Computational requirements should become less significant in the future. The *Cloud_cci* processing system is well set up for phase 2.

2.7 Plan to complete Phase 1

With the generation of the final datasets for AVHRR/MODIS/AATSR and AATSR+MERIS the key task will be conducted in the coming months. This will be accompanied by documentation of the products, their evaluation, the provision of the datasets to the user group, user feedback and analysis. Additional advanced retrieval components and further improvements on inter-calibration approaches will be developed in parallel in preparation for CCI phase 2.

2.8 General comments/feedback to ESA

The CCI programme helped the team bundle European efforts in cloud retrieval development by setting up a community framework for an optimal estimation based

scheme. A specific advantage of the programme is the focus on scientific outcome; however the time for scientific exploitation of the datasets by the project teams could be extended. The exploitation by the CCI teams themselves is considered to be crucial for providing improved dataset characteristics, e.g. uncertainty, stability, applicability. Crosscutting and inter-ECV work has helped and should be emphasized and included. The CCI programme is an important international effort supporting a better analysis of geophysical parameters and their interactions, which will lead to better understanding of the Earth's climate.

2.9 Relevant Scientific Publications

Stengel M. et al., 2012: The assessment of state-of-art cloud property retrieval systems applied to AVHRR heritage measurements. Rem Sens Env - Special Issue CCI (in preparation)

Merchant C. J. et al, 2012: Selecting Algorithms for Earth Observation of Climate: Lessons Learned within the ESA Climate Change Initiative. Rem Sens Env - Special Issue CCI (in preparation, with *Cloud_cci* contributions).

Two more CCI publications on Level 1 inter-calibration work are currently in preparation.

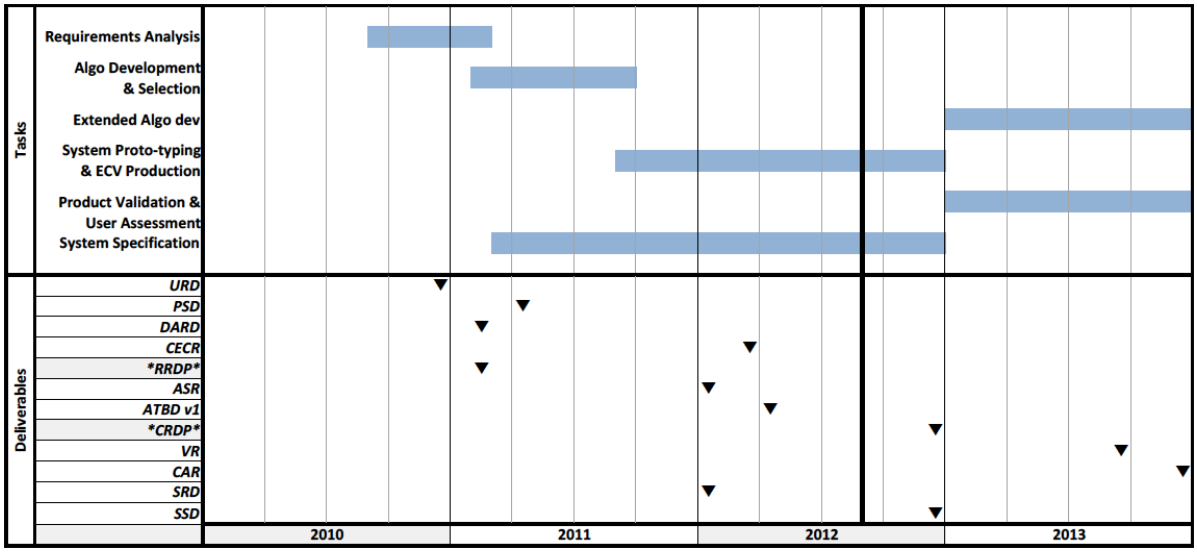
3 OZONE_CCI *(GCOS A.7)*

3.1 Overall Project Status

Summary of Overall Progress to date

The *Ozone_cci* project has made significant advances towards the generation of improved and thoroughly characterized ozone data products derived from a suite of European nadir and limb-type sensors. In particular, new harmonized level-2 nadir retrieval algorithms have been designed for application to GOME, SCIAMACHY and GOME-2 instruments. A resulting major achievement will be the full reprocessing of the European total column ozone CDR (1995-2011). Another achievement results from the MIPAS/ENVISAT Round-Robin, where new algorithm ensemble and data merging approaches are being demonstrated for the generation of high-resolution vertical profiles of ozone.

Overall Schedule



Team Composition

Prime Contractor/ Scientific Lead	(BIRA-IASB) - (Belgium)
Project Management	(BIRA-IASB) - (Belgium)
EO Science Team 1	DLR-IMF - (**lead**) (Germany) BIRA-IASB (Belgium) RT-Solutions (External Service)
EO Science Team 2	KNMI - (**lead**) (The Netherlands) RAL (United Kingdom)
EO Science Team 3	IUP-Bremen - (**lead**) (Germany) FMI, KIT, LATMOS, U. Saskatchewan, U. York, Chalmers

	Inst. Tech. Associated (QWG): ISAC-CNR, IFAC-CNR, LISA, U. Oxford, U. Leicester
Validation Team	(BIRA-IASB) (**lead**) (Belgium) AUTH, KMI-IRM, LATMOS, MeteoSwiss, Univ. Athens
Climate Research Group	DLR-PA - (**lead**) (Germany) KNMI, UCAM
System Engineering Team	DLR-DFD -(**lead**) (Germany) KNMI - (The Netherlands)

3.2 Requirements Analysis and Product Specification

User Consultation

Key members of the international climate-chemistry modelling community, through initiatives such as CCMVal (Chemistry-Climate Model Validation) and SPARC (Stratospheric Processes And their Role in Climate) contributed to the definition of the user requirements for ozone. Also the CMUG climate modelling group was consulted. The most important user requirements for *Ozone_cci* are (1) Homogenized multi-decadal records, (2) Records with good vertical resolution in the (lower) stratosphere, and (3) Records with good horizontal resolution in the troposphere. The main gap with the user requirements is the lack of multi-decadal high-vertical resolution ozone profile data sets that cover the full ozone depletion time period (1980-present) and will be possible to extend into the upcoming ozone recovery time period.

International Scientific coordination

The *Ozone_cci* team members are strongly involved in international collaborative activities on stratospheric and tropospheric chemistry and their links with climate. They contribute to the WCRP core project SPARC, for example as part of the CCMVal activity which aims to evaluate Chemistry Climate models against observations, and they are connected to major international programmes such as IOC, and IGACO-O3. They are also active in ground-based networks such WMO-GAW-NDACC and in various satellite-related committees (O3MSAF, ENVISAT QWGs and SAGs, S5/S4/S5P Mission Advisory Groups, etc.). *Ozone_cci* is strongly involved in the joint SPARC-IOC-IGACO-NDACC (SI2N) initiative to assess the current knowledge and of the vertical distribution of ozone, with the aim of providing input to the next WMO Scientific Assessment of Ozone Depletion anticipated for 2014. In this context it collaborates with the whole international ozone community, including NASA and NOAA. It also interacts with non-European agencies through participation to the CEOS Atmospheric Chemistry Constellation (ACC). The achievements of the *Ozone_cci* project have been presented at several major conferences such as the recent Planet under Pressure, London, UK and ESA ATMOS 2012, Bruges, Belgium. They will also be presented at the upcoming Quadrennial Ozone Symposium, Toronto, Canada.

ECV products description

Ozone_cci ECV products are summarized in the tables below. They correspond to three distinct families of data products: total ozone, ozone vertical profiles from nadir-viewing instruments, and ozone vertical profiles from limb and occultation-types of sensors. The main application is to derive information on the ozone variability and trends at various spatial and temporal scales and in different altitude regions. Ozone products are also used as an input in NWP models to constrain atmospheric dynamics. Developments concentrate on (1) the improvement and harmonization of level 2 retrieval algorithms for nadir sensors, (2) systematic data characterization and error analysis, (3) the design of new data merging techniques optimized for each type of ozone data product.

ECV Product Name: Total Ozone						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal Resolution †)**	**Total Data Volume #)**
Ozone total column	GOME	Global *)	320x40 km2	1995-2011	3 days	75 GB
	SCIAMACHY	Global	60x30 km2	2002-2011	6 days	90 GB
	GOME2	Global	80x40 km2	2007-2011	1-2 days	90 GB
	Merged level-3 product	Global	1°x1° (lat-long)	1995-2011	Monthly	3 GB
Explanatory text: Product: Ozone vertical column density in DU Product level: Level 2 (individual sensors), Level 3 (merged data set) Main applications: long-term changes, climatology and multi-scale variability, assimilation in NWP models Remarks: *) No global coverage since June 2003; †) Time needed to reach global coverage; #) Rough estimate of total size						

ECV Product Name: Nadir Ozone Profile						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume $)**
Ozone vertical distribution *)	GOME	Global	960x80 km2	1997	3 days	10 GB
	SCIAMACHY	Global	State dependent	2007-2008	6 days	20 GB
	OMI	Global	60 x 50 km2	2007-2008	1 day	120 GB
	GOME2	Global	80 x 80 km2	2007-2008	1-2 days	100 GB
	Merged level-3 product	Global	1°x1° (lat-long)	1997 / 2007-2008	Monthly	6 GB
	Assimilated level-4 product	Global	1°x1.5°	1997 / 2007-2008	6 hours	200 GB
Explanatory text: Product: Ozone vertical profile in units of number density, partial column or volume mixing ratio Product level: Level 2 (individual sensors), Level 3 (gridded merged data set), Level 4 (assimilated product) Main applications: height dependence of the evolution of the ozone layer, tropospheric ozone, radiative forcing, assimilation in NWP models Remarks: *) Vertical resolution of approximately 3-5 km depending on altitude in 0-65 km altitude range; †) Rough estimate						

ECV Product Name: Limb Ozone Profile						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid †)**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume #)**
Ozone vertical distribution *)	SCIAMACHY	Global	N/A	2002-2011	6 days	20 GB
	MIPAS	Global	N/A	2007-2008	3 days	100 GB
	GOMOS	Global	N/A	2002-2011	1-2 days	130 GB
	OSIRIS	Global	N/A	2001-2011	1 day	5 GB
	SMR	Global	N/A	2001-2011	1 day	5 GB
	ACE	Global	N/A	2004-2011	Several months	< 1 GB
	Merged data product	Global	N/A	2007-2008	Monthly	< 1 GB

Explanatory text:
Product: Ozone vertical profile in units of number density and/or volume mixing ratio
Product level: Level 3
Main applications: vertically-resolved trends in the lower and mid- stratosphere, radiative forcing, assimilation in NWP models
Remarks:
*) vertical resolution of approximately 2-4 km in the stratosphere for a typical altitude range of 10-70 km;
†) the natural horizontal resolution for limb/occultation geometry is approximately 10°x20° (lat-long);
#) rough estimate (upper limit) based on size of corresponding Level 2 products

3.3 Algorithm Development, Inter-comparison, Selection

Results of Round Robin inter-comparison

A major *Ozone_cci* activity addresses the development of state-of-the-art harmonized level 2 algorithms for nadir sensors. For total ozone, a new direct-fitting baseline has been successfully implemented on GOME, SCIAMACHY and GOME-2 and is being applied for a full reprocessing of the 1995-2011 time series. For nadir ozone profiles three algorithms are being tested in the Round Robin inter-comparison: the KNMI-OPERA, RAL- and the combined OPERA-RAL algorithms. Ancillary data have been homogenized for the three algorithms and a common ground pixel binning strategy has been developed to reach an optimum between calculation time and resolution. The datasets from single algorithms have been processed for evaluation by the validation team and an initial version of the combined OPERA-RAL scheme has been implemented at RAL. Concerning the MIPAS RR, the initial selection among four competing algorithms has evolved towards the adoption of an ensemble approach combining all data set in an optimal merged data product. Also here initial data sets have been generated for evaluation by validation teams.

Expected Product Improvements

For total ozone, a major improvement is expected through generation of new fully harmonized level 2 and level 3 data products obtained from the GOME, SCIAMACHY and GOME-2 instruments. The new level 2 baseline is based on an advanced direct-fitting retrieval approach and addresses inter-instrument calibration issues to bring the resulting data product at the 1 per cent accuracy level. Nadir ozone profile developments aim towards exploiting at best the profile

information available from the GOME, SCIAMACHY, GOME-2 and OMI instruments. This is achieved via Round-Robin evaluations and advancing approaches to correct for instrument degradation. For limb data products major improvements of the error analysis is expected from all instruments. Also new data merging methods are being designed aiming to demonstrate a new level-3 merged data product combining SCIAMACHY, GOMOS, MIPAS, OSIRIS, SMR and ACE instruments.

3.4 System Proto-typing and ECV Production

Data Gathering and Data Quality

Main input data sets are level 1 data sets from the UV backscatter nadir sensors GOME, SCIAMACHY, GOME-2 and OMI. All these data sets are available, however they are generally not fully harmonized. This is the case in particular for the ERS-2 GOME and METOP GOME-2 level 1 data sets. A new reprocessed version of the GOME-2 data set is awaited for late summer 2012, however it will not be possible to integrate it in the CCI processing chain for this phase of the project. Concerning limb sensors, input data sets are: existing level 2 products from the MIPAS, GOMOS, SCIAMACHY, OSIRIS, SMR and ACE-FTS instruments. In the MIPAS case, four level 2 data products have been generated as part of the MIPAS QWG for inclusion in the MIPAS Round-Robin. Regarding GOMOS, the project heavily relies on the new version 6.0 of the operational product. Recurrent delays in the generation of this data set (now awaited for September 2012) have been at the origin of delays in activities of EOST-3.

Product Generation

For total ozone, the decision to proceed with a full reprocessing of GOME, SCIAMACHY and GOME-2 data sets has been taken following the activation of an optional activity in early 2012. The generation of test products to be quality assessed during summer is on-going for each sensors and a full reprocessing campaign is planned to start in October for completion by mid-December 2012. For nadir and limb profiles, the generation of the final demonstration data sets will follow immediately after the round-Robins which are planned to be completed by late summer 2012. Prototypes are being set-up in parallel with the finalization of the selection process. All *Ozone_cci* CDR data sets will be finalized by March 2013.

3.5 Product Validation and User Assessment

Product Validation (plans)

Key ozone validation data sets are provided by ground-based network reference measurements contributing to WMO's Global Atmosphere Watch programme (GAW). Suitable data sets are collected from instruments archiving routinely their data to the World Ozone and Ultraviolet Radiation Data Centre (WOUDC) and the Data Host Facility (DHF) of the Network for the Detection of Atmospheric

Composition Change (NDACC). Additionally validation of limb and occultation data sets also relies on comparison with independent non-European satellite data sets from ERBS SAGE-II, UARS HALOE and EOS-Aura MLS. The latter satellite-satellite comparisons will complement ground-based validation by providing better coverage and co-location statistics.

Uncertainty Characterization

A detailed questionnaire about data and error characterization was distributed and filled out by all the partners of the *Ozone_cci* consortium. In total 11 datasets were evaluated from limb and nadir types of instruments. This provided a state-of-the art description of data and error characterization in use in the community, which was summarized in a chapter of the ATBD. New classifications of errors have then been introduced that partly remove inconsistencies in existing terminologies. This provided a baseline for use throughout the project, allowing for consistent error reporting among the three lines of ozone data products.

ECV Data Access and exploitation

The data products will be made available through the project's web site and also via dedicated web sites of the participating institutions. The products that are being made available to the users in phase 1 have been described in the PSD and are also listed in section 2 of this report. Ozone total column and vertical distribution products will be used by the project's CRG with a main focus on testing three Chemistry Climate models run in 3D-CTM mode using ERA-Interim data as an input. *Ozone_cci* products will also be evaluated by CMUG and by the GMES MACC project.

3.6 System Specification

The phase 1 prototype processing system can be seen as a largely decoupled distributed system spread over several organizations where each contributor provides existing systems for the generation of the committed ozone data sets. Based on this architecture, the following ECV parameters will be generated:

- Ozone total columns from GOME, SCIAMACHY and GOME-2. The level-2 generated at BIRA using the GODFIT scientific prototype will be fed into the DLR-based UCAS system for level-3 processing (merged gridded multi-sensor sensor data set).
- Ozone nadir profiles from GOME, SCIAMACHY, GOME-2 and OMI sensors. The level-2, level-3 and final assimilated level-4 products will be generated at KNMI using the NADC processing suite.
- Ozone limb profiles merged from SCIAMACHY, MIPAS, GOMOS, OSIRIS, SMR and ACE sensors. The level-2 processing is currently made outside of the CCI environment as part of operational environments or using scientific prototypes. The level-3 merged data product will be generated at FMI.

In all processing chains new merging algorithms will be developed. The main requirements for a sustainable *Ozone_cc*i system are:

- The organization of a flexible but still harmonized distributed and scalable system.
- A system supporting agile algorithm improvements.
- The acceleration of reprocessing campaigns.

3.7 Plan to complete Phase 1

The project currently is in the last phase of the Round-Robin (RR) activities. The MIPAS algorithm selection has evolved towards the demonstration of an ensemble approach involving 4 independent algorithms optimally combined to generate a single data product of improved quality. Both MIPAS and nadir profile RR activities will be fully completed by end of September 2012. Results will be documented as part of the PVASR with major support from the independent validations teams, and all data sets will be compiled in the RRDP. From September 2012 until March 2013 the *Ozone_cci* CRDP will be generated using the selected prototype algorithms. From March until December 2013 the CRDP will be validated (PVIR) and finally evaluated by the users (CAR).

3.8 General comments/feedback to ESA

Ozone_cci scientists are grateful for the flexibility offered to accommodate delays in the completion of the Round-Robin activities. This flexibility allowed for optimal use of available resources to the benefit of scientific algorithm developments and dedicated RR validation work. Generally speaking the focus in this first phase of the CCI has been strongly oriented towards R&D by opposition to operational/engineering aspects, and it is expected that this approach will enhance the final outcome and impact of the project. Although CCI will naturally evolve towards operationalization in its second phase, we still consider as essential to maintain a strong science component as required to further progress in the process of generating ozone CDRs matching the requirements of the user community. Finally, ozone scientists as others have suffered from the demanding set of deliverables imposed by ESA in this first phase of the CCI. A better balance between documentation work and scientific activities might have to be found for the future.

3.9 Relevant Scientific Publications

Braesicke, P. et al., Properties of strong off-shore Borneo vortices: a composite analysis of flow pattern and composition as captured by ERA-Interim, Atmosph. Sci. Lett., 13, 128-132. doi: 10.1002/asl.372, 2012.

Dameris, M., et al., Chemistry-Climate Connections – Interaction of Physical, Dynamical, and Chemical Processes in Earth Atmosphere, in Climate Change - Geophysical Foundations and Ecological Effects, J. Blanco, H. Kheradmand (Eds), In Tech, ISBN 978-953-307-419-1, pp. 1-26, 2011.

Loyola, D., et al., Multi-sensor data merging with stacked neural networks for the creation of satellite long-term climate data records, EURASIP Journal on Advances in Signal Processing, vol. 2012, no. 1, 2012.

Richards, N. et al., The Mediterranean summertime ozone maximum: A Satellite and model perspective, ACPD, 2012 (Submitted).

Van Roozendael, M.,et al. Fifteen years of GOME/ERS2 total ozone data: the new direct-fitting GOME Data Processor (GDP) Version 5: I. Algorithm Description, J. Geophys. Res., 117, D3, doi:10.1029/2011JD016471, 2012.

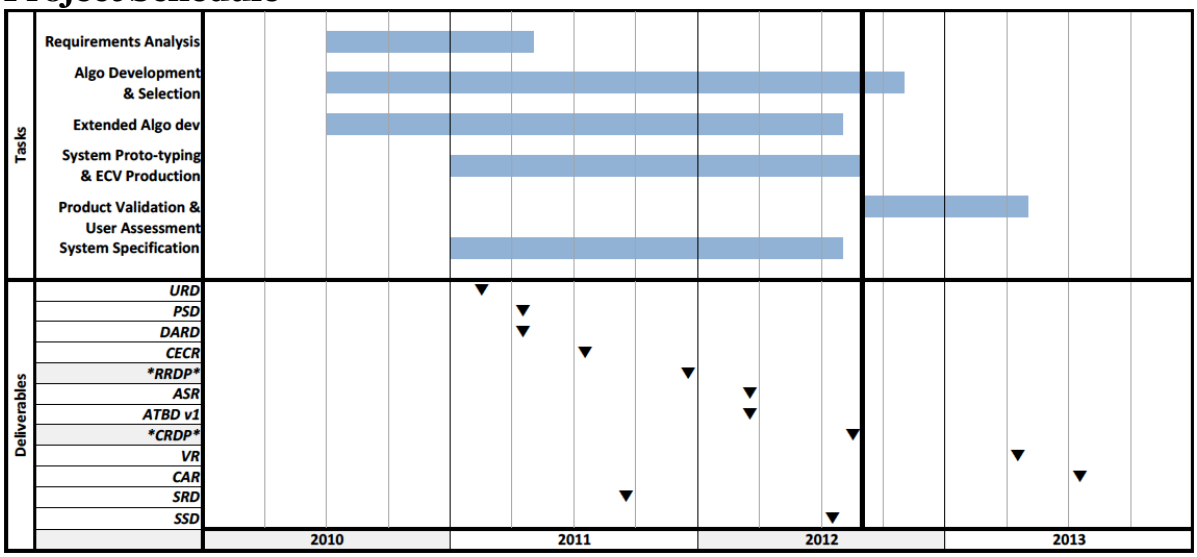
4 AEROSOL_CCI *(GCOS A.8)*

4.1 Overall Project Status

Summary of Overall Progress to date

The quality of most of the European aerosol products considered in *Aerosol_cc*i has been significantly improved as a result of intensive collaboration between major European algorithm development teams and the climate modelling community. The round robin exercise shows that some of the European products are now similar to or better than NASA products (in a statistical sense) although with lower maturity due to inherent lower coverage. However, currently there is no single product which outperforms all others in all possible situations. Therefore several products will be combined into a single European product which best meets the needs for climate assessment by UNFCC as formulated in the GCOS requirements. First results will be delivered, as scheduled, in August 2012.

Project Schedule



Team Composition

Prime Contractor/ Scientific Lead	DLR, FMI
Project Management	(BIRA-IASB) - (Belgium)
EO Science Team	DLR, FMI, Swansea University, Bremen University, Oxford University, RAL, CNRS, HYGEOS (until 07/2011), BIRA, KNMI, Free University of Berlin (since 5/2012)
Climate Research Group	MPI, Metno, NILU, PSI, CNR
System Engineering	DLR, CNRS, RAL

4.2 Requirements Analysis and Product Specification

User Consultation

The primary users are the climate modelling community representing international organizations, meteorological institutes and universities. Their requirements, in addition to those formulated by GCOS and updated in the course of the cci project, were collected through consultation with the CCI/CMUG project and, in particular, *Aerosol_cci* works intensively with the (global) aerosol modelling community, federated through the international AeroCom project (comparing 22 global aerosol models, and with ECMWF/MACC (GMES) for data assimilation. GCOS requirements (GCOS-154, Dec 2011) list four physical aerosol properties: aerosol optical depth, single scattering albedo, aerosol layer height and extinction profiles with a very demanding quantitative requirement for aerosol optical depth set to MAX(0.03 or 10%) – currently only met over ocean.

International Scientific coordination

The Aerosol_cci team includes the major European scientific groups developing aerosol retrieval from ESA instruments, as well as leaders of the global community of aerosol modellers (AeroCom), and experts in aerosol validation using independent ground based measurements from AERONET and WMO-GAW. International collaboration outside the consortium is mainly achieved via participation at major conferences, and invitation of external experts (e.g. NASA, EUMETSAT) to project progress meetings. Furthermore, through joint membership *Aerosol_cci* is linked to WMO-GAW Science Advisory Group for Aerosols overseeing general validation strategies. A dedicated meeting at ECMWF is scheduled for 11/2012 to iterate further the requirements for data assimilation and GMES (MACC). *Aerosol_cci* has started a joint option with *Cloud_cci* to assess in more detail the requirements for consistency between the 2 ECVs. At CMUG meetings *Aerosol_cci* interacted with other ECV teams, which led to documenting their requirements towards aerosol products. *Aerosol_cci* acts as co-editor of CCI special issue in RSE.
Project presentations at major international forums:

- EGU 4/2011& 2012 Vienna (Austria) oral presentations on Aerosol_cci
- WCRP meeting 10/2011 Denver (CO, USA) several posters by Aerosol_cci
- AGU 12/2011 San Francisco (CA, USA) invited oral presentation on Aerosol_cci

ECV products description

Aerosol_cci is focused on improving the accuracy of aerosol optical depth retrieval from European instruments towards the GCOS requirement, transferring new research on single scattering albedo retrieval into operational algorithms, and maximizing the contribution of GOMOS data for documenting stratospheric aerosol extinction profiles. Aerosol layer height is not addressed, as this is already covered by the existing CNES/NASA CALIPSO activities. Once the accuracy of aerosol

products has been sufficiently improved in Phase 1, the project will focus on meeting the demanding GCOS requirement for long term stability.

Aerosol_cci products have been specified to directly respond to the climate user requirements, including uncertainty characterization of all retrieved aerosol properties, and delivered in netCDF format following the well-known Climate and Forecast data standards.

ECV Product Name:						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Aerosol optical depth	PARASOL AATSR MERIS (SCIAMACHY)	Ocean only Global Ocean only	L2: 10x10km (or sensor pixels) L3: 1x1deg	2008	L2: Orbit L3: Daily/ monthly	3TB per year
Explanatory text: L2 and L3 basic products are for single sensors. For AATSR a combination of several algorithms (over deserts, coastal areas, land/ocean) is under testing. Further algorithms (synergetic multi-sensor and MERIS over land) need further development which is currently ongoing. Key user requirement is for aerosol optical depth – accuracy is approaching state of the art, but on long-term better temporal coverage (1995-2020) should be provided. Main intended application areas are model validation and data assimilation.						

ECV Product Name:						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Absorption (absorbing index, absorption optical depth over ocean)	OMI AATSR/ MERIS	Global Ocean only	L2: sensor pixels L3: 1x1deg	2008	L2: Orbit L3: Daily/ monthly	1,5TB per year
Explanatory text: L2 and L3 absorbing index is for single sensors, absorption optical depth for multi-sensor. The absorbing aerosol optical depth over ocean (in glint) is under development. Key user requirement is for absorption information which is sparsely available and critical for climate radiative forcing (the main intended application area).						

ECV Product Name:						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Stratospheric extinction profile	GOMOS	Global	L3: 2,5 x 10°	2008	L3: monthly	0,5TB per year
Explanatory text: L3 basic products are for a single sensor Key user requirement is for vertical aerosol distribution (relevant for climate radiative forcing) and stratospheric total extinction (relevant for nadir tropospheric retrievals in case of enhanced stratospheric aerosol content Main intended application areas are climate radiative forcing and nadir retrieval correction						

4.3 Algorithm Development, Inter-comparison, Selection

Results of Round Robin inter-comparison

Algorithm development and improvement initially focused primarily on understanding the various algorithms and their differences. In particular this was necessary for aerosol products retrieved using different algorithms for the same sensor (AATSR, MERIS). The *Aerosol_cci* EO team worked together to identify weaknesses in the existing algorithms and test their impacts.

Most of the problems are associated with cloud clearing, the definition of aerosol optical properties and treatment of the surface reflectance. These issues are addressed in three working groups that proposed several experiments to determine the best possible approach to reduce the uncertainties associated with each of these problems. The experiments were made for one single month (9/2008) and their results were evaluated by the independent validation team (which includes AeroCom users) by comparison with ground based sun-photometer measurements using a multi-criterion algorithm selection process (spatial, temporal correlations with AERONET, as well as qualitative criteria such as spatial coverage).

Each team selected the "best" version of their own algorithm to produce a 4-month data set (representative for the 4 seasons in 2008) for the round robin exercise. These experiments led both to improvements in the accuracies of individual retrievals as well as a better understanding of the relative performance of the different candidate algorithms. One full year of global data (2008) will be processed with each of the candidate algorithms by August 2012. The candidate data set with the best accuracy when compared to independent ground based measurements will be provided to the users by the end of October 2012.

Expected Product Improvements

An initial analysis of 4 months of *Aerosol_cci* data (AATSR, PARASOL) shows a clear improvement with respect to the baseline datasets produced at the start of the project. This is illustrated by comparison of the GlobAEROSOL AATSR data for 2008 (12 months 2008 lv3 daily validation in AEROCOM tools 1162 points) and the best AATSR algorithm of Aerosol_cci after 2 years (296 points within 4 months of 2008).

Comparison of these products versus AERONET stations shows the following results: correlation 0.49 -> 0.82 / rmse 0.18 -> 0.10. For reference, 12 months of 2008 for MODIS-terra C5 with 1243 points and (and MISR v22 with 1435 points) show correlations of 0.85 (0.74) and rmse of 0.10 (0.13). This exercise will be repeated once the 12 month dataset becomes available.

4.4 System Proto-typing and ECV Production

Data Gathering and Data Quality

Input datasets are mainly from European sensors: AATSR, PARASOL, MERIS, OMI, SCIAMACHY, and GOMOS. The main source is L1 data (except for GOMOS, where *Aerosol_cci* builds on L2 data). Data were already available at participating partners – access to complete multi-annual reprocessed datasets needs higher speed. Documentation of corrections to be applied to input data was found sub-optimal, which was communicated to the respective Cal/Val group.

Product Generation

The production in *Aerosol_cci* phase 1 started with several experiments producing and assessing 1 month global data to assess algorithm sensitivities (until 7/2011). Next, the round robin datasets comprising 4 months global data were produced (12/2011) and validated (03/2012). The ECV production of the first set of algorithms is planned for 08/2012 with subsequent validation (10/2012) and user assessment (4/2013).

4.5 Product Validation and User Assessment

Product Validation (plans)

The primary approach for product validation is to compare against ground-based total column sun photometer measurements from AERONET (and GAW-PFR). This is done for L2 and L3 products independently using the following set of adopted statistical tools: ICARE (L2, correlation, rmse analysis), AEROCOM (L3 correlation, RMSE, histograms, mapping) and scoring (spatial and temporal correlation, i.e. patterns). As reference also other datasets are compared (MODIS, MISR, AEROCOM model median, MACC). Validation is broken down to different regimes (ocean, land, coastal) and special filtering has been developed to assure identical selection of data pairs for all algorithms / sensors. As complementary validation source work is conducted on the use of WMO-GAW in situ data.

Uncertainty Characterization

For each product the characterization of the uncertainty for each pixel is under development; several examples have already been provided. Methods used to calculate this uncertainty range from experimental parameterizations to stringent error propagation. Additional quality flags (L2) and a single quantitative quality index (0-1) are planned for parts of the products based on user request. Discussion with model users on the utilization of this information is still on-going. Data assimilation users will rely on the uncertainty parameter.

ECV Data Access and exploitation

All output datasets (all algorithm experiments, round robin datasets and upcoming ECV product) are archived at the central ICARE ftp server and linked through the

Aerosol_cci website. The CRG will assess the ECV products during the period 11/2012-4/2013 after their internal validation has been completed. Due to the limited temporal length of the dataset the main focus will be on comparison to datasets provided from models and from other satellites (MODIS, MISR) to understand their usefulness. This will be facilitated by using established tools within the modelling user community. Additionally, ECMWF will look into the L2 data for data assimilation.

4.6 System Specification

The *Aerosol_c*ci prototype as it is currently implemented is highly decentralized based on the existing scientific (but sufficiently stable and capable) implementations of retrieval algorithms and validation tools.

This decentralized prototype system already comprises of almost all components of the envisaged operational system including the very important component of the science team.

New software modules in several algorithms have been shared by other partners of the consortium. A new development was the definition of a common set of basic optical aerosol component models to be used in all algorithms.

The key factors dimensioning the system are the size of the L1 input data (output typically a factor of 10 smaller) and the processing load for large datasets (1 year). A sustainable system shall be agile to allow fast adaptation (implementation, testing and validation with statistically significant data volume) of new algorithms / modules developed in the science team. It needs to be scalable to accommodate a growing number of algorithm / product versions and it needs to include all relevant documentation for the users to fully understand the products.

4.7 Plan to complete Phase 1

The major activity to the end of phase 1 is the final production of the 1-year ECV products in a common specified format, their validation and assessment. Additionally, another data year will be processed for heritage sensors (e.g. ATSR-2 for AATSR) as a baseline for validation and to start understanding long-term data series issues.

4.8 General comments/feedback to ESA

The number of technical documents should be reduced to those really needed for the end users. In our opinion Phase 1 has shown that no re-engineering of scientific code is needed and should be avoided due to its demand in resources and introducing a new source of error.

4.9 Relevant Scientific Publications

Zieger, P. et al.,2011, ACP, Comparison of ambient aerosol extinction coefficients obtained from in-situ, MAX-DOAS and LIDAR measurements at Cabauw

Zieger, P., et al., 2012, ACPD, Spatial variation of aerosol optical properties around the high-alpine site Jungfraujoch (3580 m a.)

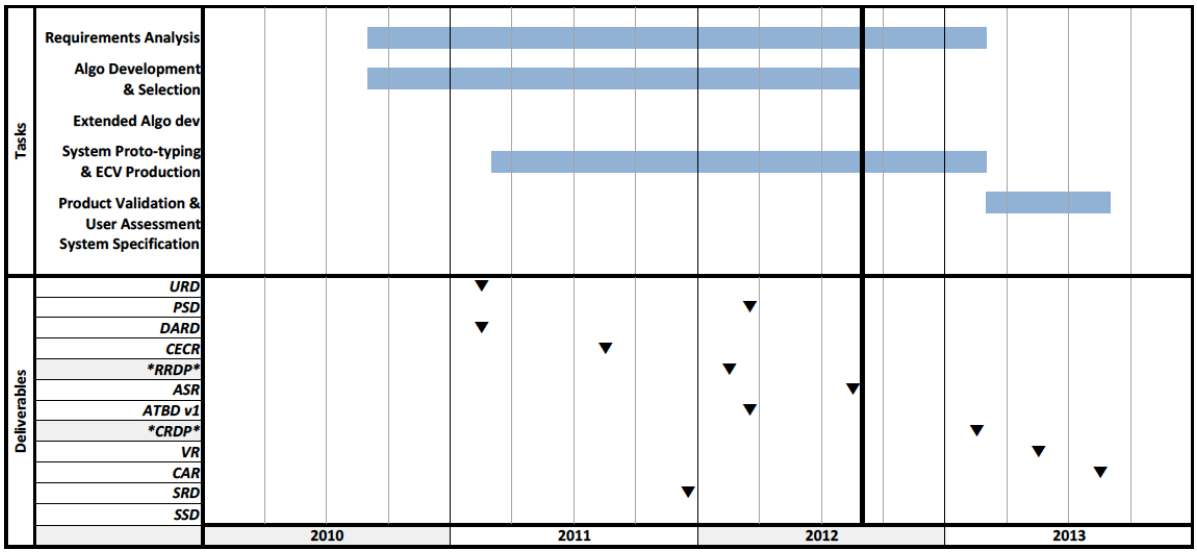
Further papers are in preparation to be published towards the end of 2012 on algorithm experiments (AMT special issue) and round robin exercise (Rem. Sens. Environ. special issue).

5 GREENHOUSE _GAS_CCI *(GCOS A.9)*

5.1 Overall Project Status

The *GHG_cci* project has significantly advanced European capabilities in the important and relatively new area of "Greenhouse Gas" (GHG) observations from space. Major achievements are, for example, first promising GOSAT GHG retrievals including first peer-reviewed publications and improved SCIAMACHY GHG time series and improved data quality and error characterization. The project is on schedule and the Round Robin (RR) exercise will be finished as initially planned end of August 2012.

Project Schedule



*) Listed is the initial time period. Task extended to 02/13 to consider future updates

§) Formally, *GHG_cci* has no Task 5 to compensate for the extended (2 year) RR. Nevertheless, the team has carried out Task 5 related activities (e.g., SRDv1.0 has been delivered on 1 Dec. 2011)

Team Composition

Prime Contractor/ Scientific Lead	IUP-UB - (Germany)
Project Management	Univ. Leicester - (**lead**) (United Kingdom) IUP-UB - (Germany)
EO Science Team Algorithm Development	IUP-UB - (**lead**) (Germany) Univ. Leicester, SRON, LMD, KIT, BIRA, Empa
Climate Research Group	LSCE - (**lead**) (France) JRC (Italy), FastOpt (Germany)

System Engineering	DLR - (**lead**) (Germany)

5.2 Requirements Analysis and Product Specification

User Consultation

The *GHG_cci* user requirements are based on *GHG_cci* CRG user expertise including MACC, peer-reviewed publications and other documents, which have been generated primarily in the context of the GHG satellite missions SCIAMACHY, GOSAT, OCO and CarbonSat. They are based on dedicated Observing System Simulation Experiments (OSSE) and experience with real data (primarily SCIAMACHY). The URD was reviewed by CMUG. The most important requirements are single measurement precision, regional scale monthly precision (corresponding to a sufficiently large number of "good" observations) and relative accuracy. Whereas the precision requirements have typically been met, achieving the demanding relative accuracy requirement of better than 0.5 ppm for XCO2 is currently the greatest remaining challenge (~1 ppm at validation sites has been achieved).

International Scientific coordination

The *GHG_cci* team members are closely cooperating with many national and international institutions (e.g., NASA, NOAA, JRC, ECMWF, NIES, WMO), programmes/projects (e.g., ICOS, TRANSCOM, MACC, GCP, IGAC, iCACGP), networks (e.g., TCCON, GAW, AGAGE) and committees (e.g., COSPAR and ESA Advisory Groups for Sentinel 5/5-P and CarbonSat. *GHG_cci* is working in close cooperation with the European GMES Atmospheric Core Service MACC (currently MACC-II). *GHG_cci* is delivering data to MACC (for delayed mode assimilation) and MACC provides feedback on the data quality. The team is also working in close cooperation with the GOSAT teams at JAXA and NIES and the NASA-ACOS team which is currently preparing for the launch of OCO-2.

Team members are participating as session chairs and co-organizer in various international conferences (e.g., EGU, IWGGMS, COSPAR). The project achievements have been presented at several major conferences such as EGU 2011 and 2012, Vienna, Planet under Pressure, London, IWGGMS-7 and 8, Edinburgh and Pasadena, and ESA ATMOS 2012, Bruges, Belgium.

ECV products description

An overview of the *GHG_cci* EVC core products is given in the two tables below. These products are generated using so-called ECV Core Algorithms (ECAs). The main application is to use these products in combination with global models within an inverse modelling framework in order to obtain information on regional CO_2 and CH_4 surface fluxes (sources and sinks).

During the on-going RR phase, several ECAs per product are being further developed and assessed in competition. In addition, algorithms to retrieve CO2 and

CH4 in upper atmospheric layers, e.g., from IASI and MIPAS, are also being further developed. These algorithms are called Additional Constraints Algorithms (ACAs). The focus of the current Phase 1 of CCI are ECAs. Therefore, ACA generated products are not listed here.

ECV Product Name: XCO_2 from SCIAMACHY/ENVISAT and TANSO/GOSAT						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume *)**
XCO_2 in ppm	SCIAMACHY	Global (cloud free land)	Sensor pixel (typic. 30x60km2)	2003-2010	Sensor resolution (cloud free land)	~50 MB/month
XCO_2 in ppm	TANSO	Global (cloud free)	Sensor pixel (10 km pixel size, non-contiguous)	Mid 2009 - 2010	Sensor resolution (cloud free)	~20 MB/month
Explanatory text: Product: XCO2 is the column-averaged dry air mole fraction of CO2 Product level: Level 2 (mole fraction in ppm) Main application: Regional-scale CO2 surface flux inverse modelling Remarks: An ensemble product using several algorithms with SCIAMACHY & GOSAT combined and/or GOSAT individually is also in preparation to be generated using the EnseMble Median Algorithm (EMMA) *) Rough estimate (depends on to be selected algorithm(s))						

ECV Product Name: XCH_4 from SCIAMACHY/ENVISAT and TANSO/GOSAT						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume*)**
XCH4 in ppb	SCIAMACHY	Global (cloud free)	Sensor pixel (typic. 30x60km2)	2003-2010	Sensor resolution (cloud free)	~80 MB/month
XCH4 in ppb	TANSO	Global (cloud free)	Sensor pixel (10 km pixel size, non-contiguous)	Mid 2009 - 2010	Sensor resolution (cloud free)	~20 MB/month
Explanatory text: Product: XCH4 is the column-averaged dry air mole fraction of CH4 Product level: Level 2 (mole fraction in ppb) Main application: Regional-scale CH4 surface flux inverse modelling *) Rough estimate (depends on to be selected algorithm(s))						

5.3 Algorithm Development, Inter-comparison, Selection

Results of Round Robin inter-comparison

The GHG-CCI Round Robin (RR) exercise is on-going until end of August 2012. Detailed preliminary comparison results are shown in the GHG-CCI Algorithm Inter-comparison and Error Characterization Report (AIECAR) available on the

GHG-CCI website. The final selection will be made following the criteria as given in the GHG-CCI RR Evaluation Protocol (RREP, also available on the GHG-CCI website). Several Figures of Merit (FoM) have been defined to guide the selection. They are largely based on differences to Total Carbon Column Observing Network (TCCON) reference data. Because TCCON is sparse other information will also be used such as user expertise and additional information such as global and regional maps and time series and satellite – model comparison results. For each of the ECV Core Algorithms (ECAs) two or more competing algorithms have been further developed and used to generate the RRDP which is currently being analyzed. For the ACAs, which are not in competition, a number of criteria have been defined in the RREP which need to be fulfilled for an algorithm to be selected. The main goal of the GHG-CCI RR is to decide which algorithms to use to generate the CRDP. The final decision and its justification will be reported in a dedicated document, the Algorithm Selection Report (ASR), available beginning of September 2012.

Expected Product Improvements

The core *GHG_cci* data products are near surface sensitive satellite retrievals of XCO_2 and XCH_4 from SCIAMACHY (launch 2002) and GOSAT (launch 2009). Pre-cursor products were generated from SCIAMACHY within previous projects like MACC. Within *GHG_cci* these data sets have been extended (now covering more than 7 years for both CO_2 and CH_4) and improved with respect to quality (higher accuracy) and better error characterization. Within the initial phase of the *GHG_cci* project the first good quality GOSAT retrievals have been generated by *GHG_cci* team members as well as by non-European institutions (NIES and NASA). Although not all problems have been solved yet for all data products, this is of high benefit for the climate/inverse modelling community as these are important input data needed to better constrain GHG surface fluxes (emissions and sinks).

5.4 System Proto-typing and ECV Production

Data Gathering and Data Quality

Core input data are SCIAMACHY and GOSAT Level 1 files. In addition, a number of other input data sets are used such as other satellite data (e.g., IASI, MIPAS, MERIS, ACE-FTS), global model data (e.g., ECMWF, TM5, CarbonTracker). Due to problems with the initial version 7 of the SCIAMACHY Level 1 data the RR suffers to some extent from calibration issues but this problem has been reported and resolved and the already existing improved Level 1 data will be used when generating the CRDP. GHG-CCI is working in close cooperation with the SCIAMACHY Quality Working Group (team members are in both groups) and with the GOSAT calibration experts at JAXA.

Product Generation

Depending on algorithm, virtually all existing data (at least until end of 2010) have been processed or will be processed soon. The *GHG_cci* CRDP will include SCIAMACHY derived products for 2003-2010 and GOSAT data for mid 2009 to

2010. The CRDP will be available in March 2013. Quality control is implemented by various measures but primarily by detailed comparisons with ground-based TCCON retrievals. During this project the quality and amount of the data products has been significantly improved. Much longer time series exist now and they have higher accuracy as documented in several peer-reviewed publications. Despite these improvements not all requirements have been met yet. More work is needed to meet the demanding relative accuracy requirement for XCO2. Therefore all algorithms are still being improved. Measures have been implemented towards a promising short-/mid-term solution ("EMMA", see below).

5.5 Product Validation and User Assessment

Product Validation (plans)

Key validation network for the validation of the *GHG_cci* core data products XCO2 and XCH4 is the Total Carbon Column Observing Network (TCCON) as this network has been designed and developed for this purpose (initially for NASA's OCO mission). The quantities measured by TCCON can essentially be directly compared with the satellite retrievals. Unfortunately, the TCCON network is quite sparse. Therefore it is planned to also use other data (NDACC XCO2 and XCH4, in-situ GAW and AGAGE combined with models) for the final validation of the CRDP.

Uncertainty Characterization

Uncertainties are quantified using different complementary methods: Simulations are primarily used to quantify various sources of systematic errors and comparisons with highly accurate and precise reference data (primarily TCCON) are used to assess the quality of the real data in terms of random and systematic errors. Reliable uncertainty estimates are very important for the *GHG_cci* users as they are key input parameters for assimilation and inverse modelling systems. Currently provided to the users are uncertainty estimates for each single observation quantifying primarily the random component of the total uncertainty.

Users would like to get also a reliable estimate of the systematic error for each observation but this is hardly possible. The main challenge is to reliably detect and quantify systematic errors remote from TCCON validation sites, especially for XCO2 but also for XCH4. To deal with this *GHG_cci* is currently developing the EnseMble Median Algorithm (EMMA). EMMA uses an ensemble of satellite XCO2 retrievals. The goals of EMMA are: (i) to obtain realistic uncertainties from the ensemble scatter, (ii) to identify outliers by comparison with the ensemble median (to be used to improve the individual algorithms), and (iii) to generate a new Level 2 product based on the ensemble. Preliminary analysis indicates that EMMA outperforms each of the individual data products.

ECV Data Access and exploitation

The products are made available via the project website but also via dedicated websites of the participating institutions. A key exploitation issue in the context of

determining the quality of the data products is the limited number of appropriate validation sites (TCCON network). A number of measures are being implemented to mitigate the impact of this (EMMA (see above), use of models, other networks). A large number of (mainly scientific) users are using data products generated with the retrieval algorithms further developed within *GHG_cci*. The *GHG_cci* CRG will perform a final evaluation of the CRDP in June-August 2013 after the CRDP has been validated (March-June 2013).

5.6 System Specification

The GHG-CCI RR phase is on-going until end of August 2012, i.e., the final algorithm selection has not yet been made (at the time of writing of this report prior to the MTR; at the MTR the RR was finished as planned and the 'algorithm selection report' (ARS) is available at: http://www/esa-ghg-cii.org/). Within *GHG_cci* existing scientific processing systems have been further developed.

The H/W configuration depends largely on the algorithm. For example the fast Look-up-table (LUT) based WFMD algorithm only requires a single workstation to process an entire orbit of SCIAMACHY data in a few minutes but the GOSAT XCO2 OCFP algorithm uses a super computer with more than 1000 CPUs. Also the S/W components differ significantly (e.g., different programming languages/compiler) but essentially all teams are using UNIX systems. Input data volumes are large (official SCIAMACHY and GOSAT Level 1 products; ~400 MB/orbit) but the output volumes are quite small (Level 2, typically 20 MB/month). The priority requirements for a sustainable GHG-CCI processing system are:

- Continuous improvements of the existing system with the goal to further enhance the accuracy of the data products and to extend the time series (a re-implementation of the complex retrieval systems is not recommended).
- The data products need frequent re-processing also during the development phase, e.g., to determine how to optimally minimize biases caused by instrument degradation; this requires high processing power.
- Availability of all required input data as soon as available (there is however no near-real-time need as quality has priority over speed for GHG-CCI).

5.7 Plan to complete Phase 1

GHG_cci is in the final stage of the RR phase which will finish end of August 2012 (for status post-MRR see above). The RR results and final selection will be documented in three major documents: PVASR written by the independent validation team, AIECARv1 written by the retrieval team and ASR (Algorithm Selection Report, written be the entire team but led and approved by the CRG). ASR will summarize the detailed results given in PCASR and AIECARv1 focusing on the decision results and decision justification. From September 2012 to February 2013 the CRDP will be generated using the selected algorithms. From March-May 2013 the CRDP will be validated (PVIR) and finally evaluated by the users (CAR).

5.8 General comments/feedback to ESA

GHG_cci acknowledges the flexibility of ESA during Phase 1 especially with respect to "scientific needs" in contrast to "system specification/engineering needs". Some comments are repeated here which have been made by GHG-CCI and other ECV projects during various meetings:

- CCI Phase 1 suffers scientifically from the large number of deliverables. This significantly limits the time available for scientific exploitation of the generated data products and other important scientific activities. All ECV projects expressed their hope that this will improve in Phase 2.
- It is considered mandatory that the CCI also in future phases not only focusses on system engineering/system development aspects but on science aspects with the primary goal to generate useful high-quality data sets as required by the climate/inverse modelling user community ("as accurate and long as possible"). The data sets must reflect the state of the art as otherwise they will not be used. This requires that CCI has to be a science driven programme also in future phases. It is important that CCI includes ECV projects which are in "science mode" rather than in "operational mode". This is particularly relevant for projects such as *GHG_cci* which are generating important challenging new key ECVs from single non-operational sensors such as SCIAMACHY/ENVISAT and TANSO/GOSAT.

5.9 Relevant Scientific Publications

Butz, A. et al., Toward accurate CO_2 and CH_4 observations from GOSAT, Geophys. Res. Lett., 38, L14812, doi:10.1029/2011GL047888. 2011.

Parker, R. et al., Methane Observations from the Greenhouse gases Observing SATellite: Comparison to Ground-based TCCON data and Model Calculations, Geophys. Res. Lett., 38, L15807, doi:10.1029/2011GL047871, 2011.

Reuter, M. et al., A joint effort to deliver satellite retrieved atmospheric CO_2 concentrations for surface flux inversions: the ensemble median algorithm EMMA, Atmos. Chem. Phys. Discuss., 12, 23195-23217 , 2012

Reuter, M., et al. Retrieval of atmospheric CO2 with enhanced accuracy and precision from SCIAMACHY: Validation with FTS measurements and comparison with model results, J. Geophys. Res., doi:10.1029/2010JD015047, 2011.

Schneising, O. et al., Atmospheric greenhouse gases retrieved from SCIAMACHY: comparison to ground-based FTS measurements and model results, Atmos. Chem. Phys., 12, 1527-1540, 2012.

Schneising, O. et al., Long-term analysis of carbon dioxide and methane column-averaged mole fractions retrieved from SCIAMACHY, Atmos. Chem. Phys., 11, 2863-2880, doi:10.5194/acp-11-2863-2011, 2011.

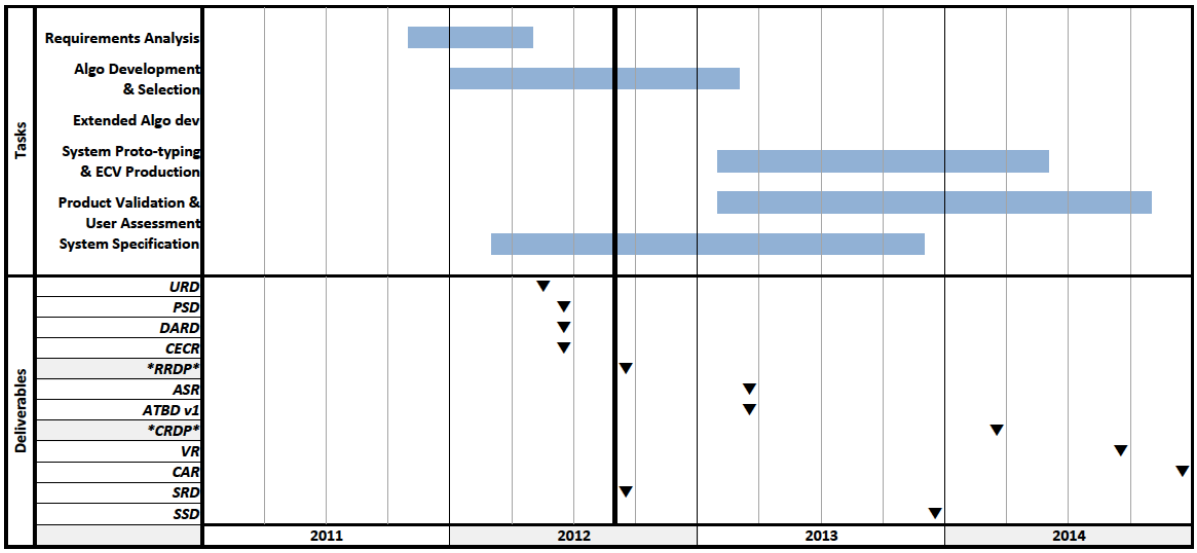
6 SEA_ICE_CCI *(GCOS O.1)*

6.1 Overall Project Status

Summary of Overall Progress to date

Sea ice is a very sensitive indicator of climate change in the Polar regions. The reduction of the Arctic sea cover in the last decades can only be comprehensively documented by analysing the satellite passive microwave observations systematically acquired over both poles since the late 1970s. . The main goal of the *Seaice_cci* project is to provide optimal algorithms for retrieval of sea ice concentration and estimate time-series of sea ice areas in Arctic and Antarctic with the best possible accuracy. The project will also provide the first quality-controlled ice thickness data set in the Arctic based on satellite radar altimeter from 1993 to present. The first milestone in the project has been to carry out a user requirement analysis for sea ice concentration and thickness, the two main ECVs for sea ice. Retrieval algorithms have been implemented and data sets required to produce ice concentration and thickness have been compiled. Validation data are prepared and presently installed in the Round Robin database. Algorithm comparison and selection is scheduled to be completed beginning of 2013.

Project Schedule



Team Composition

Prime Contractor/ Scientific Lead	NERSC – (Norway)
Project Management	NERSC – (Norway)
EO Science Team	NERSC **(lead)** – (Norway) Met. No (Norway) DMI (Denmark) DTU (Denmark) FMI (Finland) UCL (United Kingdom) University of Cambridge (United Kingdom) University of Bremen (Germany) University of Hamburg (Germany) Ifremer (France) MPI-M (Germany)
Validation Team	University of Hamburg **(lead)** (Germany) MPI-M (Germany) Ifremer (France) University of Cambridge (United Kingdom) University of Bremen (Germany)
Climate Research Group	MPI-M (Germany)
System Engineering Team	Logica – **(lead)** (Germany) Met.No (Norway)

Basic Project Data

The basic data for ice concentration retrieval is passive microwave data from 1978 to 2008 and validation data from other satellite instruments (SAR, high-resolution optical images), ice charts and airborne surveys. For ice thickness, radar altimeter data from ERS and ENVISAT are used with support from in situ data on snow and ice properties needed to retrieve ice thickness from freeboard measurements. Validation data for ice thickness includes airborne, submarine and in situ data from various expeditions. Also satellite SAR from ENVISAT and laser data from IceSat is used for validation.

6.2 Requirements Analysis and Product Specification

User Consultation

A user consultation has been conducted with 91 responses to questions on sea ice concentration and thickness data for climate research. Requirements were identified for a variety of applications: climate and sea ice modelling; validation of models; data assimilation; ice-charting and forecasting; marine biology; fisheries and ecosystem research, marine transportation and offshore operations in ice-covered seas.

For *ice concentration* the majority of the respondents require daily sampling, 10-20 km spatial resolution and measurement precision better than 10 %. For *ice thickness*, the majority of the respondents required spatial resolution better than 50 km and measurement precision better than 20 cm. Temporal resolution of ice thickness data is envisaged to be about a month for satellite altimeter retrievals.

The requirement for long-term stability is 2 % per decade for ice concentration and 5 cm per decade for ice thickness. A key requirement is also to determine the error of the sea ice concentration and thickness data sets.

Requirements for other sea ice parameters such as ice drift, ice volume, snow cover, melt pond fraction, albedo, surface temperature, sea ice salinity and others were investigated. Most respondents required daily or weekly temporal sampling and spatial resolution of 20 km or better. The project will not provide data sets on these parameters, but recommendation is made to extend sea ice data sets with more parameters in future studies of sea ice data in climate research.

International Scientific coordination

Project activities are well coordinated with other international climate and sea ice programmes and projects, such as GCOS, Eumetsat Ocean and Sea Ice SAF and Climate Monitoring SAF. Several consortium members participate in the CIMIP5 work and contribute to IPCC AR5. The user survey has included requirements from climate modellers, sea ice researchers, and other polar and marine scientists.

ECV products description

Two sea-ice ECV data products will be provided: Sea ice concentration (SIC) and sea ice thickness (SIT). The SIC will be available for both hemispheres at daily temporal resolution and spatial resolution of 50 km for the period 11/1978 to 12/2008. The SIT will be available for the Arctic Ocean with monthly temporal resolution for the period 1993 to 2012 at spatial resolution of 100 km.

ECV Product Name:						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Input Data Volume**
Sea ice concentration	SMMR, SSMI	Arctic and Antarctic	L3: 25 by 25 km	1978 - 2008	Daily	Appr. 15 Terra byte for the whole period
Sea ice thickness	RA	Arctic	L3: 100 by 100 km	1993 - 2012	Monthly	0.5 Gbyte per day
Explanatory text: Level 2, 3 or 4 product. Merging. SIC meets the main user requirements for temporal and spatial coverage, temporal and spatial resolution. SIT is a new ECV parameter and is expected to partly meet the user requirements. Bot SIC and SIT will meet the main intended application(s).						

6.3 Algorithm Development, Inter-comparison, Selection

Results of Round Robin inter-comparison

RRDB are being prepared. SIC RR exercise will start in during autumn 2012. Inter-comparison of algorithms for sea ice concentration and thickness has not been done yet.

Expected Product Improvements

The expected improvements will be the provision of homogeneous ice concentration data sets for Arctic and Antarctic with quantified error estimates based on validation data. The data sets will be produced by the best available algorithms, which will be inter-compared by the RR data sets. For ice thickness it will be the first homogeneous and validated data set for the Arctic. The methodology for error characterisation of ice concentration and ice thickness has been defined and described in the CECR report. The data sets are primarily required by climate and sea ice modellers for climate model validation and assimilation of sea ice data in ice models.

6.4 Product Validation and User Assessment

Product Validation (plans)

The products validation plan for ice concentration and ice thickness has been completed. The plan describes the validation data that are available and the methodologies to be used in the assessment of the ECV products. Ice concentration validation will be done by comparison with ice charts, classified satellite images from optical and infrared sensors, SAR-discrimination between water and ice, and SAR-based ice convergence zones to identify areas with near 100 % concentration. Ice thickness will be validated by airborne radar altimeter data, laser data, EM-bird data, upward-looking sonar data of ice draft from submarines and moorings, in situ measurements of ice freeboard, thickness and snow cover.

Uncertainty Characterization

The methods to be applied for error characterization for ice concentration and ice thickness are described in the CECR document. The ice concentration retrieval is sensitive to surface emissivity, atmospheric conditions, instrument noise, merging of data from different sensors, tie-points, footprint mismatch including variability in ice conditions within the sampling area. Ice thickness retrieval from radar altimeter has a number of error sources related to atmosphere, ocean surface height including tides, sampling errors, variability in snow thickness and snow and ice density that has impact on calculation of thickness from freeboard measurements. Many of the error sources have been investigated in previous studies, both theoretically and empirically, but there has been no comprehensive study of all the error sources. This project will therefore be the first attempt to come up with a total error assessment of the final ECV products for sea ice.

6.5 System Specification

This work will be done by Logica and Met.no

6.6 Plan to complete Phase 1

The present three-year project will be completed in November 2014.

6.7 General comments/feedback to ESA

The primary data sets for long-term monitoring of sea ice concentration in both Arctic and Antarctic are passive microwave data obtained continuously since 1978. As a supplement to the coarse resolution passive microwave data, SAR data from ERS and ENVISAT can provide higher-resolution concentration in the marginal ice zone and validate SSMI-retrievals in areas of near 100 % concentration. Also optical and infrared images can be used to validate the passive microwave retrievals SAR data can resolve leads, polynyas and discriminate between ice types such as multiyear, firstyear, young and new ice. The loss of ENVISAT will have no direct impact on the sea ice ECV products, since the main role of SAR data is to provide validation data and there is plenty of archived SAR data for this purpose.

Ice thickness retrieval from ERS and ENVISAT radar altimeter data has been developed over the last two decades and represent a unique methodology to observe spatial and temporal changes in ice thickness on global scale. With CryoSat-2 the capability to observe ice thickness from radar altimeters has developed further as a result of better geographical coverage, higher spatial resolution and improved instrument precision. In order to provide continuity of radar altimeter data for sea ice thickness retrievals, it would be beneficial to achieve overlap between the operation of Sentinel-3 and a potential extension of the CryoSat mission. For thin ice retrieval (ice thinner than 0.5m) L-band passive microwave data from SMOS have shown promising capability and will serve as a useful complement to radar altimetry which can mainly provide the thicker part of the ice thickness spectrum.

Ice type classification and ice drift from SAR and optical/IE sensors will be useful complement to radar altimeter for sea ice research in general. Future development of sea ice climate variables will include also ice drift in combination with ice area, thickness, and other sea ice variables. This will allow researchers to estimate sea ice volume and fluxes, melting/freezing processes and climate processes in general where sea ice plays a role.

6.8 Relevant Scientific Publications

Project started in January 2012.

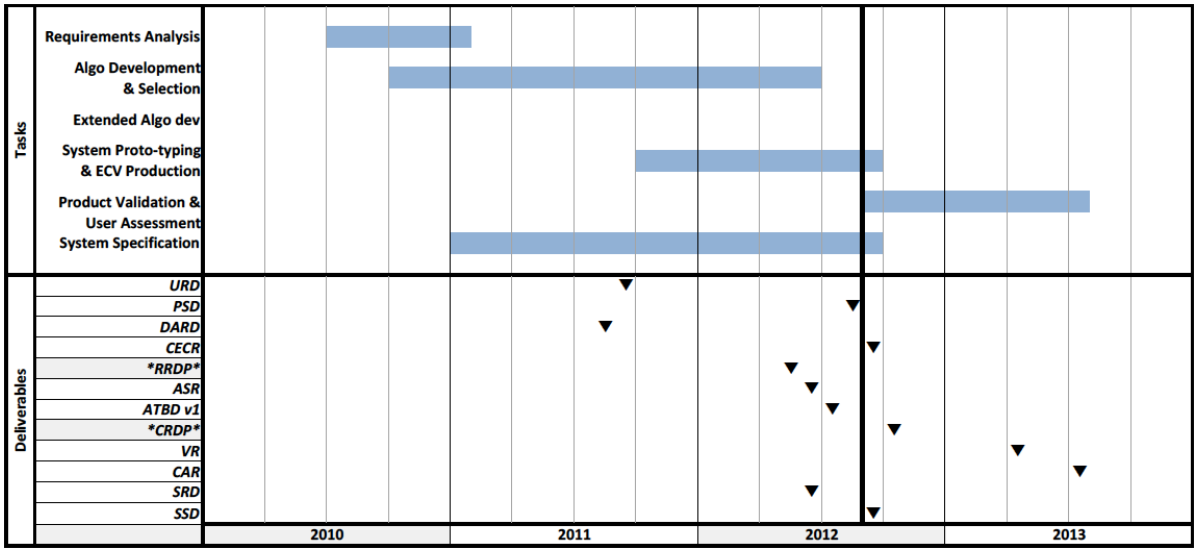
7 SEA_LEVEL_CCI *(GCOS O.2)*

7.1 Overall Project Status

The *Sealevel_cci* project is approaching the end of its second year. Important new results have been obtained on various aspects of the altimetry data processing leading to significant improvements of the sea level record, approaching the quality requested for climate study applications. Notably, the uncertainty of the global mean sea level derived from ERS-1 / ERS-2 / Envisat using the new CCI standards has decreased to the mm/year level.

The project reached a major milestone with the Algorithm Selection Meeting in May 2012. with an independent panel of 10 external international experts assessing Fifty (50) algorithms. ECV production has now started and will deliver in September 2012 (for a presentation at the "20 Years of Progress in Radar Altimetry" Symposium). Validation will start at the end 2012, in due time for project completion in July 2013. The Systems Engineering team has developed specifications for the operational system requirements, and was actively involved in the CCI Systems Engineering Working Group and cross-ECV project collaboration.

Overall Project Schedule



Team Composition

Science Lead	LEGOS - (France)
Project Management	CLS - (**lead**) (France) Logica – (United Kingdom)
EO Science Team Algorithm	CLS - (**lead**) (France) GFZ, isardSAT, DTU Space, LEGOS, National

Development	Oceanographic Centre (NOC) and University of Porto
Climate Research Group	Univ. Hamburg - (**lead**) (Germany) NERSC, ECMWF and LEGOS
System Engineering Team	Logica - (United Kingdom) CLS - (France)

7.2 Requirements Analysis and Product Specification

User Consultation

User Requirements were collected on the one hand from the international framework (GCOS, WMO, WCRP, OCEANOBS'09), and from the climate modelling communities (CMUG), through the analysis of the existing documents, and on the other hand by consulting the Ocean Surface Community. The *Sealevel_cci* project allowed to refine the existing requirements focused on global mean sea level by introducing new requirements for the regional mean sea level, the meso-scale signal and the time mean signals.

Some gaps have been identified between the requirements and the state-of-the-art for altimetry: In particular the accuracy required for the global mean sea level trends (0.3 mm/y) which corresponds to the minimum accuracy needed to distinguish the different sources of sea level variability (ocean thermal expansion, ice sheet, land water, glaciers) is not achieved today. Similarly, it is difficult to obtain an accuracy < 2-3 mm on yearly times scales for the inter-annual sea level variability.

International Scientific coordination

The project is closely connected to international activities related to global and regional analyses of the climate system specifically activities within the WCRP, such as CLIVAR or CLIC. *Sealevel_cci* has also cooperated with two EU projects, notably MONARCH-A (dedicated to the Arctic climate; led by NERC), which is a candidate model for bringing several ECVs together in a joint use and evaluation, and MyOcean. The role played by CCI partners (CLS, NERSC, DTU, University of Hamburg), ensures a good coordination between the two projects. Although the *Sealevel_cci* does not have a direct linkage with other ECV projects, a potential synergy has been identified with the *SST_cci* as well as the two recently launched CCI projects on sea ice and ice sheets. In parallel, close collaboration with Meteo-France has been set up.

ECV products description

Two types of products will be produced as part of the project, the Fundamental Climate Data Records product and the Essential Climate Variable product. The first one is a mono-satellite product containing the sea level time series measured at the nadir of each satellite together with the geophysical corrections applied in the

calculation. The second one is a multi-satellite product, containing monthly averaged of sea level anomalies.

Fundamental Climate Data Record						
Parameter	**Sensors**	**Spatial coverage**	**Spatial Resolution**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Along track Sea Level	Radar altimeter from: ERS-1 ERS-2 Envisat GFO T/P Jason-1 Jason-2	Latitude bound: -82°/82° -82°/82° -82°/82° -72°/72° -66°/66° -66°/66° -66°/66°	7 km	e.g. 1991-1996 1995-2003 2002-2010 2000-2008 1993-2005 2001-2010 2008-2010	1 s	100 GB
Explanatory text: The FCDR (SL_FCDR) is a mono-mission product generated from an altimeter level-2 product, such as geophysical data records (GDR). It contains along-track sea surface height (SSH) estimates over the ocean with a quality control indicator to remove spurious measurements. It also contains the altimeter standards applied in the SSH calculation, such as the geophysical corrections, the mean sea surface, etc. In addition, information derived from the cross-calibration of the SSH between all the missions is provided, in order to remove the global SSH bias and to homogenize long spatial scale errors (due to orbit calculation for instance). This Sea level ECV product is associated with altimetry Level 2.						

Sea Level ECV						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Gridded Sea Level	Radar altimeter from : ERS-1 ERS-2 Envisat GFO T/P Jason-1 Jason-2	Latitude bound: -82°/82°	25km	1993-2010	Monthly	1G
Explanatory text: One type of ECV product is defined herein: it is composed of monthly averaged sea level anomalies (SLA) derived from SLA grids calculated after merging together measurements from all altimetric missions into monthly grids with a spatial resolution of 1/4 degrees. Additionally, the product contains oceanic indicators. This corresponds to static files over the whole altimeter period describing the evolution of the SLA grids above described. Several indicators are provided such as the temporal evolution of the global mean sea level (MSL) with the global trend, the regional MSL trends, the amplitude and phase of the main periodic signals (annual, semi-annual). Finally, the product contains also the errors of oceanic indicators: This corresponds to the errors of the oceanic indicators, especially those concerning the estimation of the global and regional MSL trends. This sea-level ECV product is associated with altimetry Level 4.						

7.3 Algorithm Development, Inter-comparison, Selection

Results of Round Robin inter-comparison

50 Sea Level corrections, instrumental or geophysical, have been developed and/or tested. For each algorithm, Round Robin Data Packages (RRDP) gathering numerous diagnoses have been produced. All results have been synthesized by the Earth Observation Team in 12 validation reports, one for each Sea level component. The whole altimetry period (20 years) has been considered to produce the RRDP, and the new algorithms have been applied on up to 7 missions (ERS-1, ERS-2, Envisat, Jason-1, Jason-2, T/P, and GFO). Finally, a selection meeting was organized on the 2-4 May in Toulouse with 10 invited external international experts who helped selecting the algorithms to be used for the product generation, thus insuring an independent selection process.

The production of such extensive results has been made possible by the coordinated work of a pan-European organization (the consortium) from the development to the selection and by the implementation of a common, dedicated and robust testing infrastructure (database, diagnostics processing chain) based on the DUACS existing system allowing to compare each individual algorithms.

Expected Product Improvements

The project team expects to significantly improve the ECV products and in particular the regional/local sea level trends which are of utmost importance for coastal areas. Preliminary results showed also that the uncertainty of the global MSL trend derived from ERS-1 / ERS-2 / Envisat using the new CCI standards decreased to the mm/year level thanks to the specific effort done on these missions. Significant progress has been made on the characterization of the errors.

7.4 System Prototyping and ECV Production

Data Gathering and Data Quality

30 types of data were necessary to run the algorithms and to perform the inter-comparison and selection task: satellite and ancillary data from 6 altimeter missions (ERS-1, ERS-2, Envisat, Jason-1, Jason-2, T/P, GFO) as well as in situ data. Among all required input datasets, several issues were raised, causing a delay in the development planning. Moreover, the team had to deal with a mis-matched phasing of the *Sealevel_cci* project with the ESA mission reprocessing activities (e.g., Envisat and ERS data reprocessing). Strong efforts were made by the SL project in terms of coordination: several meetings and teleconferences with ESA and CNES were organized in order to mitigate this issue. This allowed the project to benefit from the optimal input data from the external projects. Notably a very good link was established between the SLCCI project and the Envisat Quality working group, with very positive feedbacks through specific presentations at the 3 last QWG meetings.

Product Generation

The processing chain and associated database were finalized in May 2012, taking into account the outcome of the selection meeting. The production of the Phase 1 SLCCI ECV products started by mid-May 2012 and will be delivered in September 2012. Thanks to the new and homogeneous algorithm used, this new ECV dataset will improve the available sea level data, notably the trends at regional scales.

7.5 Product Validation and User Assessment

Product Validation (plans)

These products will be validated with two approaches. First a direct comparison between the new ECV and the V0 reference product (Aviso) will be performed using the RRDP infrastructure developed in this project. Then assessment of the product quality will be performed through an assimilation exercise and through comparisons with climate and ocean model outputs products.

Uncertainty Characterization

The RRDP exercise allowed to better characterized the uncertainty, with estimates of different climate products: global mean sea level, regional mean sea level, meso-scale activity, etc., as defined in the URD. Consequently, this allows the team verify if the new products answer or not to the user requirements.

ECV Data Access and exploitation

Reprocessing and validation of 18 years of altimetry data taking into account all altimeter missions will be performed in 3 months, to have them ready for the “20 Years of Radar Altimetry” Symposium to be held in Venice, 24-29 September 2012. This is a big challenge. Moreover, despite its relatively good maturity, the sea level ECV is not yet really used by the climate models for their validation. The ESA CCI program represents a very good opportunity to enhance closer links between modelling and observations.

7.6 System Specification

The System Requirements Document (SRD) provides a complete set of system requirements for an SLCCI operational system based on DUACS, an existing operational system. Reuse of DUACS is undertaken in context of ECSS standard Q-ST-80C on system reuse, with hardware and software specification reasoned in the forthcoming System Specification Document (SSD) V1 based on architectural specification standard ISO 42010. Major operational software sub-systems will comprise of the Production Chain (used in Task 3), alongside Monitoring, Product Management, and Product Access subsystems.

Sustainability is a crucial aspect of the specification of the *Sealevel_cci* operational system, as longevity of the system beyond the end of the CCI program needs to be

ensured. Key requirements include provision for future algorithm changes in order to accommodate the system to future science developments (and not solely to CCI Phase I Task 3, an archiving facility for operational long term data preservation of ECV products, and architectural consideration to ensure a means for pan-ECV product integration for future users).

7.7 Plan to complete Phase 1

Three kinds of activities are necessary to complete Phase 1. First, once the ECV time series has been produced, the validation activities have to be performed by each member of the CRG. In parallel, the WP5 system tasks and notably the reports describing the future system have to be finalized. Then, and it is probably the most important, the team will promote the ECV products by writing scientific articles and participating to international meetings, such as the 20 year of altimetry meeting in September 2012.

7.8 General comments/feedback to ESA

This program allowed setting up an efficient pan-European organization and a robust approach for improving the sea level products as needed for climate research. It has also facilitated the link with the climate scientists and their needs in terms of ECVs. The transverse activities, coordinated at high level by ESA, were necessary but still need to be reinforced and anticipated for the Phase 2.

7.9 Relevant Scientific Publications

Presented at the European Geosciences Union General Assembly, 2012, Vienna:

- Ablain et al., Improvement of global and regional Mean Sea Level trends derived from all the altimetry missions.
- Rudenko et al., Computation and evaluation of new consistent orbits of Envisat, ERS-1 and ERS-2 in the ITRF2008 reference frame"

Presented at Ocean Surface Topography Science Team, 2011, San diego OSTST:

- Ablain et al, "Improvement of global and regional Mean Sea Level trends derived from all the altimetry missions"
- Thibaut and Roca, "New assessment of the RA-2 instrumental corrections and impact on the Mean Sea Level Trend"
- Carrere et al, "Improving the dynamic atmospheric correction for mean sea level and operational applications of altimetry"
- Fernandes et al., “Wet Tropospheric Correction: Filling the Gaps from Coast to Coast”
- Cipollini et al., A New Parameter to Facilitate Screening of Coastal Altimetry Data and Corrections

Project presentation, "The ESA Sea Level CCI project", at various meetings:

- OSTST, 2011, Lisbon

- EGU, 2011, Vienna
- MARCDAT-III, 2011, Frascati
- Planet Under Pressure Symposium, 2012, London

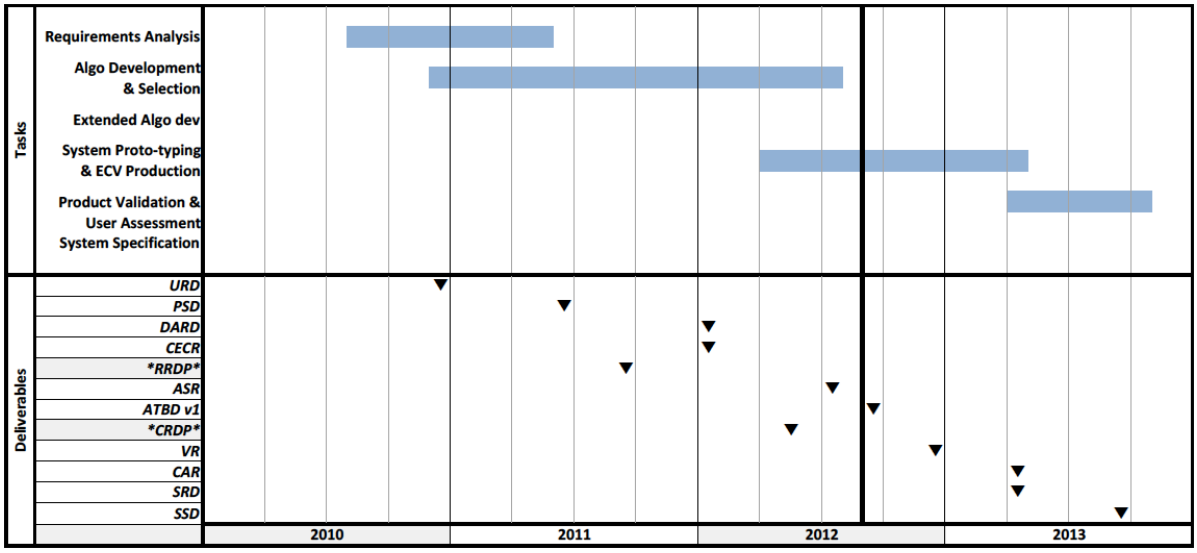
8 SEA_SURFACE_TEMPERATURE_CCI *(GCOS O.3)*

8.1 Overall Project Status

Summary of Overall Progress to date

The *SST_cci* project has developed new techniques for the ESA Along Track Scanning Radiometers (ATSRs) that will make them the reference for all sensors used in the SST ECV. This is new, and will give the first climate-quality observations from other traditional SST sensors that preserve independence from *in-situ* records. The *SST_cci* product generation should complete by April 2013, and their full climate assessment by October 2014.

Overall Project Schedule



Team Composition

Prime Contractor/ Scientific Lead	Univ. Edinburgh - (United Kingdom)
Project Management	Space ConneXions Ltd (United Kingdom)
EO Science Team	Univ. Edinburgh (United Kingdom) Météo France (France) Danish Met Inst (Denmark) Meteorology Norway (Norway) Univ. Leicester (United Kingdom)
Climate Research Group	Met Office Hadley Centre (United Kingdom)
System Engineering	Brockmann Consult (Germany)

Team	

8.2 Requirements Analysis and Product Specification

User Consultation

Eight hundred users of SST for all types of climate applications were targeted, with 108 responding. 130 detailed User Requirements were identified. Three key requirements and the corresponding state of the art are:

Requirement	**Approach**
Need consistent climate-quality SST covering >30 years.	*SST_cci* spans 21 years; needs to be extended back (12 years) and to the present, using AVHRR sensors; requires new techniques ensuring consistency.
Improved characterization of uncertainties in SST.	*SST_cci* prototype products will be state-of-the-art in this regard.
Reliable extension in time of climate SST records within 1 month of real time.	Designed into the *SST_cci* System Specification

International Scientific coordination

Applicable requirements for the SST ECV are set and managed by GCOS. The reference science body is the Group for High Resolution SST (GHRSST). GHRSST has had presentations and consultations on *SST_cci*. Key insights and ideas from this project are now driving the GHRSST agenda in the Climate Data Record, Estimation and Retrievals, and Validation working groups. The *SST_cci* project interfaces with MyOcean and co-operates with NOAA's Climate Data Records programme on AVHRR. Output from the "ERA-CLIM" FP7 project has been utilized in the project. The team is working closely with the *OceanColour_cci* project and CMUG. The project was presented at WCRP (Denver, 2011), Ocean Sciences (SLC, 2012) and GHRSST (annually).

ECV products description

The main *SST_cci* prototype product will be an SST record for 1991 to 2010 based on ATSRs and AVHRRs. This addresses users' needs for multi-decadal, independent, stable records with daily coverage – a combination that cannot be provided from either series of sensors alone.

The ATSR SSTs in *SST_cci* products will be the most accurate (≤ 0.1 K bias, all regions) and stable (constant calibration to <0.005°C/yr) obtained from space. Their independence from in situ measurements means they can be used rigorously to verify and/or challenge the current assessment of recent marine climate change.

The AVHRR observations will be tied to the ATSR calibration, using new techniques developed within the project. This approach addresses sampling limitations arising from the relatively narrow swath of SST, while preserving climate quality.

Demonstration products of 3 months will be produced that show the impact of other sensors. One demonstration will clarify the potential role of passive microwave SST observations for climate-quality SST, the second will clarify use of Metop AVHRR full resolution and geostationary SST from SEVIRI.

ECV Product Name:						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Skin Sea Surface Temperature (at time of observation)	All ATSRs and AVHRRs	Global oceans	ATSRs: 0.05 deg grid (L3) AVHRRs: satellite project, resolution ~4 km (L2)	1991 - 2010	Up to twice daily per sensor, depending on clouds	ATSR: ~0.4 TB/yr AVHRR: ~1.8 TB/yr (Both skin and depth SST are in same files.)
Depth Sea Surface Temperature (at standard local time)	All ATSRs and AVHRRs	Global oceans	ATSRs: 0.05 deg grid (L3) AVHRRs: satellite project, resolution ~4 km (L2)	1991 - 2010	Up to twice daily per sensor, depending on clouds	
Analysed Depth Sea Surface Temperature	All ATSRs and AVHRRs	Global oceans	0.05 deg grid (L4)	1991 - 2010	Daily, spatially complete	~0.05 TB/yr
Analysed Depth Sea Surface Temperature	AATSR, AVHRR, TMI, AMSRE	Global oceans	0.05 deg grid (L4)	Jun-Aug 2007	Daily, spatially complete	~0.05 TB/yr
Analysed Depth Sea Surface Temperature	AATSR, Metop AVHRR, SEVIRI,	Global oceans	0.05 deg grid (L4)	Jan-Mar 2012	Daily, spatially complete	~0.05 TB/yr
Explanatory text: Skin SST is the primary variable, in the sense that satellite radiometers are sensitive to the temperature of the ocean's surface skin. Skin SST is directly relevant to air-sea fluxes, etc. Depth SST is estimate from the skin SST plus a model that adjusts (i) to the 20 cm typical depth of buoy measurements, and (ii) to standard local times of day (10.30/22.30h) in order to remove from the long term trend the influence of the diurnal cycle in SST (since particularly AVHRRs sample at different local times). The depth SSTs are therefore more stable, and more comparable to in situ measurements and climate model upper layer SST.						

8.3 Algorithm Development, Inter-comparison, Selection

Results of Round Robin inter-comparison

Ten groups (5 US, 4 EU, 1 other) indicated interest to participate. The sensors involved were: ATSR2, AATSR, NOAA-AVHRRs 17-19 and Metop AVHRR. The protocol was a blind trial: participants, including the SST CCI EO team, undertook

SST retrievals without access to the corresponding validation data. Pre-defined selection metrics were used for the assessment. One US and one UK external team contributed selection data, and selection metrics were calculated for 35 different algorithms. A common optimal estimation (OE) retrieval has been selected for ATSRs and AVHRRs. This should give excellent consistency.

Expected Product Improvements

SST CCI will produce a satellite SST record that achieves the following improvements:

- stable (<0.005°C/yr), accurate (≤ 0.1 K), independent SSTs across 20 yrs and 12 different sensors (previously only 3 ATSR sensors with this quality)
- SST skin and depth estimates for AVHRRs (new)
- new uncertainty information in response to user requirements

8.4 System Proto-typing and ECV Production

Data Gathering and Data Quality

Input data sets include satellite data (ATSRs, AVHRRs plus others) and auxiliary data (ECMWF reanalysis fields). No data availability problems. Interaction with AVHRR re-calibration programme in NOAA is an important development. The *SST_cci* team was represented on the AATSR quality working group. A major innovation in the project has been collation of data extracts into a Multi-sensor Match-up System, which has been or will be the foundation for all algorithm development, algorithm selection, product verification and product validation work.

Product Generation

The 20-year time-series will be generated first, commencing October 2012, followed by the two demonstration products. The satellite (L2/L3) processing will take place at University of Edinburgh and (SEVIRI, Metop AVHRR) Météo-France. Analysed SST (L4) will be generated at the Met Office. The data volume involved is >40TB but the technical challenge this presents is well in hand.

8.5 Product Validation and User Assessment

Product Validation (plans)

Product validation will include independent validation against a set of reserved drifting buoy observations (not used in any algorithm development or selection). Other independent validation will be done against all collected ship-mounted radiometer and profile float (Argo) data, as well as tropical moored buoys. Climate assessment will exploit well-tried methods at the Hadley Centre, and comparisons against 12 other global SST data sets. Trends (global and regional), specific SST indices (such as El Nino indices), multi-annual averages, autocorrelations in time and ocean fronts will all be analysed. The validation activities validate the SSTs and the SST uncertainties.

Uncertainty Characterization

The principles adopted in SST CCI are:

- All SSTs should have a realistic total uncertainty attached to them
- Realistic uncertainties need to be calculable for averaged products, and we have defined a new decomposition of the total uncertainty that permits this
- Uncertainties are part of the product, and as such will themselves be validated to give users confidence in them

The approach to uncertainty characterisation in this project is thus very clear and well advanced. Remaining challenges relate to:

- Developing new techniques to validate uncertainty estimates
- The need to better understand spatiotemporal covariance of errors
- Encouraging exploitation of uncertainty information by users

ECV Data Access and exploitation

Data access using ftp is foreseen. Users beyond SST CCI will be engaged within the climate assessment process in the final 6 months of the project. These will include use: by climate modellers for monthly to decadal prediction; for climate variability and change research; by the GCOS SST working group; and by the GHRSST Climate Data Record, Inter-comparison and Validation working groups. Feedback will be gathered via dedicated WebEx interaction sessions and in the context of GHRSST-XIV (in 2013). The project's Climate Research Group will use SST CCI products within the Hadley Centre climate assessment framework. Many users want >30 year records: a key challenge is to persuade them to exploit the products now, and provide feedback to help build a >30 year record.

8.6 System Specification

The phase 1 prototype system comprises three geographically separated units. The main processing for ATSRs and AVHRRs takes place on a Sun grid engine cluster of several hundred nodes at the University of Edinburgh. SEVIRI and Metop AVHRR files have been generated at Météo-France Lannion. The combined SST outputs of these units will be processed to L4 analysis at Met Office. Each element adapts precursor systems, and they are brought together in a new way within SST CCI. With the available processing power, the rate-determining factor is data volume, despite the complex cloud detection and retrieval algorithms.

A sustainable system must accommodate, in addition to the data inputs in this Phase 1, full resolution Metop AVHRR and future Sentinel 3 SLSTR data streams, which represent an order-of-magnitude increase over the prototype inputs per annum. The future system must have capacity to maintain routine extension of a current version of the climate data records in short delay mode, while simultaneously being able to reprocess past data for major upgrades to the versions, so that a complete record is always available to the users. The future system must support collection of user feedback and sophisticated multi-sensor match-up

techniques, that together allow a rapid improvement cycle in products in response to user feedback.

8.7 Plan to complete Phase 1

The critical path is: prototyping of the (newly selected) algorithms, product generation and verification, and product validation and climate assessment. User consultation and feedback is to be obtained at the earliest possible points after product generation, and on-going thereafter.

8.8 General comments/feedback to ESA

Appreciation to ESA for funding this essential project to release the full potential of satellite archives to address the need for high-quality information on climate for policy and science.

8.9 Relevant Scientific Publications

Merchant C.J., et al. A twenty-year independent record of sea surface temperature for climate from Along Track Scanning Radiometers, in preparation for Journal of Geophysical Research.

The Sea Surface Temperature Climate Change Initiative: Protocol and Outcome for Selecting Sea Surface Temperature Retrieval Methods. Christopher J Merchant, et al., in preparation for RSE special issue on algorithm selection for climate products

Bulgin et al., The Sea Surface Temperature Climate Change Initiative: Alternative Image Classification Algorithms for Sea-Ice Affected Oceans. in preparation for RSE special issue on algorithm selection for climate products

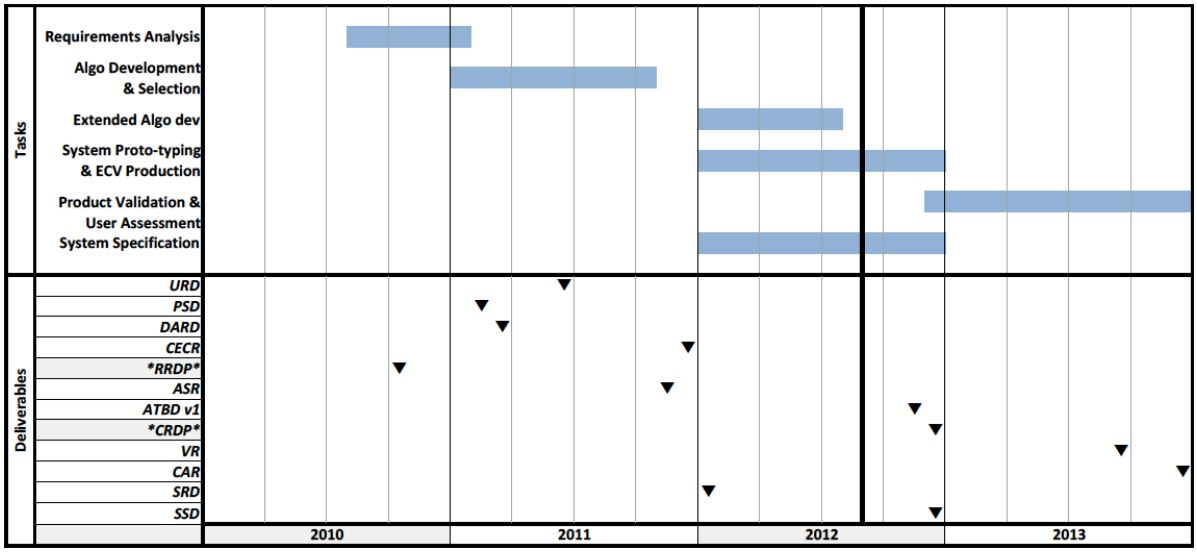
9 OCEAN_COLOUR_CCI *(GCOS O.4)*

9.1 Overall Project Status

Summary of Overall Progress to date

The *Oceancolour_cci* project has achieved very credible results from the Round Robin exercise and 5 peer review papers under preparation. A processing infrastructure supporting an agile development and production process is being setup. There is close cooperation with US colleagues in the development of processing algorithms and error characterisation. Dialogue has been opened with the modellers and the climate research community to test and evaluate the advantages of *Oceancolour_cci* products in comparison with existing products. Investigation into the required evolution of the current processing infrastructure (including the PML processing chains and the Calvalus system) to the future operational system is underway. The schedule for year 2 remains as the major on-going project challenge. The project continues to remain on track to meet its 3-year objectives.

Overall Project Schedule



Team Composition

Prime Contractor/ Scientific Lead	PML – S. Sathyendranath (United Kingdom)
Project Management	Telespazio VEGA (United Kingdom)
EO Science Team	Helmholtz-Zentrum Geestacht (Germany) Brockmann Consulting (Germany) JRC (Italy); HYGEOS (France)

Climate Research Group	NERSC (Norway)
System Engineering Team	PML - (United Kingdom) Telespazio VEGA - (United Kingdom) Brockmann Consulting (Germany)

9.2 Requirements Analysis and Product Specification

User Consultation

The users contacted include EO Scientists and Climate Modellers via email and targeted meetings. The total number of responding scientists to the questionnaire was 78. The most important requirements are: global scale analysis, primary production studies and ecological provinces (EO Scientists); model validation (Modellers). The GCOS requirements for accuracy (5% for radiances and 30% for chlorophyll) and stability (0.5% for radiance and 3% for chlorophyll) remain the main gap between user requirements and state of art.

International Scientific coordination

International collaboration continues with NASA on the SeaWifs, MODIS and MERIS data exchange, and with a broader US community on participation in the inter-comparison of algorithms. *Oceancolour_cci* reports to the International Ocean Colour Coordination Group (IOCCG) periodically, and IOCCG is invited to review key documents. In September 2011, the IOCCG decided to establish a standing Working Group (WG) on the ocean colour ECV to evaluate water-leaving radiance and chlorophyll-a concentration products for climate research. It is anticipated that *Oceancolour_cci* will be contributing strongly to the activities of the WG. The team continues to work closely with the *SST_cci* (assessment of ocean fronts; system design for Phase 2). The CMUG meeting in Toulouse on 14-16 May was attended by the *Oceancolour_cci* Science Leader and a representative from the Climate Research Group with positive progress being reported. Three scientific papers have already been published in Optics Express and the Journal of Marine Systems. Papers have been accepted for the IGARSS 2012 and 44th Liège Colloquium events and 3 related papers are planned for the CCI special issue of Remote Sensing of the Environment on the Round-Robin comparison on In-water bio-optical algorithms, spatial and seasonal homogeneity of atmospheric Correction Algorithms and an assessment of atmospheric correction algorithms based on in-situ measurements.

ECV products description

The *Oceancolour_cci* product list includes spectral water-leaving radiances; and in-water bio-optical and biogeochemical properties derived from the water-leaving radiances such as the chlorophyll concentration, and key Apparent Optical Properties (AOPs) and Inherent Optical Properties (IOPs).

The project focuses on the water-leaving radiances in the visible domain, derived chlorophyll and inherent optical properties and will utilise data archives from ESA's MERIS and NASA's SeaWiFS and MODIS sensors archives. The goal is to generate time series of multi-mission merged products, starting with the remote sensing reflectance RRS. Merging RRS from various satellite missions has to rely on a thorough knowledge of each mission-specific data record, and a complete inter-comparison analysis.

Inter-mission biases are particularly important to quantify since they can lead to artificial trends in the merged data set that would lessen the usefulness of the series for climate studies. In turn, the determination of inter-mission biases is hampered by the fact that the ocean-colour missions considered (MERIS, MODIS, SeaWiFS) have differing spectral band specifications. This issue is addressed by using a band-shift correction scheme that corrects for differences in spectral bands and leads to a common band set. Then, bias correction methods are developed to account for inter-mission biases, allowing the construction of a consistent multi-sensor time series of RRS.

An overall scheme for addressing these challenges has been established, and is currently being tested.

The choice of products to be generated is in line with the feedback received from the EO Scientists and Modellers via the questionnaire. The primary outputs are daily-composited level 3 binned merged data at 1/24 degree (~4km), though we will produce a number of intermediate products and retain and distribute as many as storage capacity allows. The size estimates are for netCDF files with all products included (split out by product in tables below). The priority order for these are:

- level 3 binned merged composites (daily, weekly, monthly, yearly)
- level 3 geographic projection merged composites
- level 3 binned + geographic projection single scenes
- level 2 data

There is an ambition to produce 1km data too, though this requires a significant step increase in data volume (16x).

ECV Product Name: Biogeophysical Products						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Phytoplankton Chlorophyll-a concentration (Chl-a) [mg m-3]	MERIS, MODIS, SeaWiFs	Global	4x4km	1997-2012	daily	2 TB
Explanatory text: These are level 3 binned, multi-sensor merged, daily composites (primary product, others not listed). Uncertainty layers are also included. This is one of the main OC products.						

ECV Product Name: Apparent Optical Properties						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Water-leaving Radiance	MERIS, MODIS, SeaWiFs	Global	4x4km	1997-2012	Daily	12 TB
Explanatory text: These are level 3 binned, multi-sensor merged, daily composites (primary product, others not listed). Uncertainty layers are also included.						
Spectral attenuation coefficient for downwelling irradiance (Kd) [m-1]	MERIS, MODIS, SeaWiFs	Global	4x4km	1997-2012	Daily	2 TB
Explanatory text: These are level 3 binned, multi-sensor merged, daily composites (primary product, others not listed). Uncertainty layers are also included.						

ECV Product Name: Inherent Optical Properties						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Absorption (a) and backscattering coefficients (bb) [m-1]	MERIS, MODIS, SeaWiFs	Global	4x4km	1997-2012	Daily	48 TB
Explanatory text: These are level 3 binned, multi-sensor merged, daily composites (primary product, others not listed). Uncertainty layers are also included. This is one of the main OC products.						
Coloured dissolved organic matter absorption (aCDOM) [m-1]	MERIS, MODIS, SeaWiFs	Global	4x4km	1997-2012	Daily	2TB
Explanatory text: These are level 3 binned, multi-sensor merged, daily composites (primary product, others not listed).						
Suspended Particulate Matter (SPM) and Phytoplankton absorption [m-1]	MERIS, MODIS, SeaWiFs	Global	4x4km	1997-2012	Daily	2 TB
Explanatory text: These are level 3 binned, multi-sensor merged, daily composites (primary product, others not listed).						

9.3 Algorithm Development, Inter-comparison, Selection

Results of Round Robin inter-comparison

Eight IOP models (12 versions in total) and 16 chlorophyll-a models from Europe and North America were included in the comparison. On the basis of the round-robin results, MERIS data are being processed using the POLYMER algorithm. For processing SeaWiFS and MODIS data, the best performer is the SeaDAS processor.

The in-water algorithm that best satisfies the *Oceancolour_cci* criteria is the Quasi Analytic Algorithm.

An important lesson from the exercise has been that most algorithms perform well, but that no algorithm is perfect. The difference between the "best" algorithms and the rest is small, and so the *Oceancolour_cci* project has to be vigilant to keep abreast of progress in the field.

Expected Product Improvements

GCOS requirements call for daily maps of water-leaving radiances at 4km resolution. POLYMER's ability to retrieve data under sun glint will help improve MERIS coverage, and reduce gaps in daily images. Since tests are still being carried out, it is too early to make definite statements, but in one example of a 10-day MERIS composite, the global coverage was 69% using POLYMER whereas it is 49% in the the standard MERIS Level 2 product, which is in this case comparable with the GlobColour product. Comparisons with in situ data did not indicate any significant increase in errors under sun glint.

However, the GCOS requirements for accuracy (5% for radiances and 30% for chlorophyll) and stability (0.5% for radiance and 3% for chlorophyll) remain difficult targets. A serious problem with regard to continuity is presented by the demise of MERIS. The timely launch of Sentinel-3 is a key issue for *Oceancolour_cci.*

9.4 System Proto-typing and ECV Production

Data Gathering and Data Quality

The input datasets include MERIS, SeaWiFS and MODIS, global coverage. Data acquired in 2003 will be processed initially (all three sensors were operating well in 2003 thus enabling inter-sensor comparisons under ideal conditions) followed by 2008 and then the remaining years. There has been close interaction with the MERIS Quality Working Group, where the results of the Atmospheric Correction round robin will be discussed in October.

Product Generation

The 2003 data will be ready by September 2012 and the 2008 data by December 2012. It is planned that all data will be ready by May 2013. The schedule for year 2 remains the biggest on-going challenge. Expected success is the uptake of the OC-CCI products as part of the MyOcean offering. The demise of MERIS in 2012 is a major challenge. Potential use of the Indian OCM-2 and NOAA's VIIRS data as additional data sources needs to be explored.

9.5 Product Validation and User Assessment

Product Validation (plans)

The Product Validation methodology is defined in the Product Validation Plan, which is summarised by the following stages:

- Algorithm selection criteria
- The round-robin for atmospheric correction (MERMAID data)
- The round-robin for in-water algorithms (NOMAD dataset)
- Stability and Angle tests
- Error Budget analysis
- Validation of pixel Identification
- Detailed description of the work plan

The results are described in the PVASR and will be published in peer reviewed papers. Brockmann Consult has collected a large dataset of manually classified MERIS pixels (PixBox Dataset). This work was done outside the project but can be used for validation of the *Oceancolour_cci* pixel identification.

Uncertainty Characterization

The following approaches were considered regarding uncertainty characterisation:

- Simple binning: Partition validation data into discrete class intervals, establish errors for each class interval, map error according to class interval
- Optical Water Types: Use fuzzy logic to establish membership of different optical water types at each pixel, and use errors associated with each optical water type and the membership, to calculate error at pixel.

After comparison and evaluation, it was decided to follow the approach based on optical water types for the error characterisation. End users are provided with a per pixel estimates of associated errors. The uncertainty approach is now well defined with no foreseeable problems.

ECV Data Access and exploitation

The products are currently made available to users on an FTP site. There is continual engagement with the modellers to ensure constant feedback is provided regarding the suitability of products. Revised versions of products are generated based on this feedback.

9.6 System Specification

The prototype processor gathers together the best-in-class processing subsystems for each sensor, as evaluated in the PVASR documents and combines these with novel components created during the CCI programme (e.g. the uncertainty classification scheme based on fuzzy class memberships, bias-correction and band-shifting in the data merging stages). As such, it is a collection of varying components from multiple sources compiled into a processing chain in a pragmatic manner and designed to be flexible and adaptable to meet changing requirements

and processing deadlines. The core components are: NASA's SeaDAS, ESA's BEAM processing framework, JRC's new data merging algorithms, Moore et al's uncertainty classification and a large amount of support framework code. The primary constraints on the system are development time and storage. Integrating many very different components is a slow process, although generally faster than redeveloping them. The OC storage requirements are also very high - if all intermediate products were kept, multiple petabytes of storage would be needed.

The prototype processor currently runs in a batch-oriented cluster of Linux machines, with a single orbit being the basic unit of parallelisation, and is easily adaptable to grid environments. Parts of the system will run on Brockmann Consult's Calvalus system, which is a more tightly integrated Hadoop-based cluster. This has significant advantages for processing large data areas, because it can split processing at a finer level across multiple machines, using the map-reduce paradigm popularised by Google and other major data handlers, and because it supports data locality (moving processing close to the data and reducing the amount of data moving around slow networks). During the course of the project, the development team aim to move components into the Calvalus and BEAM frameworks where this is pragmatic and appropriate, in order to produce a cleaner prototype that can be taken into the later operational development stages of the CCI programme.

System dimension – key factors:

- Data input: 188 TB
- Data output: 66 TB (primary products only)
- Processing time: 330,000 CPU hours
- Validation time: 200 man hours

9.7 Plan to complete Phase 1

Global datasets for 2003 and 2008 remain the focus for the rest of 2012 with a complete time series of products available during May 2013. Interaction and engagement with the climate modellers have started and the process of model assessment and comparison with in-situ and inter-satellite measurements will be the focus in 2013.

9.8 General comments/feedback to ESA

Progress to date on the *Oceancolour_cci* has been very rapid. The project is well into the second phase of work and on target for completion by December 2013 although the schedule remains very tight.

9.9 Relevant Scientific Publications

Brewin, RJW, et al., (2011) A model of phytoplankton absorption based on three size classes. Appl. Optics, 50: 4535-4549.

Mélin, F, et al., (2011) Assessment of MERIS reflectance data as processed with SeaDAS over the European seas. Optics Express, 19 (25) 25659-71.

Racault, M-F, et al., (2012) Phytoplankton phenology in the global ocean. Ecological Indicators, 14 (2012) 152–163. doi:10.1016/j.ecolind.2011.07.010

Roy, S, et al., (2012) Sequential variations of phytoplankton growth and mortality in an NPZ model: A remote-sensing-based assessment. Journal of Marine Systems 92 (2012) 16–29.

Steinmetz, F, et al., (2011) Atmospheric correction in presence of sun glint: application to MERIS. Optics Express 19 (10): 9783-9800.

Zhai, L, et al., (2011) Ocean response to attenuation of visible light by phytoplankton in the Gulf of St. Lawrence, J. Mar. Syst. (2011), doi:10.1016/j.jmarsys.2011.05.005

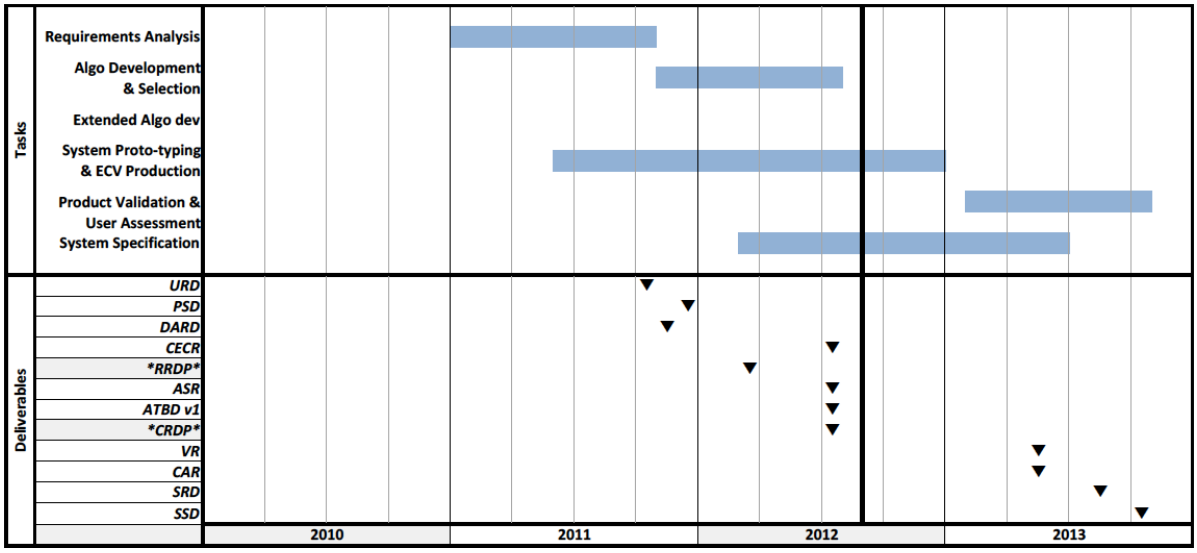
10 GLACIERS_CCI *(GCOS T2.1)*

10.1 Overall Project Status

Summary of Overall Progress to date

Thanks to the substantial contribution of the Glaciers_cci project we now have a globally complete glacier inventory that is heavily used for numerous IPCC AR5 related modelling efforts. Also for the other products investigated in the project (elevation change, velocity) substantial progress has been made on more automatic and/or consistent data processing. As work originally foreseen in year 3 (data production) was already accomplished in year 1, the project is currently shifted by about 1/2 year against its original schedule. This shift will be compensated for in year 3

Overall Project Schedule



Team Composition

Prime Contractor/ Scientific Lead	Department of Geography, University of Zurich (Switzerland)
Project Management	Department of Geography, University of Zurich (CH)
EO Science Team	Department of Geography, University of Zurich (CH) ENVironmental Earth Observation IT GmbH (ENVEO)(Austria) Univ. Leeds (UL), School of Earth and Environment (UK) Gamma Remote Sensing AG (GAMMA)(CH) Department of Geosciences, University of Oslo (GUIO)(N)
Climate Research Group	University of Bristol, School of Geosciences – CRG Lead (UK)

	ETH Zurich, Institute for Atmosphere and Climate (IAC) (CH) Academy of Sciences & Humanity Munich, (KfG) (D) University of Zurich, World Glacier Monitoring Service (WGMS) (CH) National Snow and Ice Data Center (NSIDC) (USA) Norwegian Water Resources and Energy Directorate (NVE) (N) International Centre for Integrated Mountain Development (ICIMOD) (Nepal)
System Engineering Team	Gamma Remote Sensing AG (GAMMA)

10.2 Requirements Analysis and Product Specification

User Consultation

The determination of user requirements was based on documents from various organizations (e.g. GCOS Implementation Plan, IGOS-P Cryosphere Theme Report, IPCC AR4), the published scientific literature, specific user consultation via mailing lists (Cryolist and GLIMS list), and feedback from more than 20 persons. The most important user requirements were the completion of the global glacier inventory, especially for specific regions of interest, and more spatially complete information on glacier elevation changes and velocities. The unsatisfactory spatial coverage of these datasets is the main gap in achieving the requirements with currently available EO data.

International Scientific coordination

Closest interactions of Glaciers_cci with key science bodies are with WGMS, GLIMS and GTN-G that have representatives in the CRG. The leader of the CRG is lead author of the Sea-level Change Chapter in IPCC AR5 and the science lead is lead author in the AR5 Cryosphere Chapter. The WGMS and GLIMS databases will host the products generated by *Glaciers_cci,* help to set-up, establish and conform to the standards of the community, and provide contact to further organizational bodies (e.g. GCOS, IACS, UNEP, WMO).

Glaciers_cci has strong linkages to the EU FP7 projects ice2sea and High-Noon, ESA CryoClim, and GMES CryoLand. Together they allowed us to complete the global glacier inventory, the Randolph Glacier Inventory (RGI), following closely the formerly established standards (e.g. from GLIMS and GlobGlacier). This global map of glacier outlines was provided to the Landcover_cci as a reference dataset. The methods for determining glacier elevation changes and velocities will also be applied by the Icesheets_cci.

The direct interactions with the climate modellers in CMUG are limited as climate models do not yet assimilate glacier data. However, the key group interested in the

glacier outline product data are glaciologists and hydrologist that model, among others, the sea-level rise contribution of glaciers for IPCC AR5 (using the RGI). This work is currently in progress and will result in a large number of publications from these studies.

The project and first results have been presented at several international conferences, for example, IGARSS, Munich (Germany), EGU, Vienna (Austria) and WGMS mass balance workshop, Tarfala (Sweden).

ECV products description

Based on the results of the user requirements analysis, the following three main products will be created by the project: (1) Glacier area, (2) elevation changes and (3) velocity fields. The elevation change product will be created from two different methods: (2a) DEM differencing (dDEM) and (2b) altimetry (ALT); whereas for the velocity fields product two different sensor types will be considered: (3a) optical (OPT) and (b) microwave (MW). The required input data are available and algorithms are all in a mature state to create these products globally. However, to achieve a certain quality level, manual intervention is required at several stages of the processing for all three products.

The **glacier area** product is a vector outline of a glacier perimeter derived by raster-vector conversion of a binary glacier map generated from multispectral (optical) satellite images (Landsat type). The raw outlines are corrected manually for misclassification (e.g. debris, water, clouds) and are digitally intersected with drainage divides derived from a DEM to create the individual glacier entities. Key topographic attributes (e.g. minimum, maximum and mean elevation) for each glacier are derived automatically from a DEM.

The **elevation change** product is calculated by differencing two DEMs obtained over a c. 5-20 year time interval, or from satellite altimeter data with a repeat period of a few months. DEM differencing cover glaciers completely, and performs best in rugged high-mountain topography, while altimetry provides sparse measurements at points or along lines and performs best over large and flat ice masses (e.g. extended ice caps). The annual elevation change of the glacier surface is directly related to the prevailing atmospheric conditions. The mean change over the entire glacier multiplied by its area gives volume change which is directly related to sea level contribution.

The flow **velocity** at the surface of a glacier provides important complimentary information (the horizontal components) about the elevation changes of a glacier at a point as well as for mass loss by calving. It also helps to identify drainage divides on very flat glaciers or ice caps and gives information about glacier health. Velocity fields are derived from offset tracking using both optical and microwave sensors. This product requires satellite data obtained from two points in time (repeat pass) that cover the same region after some months (MW) or typically a year (OPT) and are properly co-registered.

Summary tables for each product

In the following tables we refer to the *possibilities* and *requirements* (according to the DARD and PSD) rather than to products to be generated by the project. For example, temporal coverage '1984-2011' means that data are available for this period, not that data will be produced for this period. Regions and periods for data production will be coordinated with the wider glaciological community.

ECV Product Name: Glacier area						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Area (i.e. a vector outline of a glacier with polygon topology)	Landsat TM / ETM+, ASTER, SPOT (Sentinel-2)	Global	Vector data	1984 - 2011	Acquisition annually, products once per decade	Raw data: several TB Product data: < 1 GB
Explanatory text: This is a vector outline product with attribute data. The final product is normally derived per full scene or from 2-3 mosaicked scenes of the same path and date. On a global scale (e.g. the RGI) it can be called an ensemble product, as non-EO data (e.g. outlines derived from topographic maps) are also included. This latter product (a globally complete glacier inventory) fully meets the user requirements. Some of the main applications are the determination of glacier volume and future glacier evolution (e.g. to determine the contribution of glaciers to past, current and future sea-level rise).						

ECV Product Name: Elevation change (dDEM)						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Elevation change rate (m/year) over entire glaciers	DEMs (e.g. from SRTM, ASTER/SPOT optical stereo, aerial photogr., topogr. maps)	Selected key regions globally	DEM resolution (typically 10-100 m)	1950s - today	Typically decadal, but dependent on the magnitude of change	Raw data: a few TB, Product data: < 1 GB (vector), TB (grid)
Explanatory text: This is a CEOS level 3 product for the distributed grid and a vector product (point location with attribute data) for glacier specific mean values. The final product is derived from two DEMs covering the same region with a typical temporal separation of a decade. As sources and spatial resolution differ, spatial resampling and proper co-registration is required. Potential snow penetration (e.g. from C-band radar data) and data voids have to be considered as well. The product is tailored to the user requirements and will mainly be used to determine glacier volume change.						

ECV Product Name: Elevation change (ALT)						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Elevation change rate (m/yr) and trends at point locations	ICESat GLAS, RA / RA-2	Selected key regions globally	Vector data	1991 (ERS1) - 2011 (Envisat)	Monthly to seasonal	Raw data: a few GB Product data: < 1 GB

Explanatory text:
This is a CEOS level 2 product. The product is derived from repeat measurements at about the same point locations (radar altimeters, ICESat crossover points) or from nearby tracks (ICESat).). Different algorithms are applied to derive the product, which is normally used as it is or interpolated over areas where no measurements are available. The product meets the basic requirement to determine elevation changes and trends over unmeasured glaciers and has a higher temporal resolution than from DEM differencing (dDEM). The method is thus complimentary to dDEM (in space and time).

ECV Product Name: Glacier Velocity						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Surface displace fields (m/year)	Optical (Landsat ETM+ pan, ASTER) and mcrowave (e.g. Palsar)	Selected key regions globally	Vector data	1999 - 2011	Acquisition:annually (optical) to monthly (microwave)	Raw data: several TB Product data: a few GB
Explanatory text: This is a CEOS level 2 (vector) or 3 (gridded) product. The product is normally derived from an image pair with a sufficient temporal gap to detect changes in surface glacier flow at sensor resolution due. It is a merged product that is derived from the same sensor. It meets the key user requirement for spatially and temporarily more extended information on glacier flow fields and is used to derive glacier mass flux (e.g. to determine calving, model glacier thickness, correct surface mass balance measurements, and others.)						

10.3 Algorithm Development, Inter-comparison, Selection

Results of Round Robin inter-comparison

The round robin (RR) for the glacier **area** product assessed first the accuracy of automatically derived glacier outlines in Alaska and the Alps by comparing them to a reference dataset obtained by manual digitization, and secondly, glacier mapping algorithms of free choice for a challenging test site in the Himalaya. The RR results revealed that mapping accuracy cannot be determined, as the precision of the reference dataset (from higher resolution sensors) (about 4% of the area), is similar to the area difference (about 2-3% in the mean) of the automatically mapped glacier area from the mean value of the manual digitisations. The precision does not increase for higher resolution datasets and the interpretation of debris-covered glacier parts is the key source of uncertainty (showing area differences larger than 30%).

For the glacier **elevation change** product (DEM differencing) the RR tested methods for co-registering DEMs and the chosen processing procedure including resampling techniques. In total, three methods were investigated and six results obtained. One co-registration algorithm was selected due to its robustness with multiple data types. Accuracy of co-registration may reach 10% of the pixel size (depending on data and sample). A main outcome is that a single software product should be used within the processing chain as the use of multiple software products can introduce shifts after co-registration (due to a different interpretation of the coordinates of the upper left cell of a DEM). Re-sampling one DEM to another should always be to the larger pixel size, preferably using averaging filters.

The RR for the **elevation change** product (altimetry) focused on the validation of different repeat altimetry algorithms for product generation, and the selection of a 'best' performing algorithm based on the accuracy against reference data (e.g. airborne), coverage, and processing effort. Elevation changes using both crossover or repeat track methods were assessed, using radar altimeter data as input for the cross-over method and the laser altimeter data as input for different implementations of the repeat-track methods. The limitation of the cross-over method in terms of spatial coverage was quite evident when compared with the repeat-track algorithm. The comparison between the different repeat-track implementations showed a good agreement between them indicating their almost equivalence. Validation against airborne data showed that the repeat-track method provided estimates of surface elevation change with greater accuracy than the cross-over method. Therefore the repeat-track method applied has been selected as the most reliable technique for developing satellite based observations of ice cap surface elevation change.

The glacier **velocity** RR tested different methods for image matching, whether the input is optical or microwave satellite data, for global-scale mapping and monitoring of glacier velocities. Test regions were located in Iceland, the Karakoram and Svalbard. For optical data, results indicate that 2-3 algorithms are needed depending upon the input data and situation. Algorithm implementation may vary significantly and the various pre- and post-processing routines may affect the quality of the results. For microwave data, the intensity cross-correlation performs better compared to the other SAR methods (fringe-visibility, InSAR and MAI).

Expected Product Improvements

The key improvement for the **glacier area** product results from the availability of a globally complete dataset of glacier outlines (Arendt et al., 2012) for global modelling applications (e.g. glacier volume and future sea-level rise for IPCC AR5). A major contribution results also from an improved error characterisation of the final products that was developed for the round robin (Paul et al. 2012, in press.).

The key improvement of the **elevation change** product is the development of a universal co-registration routine for DEMs and other elevation data (i.e. laser profiles) that will reduce bias in future elevation change grids. Co-registration accuracy is 1/3rd of the pixel size at worst, and triangulation between 3 or more datasets (co-registration vector sum) ensures internal consistency and provides estimates of the random error and un-removed systematic bias (Nuth and Kääb, 2011). The key improvement of the altimetry elevation change product is the identification of the algorithm and sensor that performs better over ice caps and in particular over glacier areas characterised by a surface with high roughness and steep slopes.

Key improvements for **velocity** mapping include better understanding of which algorithms work best in certain situations. Many of the current algorithms for velocity determination in optical images perform similarly, though some return

more spatially complete data than others. These algorithms, applied in the correct situations will improve the spatial coverage of velocities on glaciers. Initial studies indicate the capability to monitor glaciers globally and provide velocity information in various glaciated regions of the world (Heid and Kääb, 2012). Generally, cross-correlation of chips in amplitude SAR images has a very high potential to be efficiently implemented in a routine processing of satellite data for ice surface displacement estimation.

10.4 System Proto-typing and ECV Production

Data Gathering and Data Quality

For the glacier **area** product the main input dataset is from Landsat TM/ETM+ that is freely available in an already ortho-rectified version from USGS. Where the raw data has insufficient quality (e.g. due to snow fields, clouds or SLC-off striping), scenes are mosaicked or disregarded. The first two versions of the completed global glacier inventory (i.e. map of outlines) were highly anticipated by various user communities (more than 80 registered individuals or groups have downloaded the data). The high quality standards of the USGS L1T product and the easy access to ortho-rectified full scenes are currently not met by the Sentinel-2 set-up. It is highly recommended to improve this situation.

For the glacier **elevation change** (DEM differencing) product, input datasets include the SRTM, SPOT (IPY-SPIRIT) and ASTER (not ASTER-GDEM) satellite DEMs, and other national products. Additional potential DEMs include those from the TanDEM-X and Pléiades DEM, though these products need to be analysed in terms of timing, quality and accuracy before use. Co-registration is a universal pre-processing step to minimize bias in the final products, and further should be performed solely in one software system. Biases have been reported in some products (e.g. ASTER DEMs) due to the limited resolution of the satellite auxiliary information. These biases currently limit the accuracy and precision of the final products but have the potential to be reduced. For the glacier elevation change product using altimetry, the input dataset is the ICESat / GLAS (in particular the GLAS06 product level) which is freely downloadable for the NSIDC website. The ICESat/GLAS archive covers the period 2003-2009. An auxiliary DEM is necessary as input for the slope correction effects when applying the repeat-track algorithm.

For the glacier **velocity** product from optical images, the main input dataset is from Landsat TM/ETM+ L1T product. In addition, the archives from ASTER, SPOT, ALOS, Ikonos, Geoeye etc. may be used. For global applications, the archives from Landsat and ASTER are to date the most appropriate. Obtaining the product from microwave data allows a wide range of sensors to be used, among others ERS1/2, Radarsat 1/2, ALOS Palsar, Envisat, and TerraSAR-X. Data from some of these sensors are not free of charge.

Product Generation

Large datasets have already been produced for glacier area and velocity. For **area** the regions contributed to the RGI include western Alaska, Baffin Island, Greenland, Svalbard, Norway, Alps and Himalaya. Velocity fields were generated for glaciers in the Karakoram, Pamir, Caucasus, Penny Ice Cap, Alaska Range and Patagonia.

10.5 Product Validation and User Assessment

Product Validation (plans)

The approach for validating the glacier **area** products consists of a comparison of glacier areas and outlines (overlay) from multiple digitisation of debris-free and debris-covered glaciers with different sizes on high and low resolution remote sensing data. In addition, all glacier outlines are visually controlled and corrected against the satellite image (contrast enhanced false colour composites) as an important step in the post-processing stage.

The approach for validating the glacier **elevation change** (DEM differencing) product is to use differences over assumed stable terrain (outside glaciers) to co-register three or more DEMs for internal validation and estimating potentially un-removed systematic bias. Further validation activities involve comparing satellite DEM products to airborne laser scanning DEMS that are temporally similar. Good reference datasets include the ICESat laser points due to their precision and easy access and despite their spatially limited acquisition. The validation activities for elevation change from repeat altimetry were based on the comparison of temporally consistent airborne elevation changes; on the comparison of elevation changes derived from different sensors, i.e. radar vs. laser, and on the comparison of elevation changes from different algorithms, i.e. cross-track vs. repeat track.

Product validation for glacier **velocities** from optical images is an internal validation by testing the matching on stable terrain (off-glacier), to compare raw displacements to filtered displacements, and a visual inspection to ensure that the displacements are glaciologically consistent. External validation can be performed for the few sites where point GPS measurements are available, however a point to pixel conversion is required.

Uncertainty Characterization

For the glacier **area** product, the uncertainty characterization is part of the product validation. End users will receive glacier outlines generated by a best efforts approach following established guidelines. For current applications of the generated products the uncertainty of the product only plays a minor role as spatial completeness is much more important. From this point of view, there are no major issues related to uncertainty characterization. A key challenge is, however, how to assess uncertainty in the absence of appropriate reference data (see Paul et al., in press).

The uncertainty of a glacier **elevation change** (DEM differencing) product is defined by the statistical uncertainty of the differences off-glacier (assuming stable terrain). This approach is universal but it remains to be determined whether the estimates off-glacier are representative (or at least conservative) for on-glacier results. Furthermore, this approach outlines the random errors of the dataset, and systematic biases may still persist. One approach to estimate the potential un-removed systematic bias is to compare three or more datasets. The total combined error is then the sum of these two, and mainly used to determine variation between glaciers or of the same glacier through time. The uncertainty of the repeat altimetry product is based upon the absolute difference of the elevation change maps obtained using different methods and/or sensors with the airborne surface elevation change values. In addition, the root mean square error, RMSE, and the correlation coefficient, R, are used to characterize product uncertainty.

The uncertainty of glacier **velocities** from optical images is both a function of the matching algorithms, their implementations and the accuracies of the geolocations of the individual pixels in the optical satellite scene. Uncertainties assessed using stable terrain matches result in sub-pixel accuracies of the matching algorithms themselves. Since the accuracy is down to fractions of a pixel, attitude variations and accompanying pixel geolocation errors of the Landsat sensor, and erroneous topographic corrections may influence the RMSE. From this analysis it is clear that sub-pixel level accuracies are dominated by the sensor noise and not the accuracy of the matching methods.

ECV Data Access and exploitation

The key exploitation challenge for the glacier **area** product is the coordination of glacier mapping by Glaciers_cci with ongoing activities by the GLIMS community. This can be politically delicate if not properly clarified. The products are made available via the well established GLIMS and WGMS database. An ad-hoc solution was found for the RGI (as an GTN-G index dataset) and since the RGI is already heavily used by the glaciological community for all kinds of modelling, feedback from users via papers with new approaches in journals with open review (e.g. The Cryosphere) and email or mailing list discussion will be considered for improving the dataset. For the other products these issues have not yet been determined.

10.6 System Specification

The Glaciers_cci processing system is currently under development. It will only require very limited computational resources (e.g. disk space, computing performance), but is rather demanding in regard to human resources because operator interaction is required at various stages of the pre- (e.g. scene selection), main (e.g. threshold selection), and post-processing (e.g. debris cover correction). The degree of automation in data processing will vary from ECV product to ECV product.

10.7 Plan to complete Phase 1

The main activities to complete phase 1 will be related to the compilation of the remaining Task 2 deliverables and the accomplishment of the Task 3, 4 and 5 deliverables according to a revised project management plan. On the data production side, we will endorse the integration of the RGI into the GLIMS database and further operationalize the processing of the glacier velocity and elevation change from altimetry products.

10.8 General comments/feedback to ESA

To be available in time for IPCC AR5, we have shifted a large part of the data production (glacier outlines for a globally complete inventory) from year 3 to an extended year 1. The current partitioning of the Sentinel 2 data product (100 km tiling, SRTM for orthorectification) is considered non-optimal for glaciological studies at a global scale.

10.9 Relevant Scientific Publications

Bolch, T., et al. (2012): The state and fate of Himalayan glaciers. *Science*, **336**, 310-314.

Heid T. and Kääb A. (2012): Evaluation of existing image matching methods for deriving glacier surface displacements globally from optical satellite imagery. *Remote Sensing of Environment*, **118**, 339-355.

Kääb A., et al. (2012): Contrasting patterns of early 21st century glacier mass change in the Hindu Kush - Karakoram - Himalaya. *Nature*.

Nuth C. and Kääb A. (2011): Co-registration and bias corrections of satellite elevation data sets for quantifying glacier thickness change. *The Cryosphere*, **5**, 271-290.

Paul, F., et al. (in press): On the accuracy of glacier outlines derived from remote sensing data. *Annals of Glaciology*, **54** (63).

Rastner, P., et al. (2012): The first complete glacier inventory for the whole of Greenland. *The Cryosphere Discussions*, **6**, 2399-2436.

Arendt, A., et al. (2012): Randolph Glacier Inventory [v1.0]: A Dataset of Global Glacier Outlines, Global Land Ice Measurements from Space, Boulder Colorado, USA. Digital Media, 2012.

Heid, T. and Kääb, A. (2012): Repeat optical satellite images reveal widespread and long term decrease in land-terminating glacier speeds. The Cryosphere, 6, 467-478

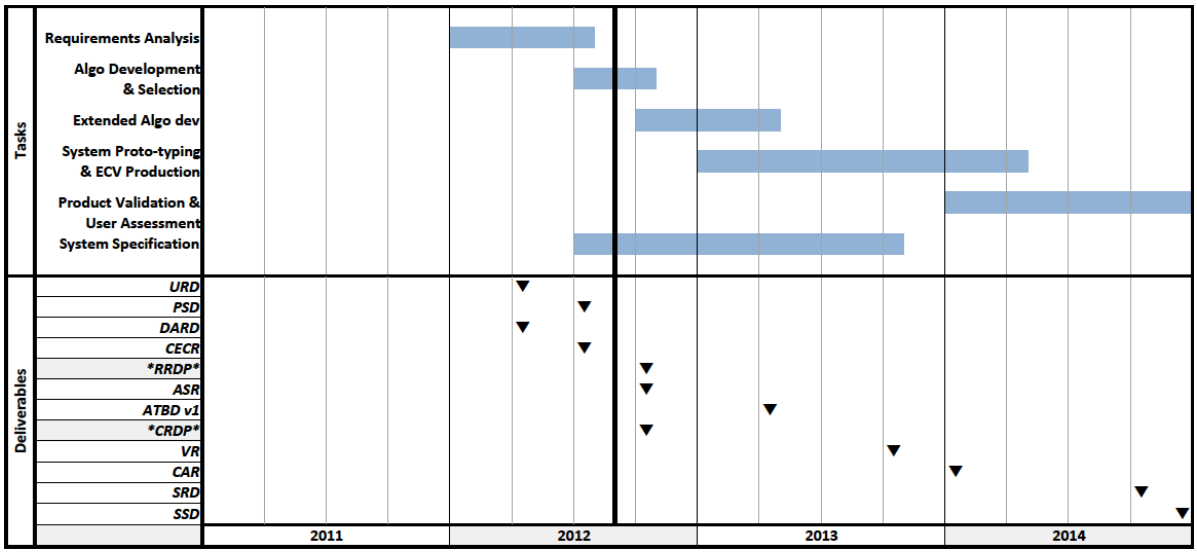
11 ICE_SHEETS_CCI *(GCOS T.2.2)*

11.1 Overall Project Status

Summary of Overall Progress to date

The *Icesheets_cci* project, which is focused on the Greenland ice sheet (not Antarctica), started in January 2012, is running well and on schedule (only very minor delays). The project has passed its 2nd Progress Meeting, when the ATDB v0, PSD, PVP and the draft CECR were reviewed. The project is now entering the Round Robin Exercise.

Overall Project Schedule



Team Composition

Science Lead	Technical University of Denmark, National Space Institute (Denmark)
Project Management	Science [&] Technology AS (S[&]T) (Norway)
EO Science Team	ENVironmental Earth Observation IT GmbH (ENVEO) Univ. Leeds (UL), School of Earth and Environment Nansen Environmental Remote Sensing Center (NERSC) Geological Survey of Denmark and Greenland (GEUS) Niels Bohr Institute (NBI), Danish Meteorological Institute (DMI)
Climate Research Group	GEUS – (CRG Lead) Danish Meteorological Institute University of Utrecht Alfred Wegener Institute University of Oslo

	Finish Meteorological Institute Bird Polar Centre, Ohio State University Polar Science Center, APL, University of Washington
System Engineering Team	Science [&] Technology AS (S[&]T) ENVironmental Earth Observation IT GmbH (ENVEO)

11.2 Requirements Analysis and Product Specification

User Consultation

A wide group of scientists and others were contacted through personal contacts, relevant scientific projects, organised user groups, and public mailing lists within the cryosphere science community. The project was presented at the Ice2Sea Open Forum in Amsterdam, February 2012, and the EGU General Assembly in Vienna, 2012. 67 people answered the questionnaire.

Three most important user recommendations:

- The preferred priority by users is to have low resolution in the interior areas of Greenland and a high resolution in the margin areas for both SEC and IV (other scenarios are also useful).
- Open access to data is critical. The team advocates using NSIDC (US) or similar channels, as recommended by GCOS. Users will continue using publicly available datasets.
- Long and continuous records are needed: in particular for SEC. Ensuring long-lasting records, is an important issue and must be taken into account when planning future satellite missions.

User requirements compared with GCOS:

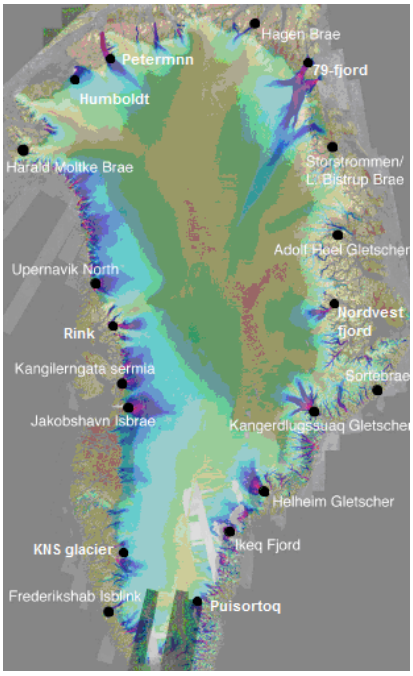
- Surface Elevation Change (SEC): the minimum spatial requirements are similar to GCOS requirements, but the required optimum spatial resolution of <500m is much higher than current capabilities of 5 km.
- Ice Velocity (IV): users require a higher spatial resolution than the GCOS requirements for IV, but within the current capabilities.
- Grounding Line Locations (GLL), Calving Front Locations (CFL): users require higher spatial resolution than the IGOS requirements, but within the current capabilities.

ECV products description

The Ice Sheets ECV products encompass 4 key parameters: Surface Elevation Change (SEC), Ice velocity (IV), Calving Front Location (CFL), and Grounding Line Locations (GLL). ECV production results will be given as grids and line files with associated error estimates, both in common data formats (NetCDF, GEOTIFF, shapefiles) as well as simple ASCII formats. An auxiliary new digital elevation model of Greenland will also be produced, to aid in both the SEC, IV and GLL ECV production.

The primary parameters for the ECV's are given below:

ECV Product Name: Ice Sheet						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
SEC	ERS-1, ERS-2, Envisat, Cryosat, Sentinel-3	Greenland	5 km grid	1991-present	4 per year	
IV	ERS-1,ERS-2, Envisat, Palsar, Sentinel-1, RadarSat?	Greenland	500 m grid	1991-present	1 per year	
CFL	ERS, Envisat, Landsat, MODIS, Sentinel-1	Greenland	250 m shapefile	1991-present	4 per year	
GLL	ERS-1, ERS-2, Envisat, Radarsat?, Sentinel-1	Greenland	250 m shapefile	1991-present	1 per year	
Explanatory text: These are level 3 binned, multi-sensor merged, daily composites (primary product, others not listed). Uncertainty layers are also included. This is one of the main OC products.						



Different regions of the Greenland Ice Sheet will be processed in the first phase of the project. For SEC the entire ice-sheet, for a 20-year time extent; for IV covering the more rapidly changing coastal regions in two separate epochs, as well as some larger drainage basins at selected epochs. Fig 1 shows the selected glaciers for the CFL ECV's; but to few floating glaciers in Greenland only the marked three northern glaciers will have GLL data.

Fig. 1: The selected CFL/GL glaciers (IV background plot)

11.3 System Proto-typing and ECV Production

Data Gathering and Data Quality

The project will use data from Envisat and ERS-1/2 for algorithm development and product generation. For validation purposes data from ALOS, Landsat, IceSAT and Terra may be used.

11.4 Product Validation and User Assessment

Product Validation (plans) – for the two primary ECV parameters

SEC:

- Comparison of temporally consistent airborne elevation changes with satellite altimeter elevation changes,
- Comparison of elevation changes derived from different sensors (e.g. radar vs. laser), and
- Comparison of elevation changes derived from different algorithms (cross-track vs. repeat track).

IV:

- Internal consistency checks:
  - Inspection of measurement quality parameters (e.g. coherence, cross-correlation peak SNR ratio)
  - Retrievals over stable ground (bedrock outcrops, nunataks)
- Algorithm/sensor cross-comparisons;
- Validation with in-situ observations.

11.5 Plan to complete Phase 1

After the initial six months activity, the project has gained momentum and is on track to achieve the Phase 1 objectives within the planned three-year duration.

11.6 General comments/feedback to ESA

The project is found to perhaps have too much weighting on the documentation, and thus too little time is left for the research and development, which still needs to take place.

11.7 Relevant Scientific Publications

Poster presentations at Ice2Sea project meeting (Amsterdam, Feb 2012), and the European Geophysical Union meeting (Vienna, April 2012).

Shepherd. A., et. al (2012) A Reconciled Estimate of Global Ice Sheet Mass Balance. submitted to *Science*.

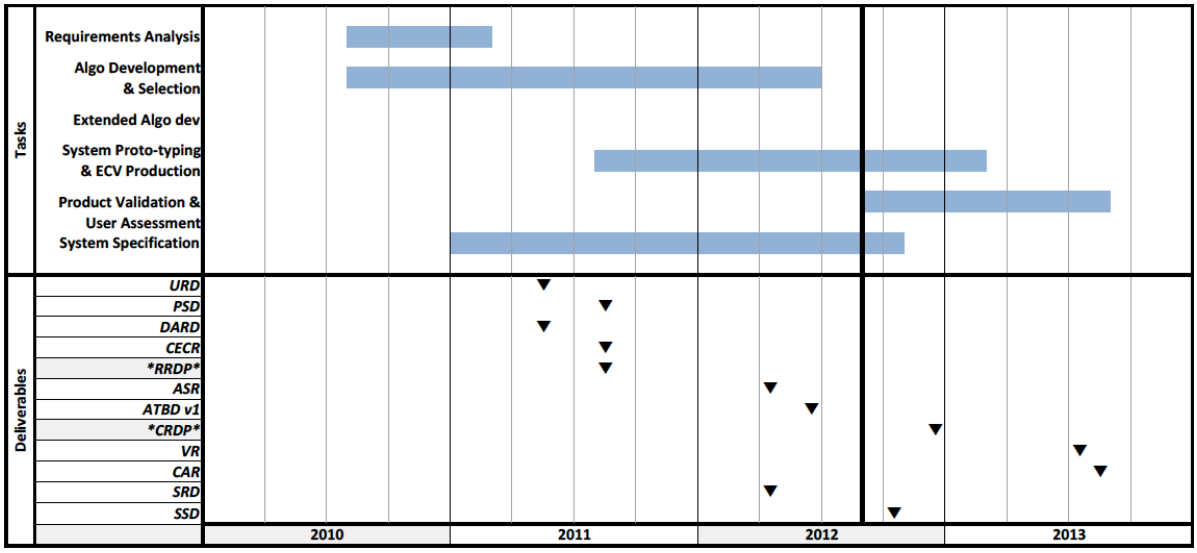
12 LAND_COVER_CCI *(GCOS T.5.1)*

12.1 Overall Project Status

Summary of Overall Progress to date

The *Landcover_cci* project aims to produce, for the first time, a global land cover map for three distinct epochs using for each epoch 5 years of SPOT VGT, MERIS FR and MERIS RR data. After a successful user consultation and a round robin exercises new pre-processing and classification algorithms were developed and successfully implemented. A new land cover concept based on land cover state and land cover conditions is developed in this project. The project has now entered into its production phase and aims to deliver the first epoch near mid-September 2012.

Overall Project Schedule



Team Composition

Prime Contractor/ Scientific Lead	Université Catholique de Louvain – Pierre Defourny (Belgium)
EO Science Team	Université Catholique de Louvain (Belgium) University of Jena (Germany) Brockmann Consult (Germany) Gamma Remote Sensing (Switzerland) Joint Research Center (Italy)
Climate Research Group	Wageningen University (The Netherlands) Met Office-Hadley Center (United Kingdom) Max-Planck Institute for Meteorology (Germany) Laboratoire des Climats et des Sciences de l'Environnement (France)

12.2 Requirements Analysis and Product Specification

User Consultation

The user consultation involved three types of users: 1) a group of key users (most of them also participating in CMUG), 2) associated climate users who are involved and leading the development of key climate relevant models and application, and 3) the broad land cover data user community reflected in the scientific literature and represented by users of the ESA GlobCover product. The three most important user requirements concern the accuracy, the spatial detail and the temporal stability of the land cover products.

International Scientific coordination

Most interactions with external scientific bodies took place within the sphere of the CCI Programme. These are the following ones:

- Interactions made with *aerosol_cci* during a workshop on surface treatment and cloud screening (Q1 2011),
- Interactions made with *Fire_cci* (agreement on the way to deliver compatible final products to users in terms of format, projection and tiles)
- *landcover_cci* involved in Data Standards Working Group to discuss common issues on data standards

Presentations at:

- EARSeL Workshop SIG LULC, Pragues, June 1-3, 2011
- GOFC-GOLD and CEOS WGCV expert meeting on “Global land cover validation
- ESA Sentinel-2 preparatory symposium
- EGU 2012

ECV products description

The outputs of the *Landcover_cci* project are global land cover databases - made of land cover state and land cover condition products. In addition to this, the global satellite radiance (SR) composite time series for the period 1998-2012, which serve as inputs for the generation of the global land cover databases will also be delivered.

Three different global LC maps are delivered, centered to the epochs 2000, 2005 and 2010. The global LC map from 2010, which is the more recent product, is aimed to be the “best existing map”, both in terms of accuracy and stability. In addition, the project also provides information about LC conditions through the observation of selected variables along the entire 15-year period (1998-2012).

CCI Global Land Cover Map						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Land cover	MERIS SPOT-VGT	Global	300m*300m	2008-2012	1 product over 5 years	~350MB

Explanatory text:
The global LC map from the 2010 epoch (2008-2012) is a Level 4 product according to the CEOS definition. The product contains a land cover classification and various classification flags. The classification is associated with a legend expressed using the Land Cover Classification System (LCCS) developed by the UN-FAO, which is compatible with the Plant Function Types (PFTs). The legend counts 22 of classes and is delivered at its full spatial resolution (300m), along with an aggregation tool. This tool will allow users to aggregate the LC maps to the spatial resolution which is suitable for their models.
The map is made with a dominance of MERIS FR products while MERIS RR and SPOT-VGT datasets are used to compensate for a lack of MERIS FR acquisitions and to increase the MERIS spectral resolution by providing a Short-Wave Infrared (SWIR) channel.

CCI Global Land Cover Condition products						
Parameter	**Sensors/auxiliary products**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Normalized Vegetation index (NDVI)	MERIS RR SPOT-VGT	Global	1000m*1000m	1999-2011	1 product over 13 years	~500GB
Burnt Areas (BA)	GlobCarbon MCD64A1	Global	500m*500m	1998-2012	1 product over 15 years	~200GB

Explanatory text:
The global LC condition products characterizing the 1998-2012 epoch are Level 4 products according to the CEOS definition. The land cover condition products provide information about the dynamic processes which affect the land cover through the observation of bio-physical variables (NDVI, BA) on an annual basis.
The NDVI condition product is made of two main types of measurements: the annual behaviour of the vegetation and its inter-annual variability. The BA condition product presents the frequency at which burnt areas would be detected on an observed pixel, based on observations of the 1998-2012 period.
Each LC condition product is delivered in 52 files (1 file by 7-day time interval) at their full spatial resolution (1000m or 500m depending on the product).

Global SR composite time series:
The MERIS 7-day time series that serve as inputs for the classification algorithms are also delivered. These data cover the period 2003-2012. The spectral content encompasses the 15 MERIS spectral channels and the spatial resolution is of 300 m for the Full Resolution mode and of 1km for the Reduced Resolution mode.

Since observations acquired by the SPOT-VGT sensor might also be used to increase the MERIS spectral resolution by adding a SWIR channel, the SPOT-VGT 7-day

time series covering 1998-2012 could also become a deliverable of the project. Currently, the classification chain is run based on SPOT-VGT S1 dataset and not on pre-processed SPOT VGT P data. This is indeed the only SPOT-VGT dataset now available. Yet, in the coming months, it is planned to pre-process SPOT-VGT P products so that they can finally be ingested in the classification chain.

CCI_LC 7-day composites						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
7 day composite MERIS FR	MERIS FR	Global	300m*300m	2003-2012	52 global products per year 5°x5° tiled	~50TB
7 day composite MERIS RR	MERIS RR	Global	1000m*1000m	2003-2012	52 global products per year 5°x5° tiled	~5tb
7 day composite SPOT VGT P	SPOT VGT	Global	1000m*1000m	1998-2012	52 global products per year 5°x5° tiled	~3TB
Explanatory text: The SR products delivered by the CCI-LC project consist in MERIS FR and RR global SR composite time series covering the period 2003-2012 that are the input for the classification algorithms. The spectral content encompasses the 15 MERIS spectral channels and the spatial resolution is of 300 m for MERIS FR and 1000m for MERIS RR. T Since observations acquired by the SPOT-VGT sensor might also be used to increase the MERIS spectral resolution by adding a SWIR channel, the SPOT-VGT 7-day time series covering 1998-2012 could also become a deliverable of the project. SPOT VGT provides 4 spectral band and the spatial resolution is of 1000 m In order to simplify the handling and analysis of the global datasets, the SR time series are being delivered in tiles. Global products are subdivided into 72 x 36 tiles.						

12.3 Algorithm Development, Inter-comparison, Selection

Results of Round Robin inter-comparison

The Round-Robin was launched on 1st April 2011. On the pre-processing side, it focused on five steps: (i) pixel identification, (ii) aerosol retrieval, (iii) atmospheric corrections, (iv) BRDF correction and (v) compositing algorithm. On the classification side, the activity tested (i) a global and generic classification method and (ii) class-specific algorithms for urban areas and for water bodies based on optical and SAR data. Some of these steps were only tested internally by the consortium. For other ones, external participants were engaged.
On 9th November 2011, a meeting was held at the Université Catholique de Louvain (Belgium) to present other round-robin results. Among them, a consortium made of University of Jena (Germany) and University of Pavia (Italy) research groups

demonstrated the usefulness of SAR dataset for urban detection. A second group led by Wageningen University presented results addressing the issue of remote sensing signals temporal stability. The algorithms developed by U. Jena for SAR-based urban area detection were deemed successful and are being included as a new project activity.

Expected Product Improvements

The expected improvements of the CCI land cover products can be formulated in terms of:

- **Relevancy**: the land cover concept has been revisited to characterize the land surface in a relevant manner for the climate modelling science. Stable and dynamic components of the land surface will be characterized separately;
- **Consistency**: 3 products will be generated over a 15-year periods, each one being representative of a 5-year period. It aims at making consistent products along the seasons and over the years;
- **Reliability**: land cover products associated with higher overall accuracy than current ones are expected (80% instead of 75%).

12.4 System Proto-typing and ECV Production

Data Gathering and Data Quality

Input data sets mainly consist of SPOT VGT, MERIS RR and MERIS FR surface reflectance data as well as Wide swath ASAR data.

The first epoch of MERIS FR and RR 7-day composites (which were provided by BC to UCL end of January) were provided and assessed by the *Landcover_cci* team. Annual FR and RR composites and seasonal RR composites were generated and visually assessed. Critical problems were raised w.r.t erroneous input data and constraints in the algorithm, and partially solved. With regard to the first and second issue (presence of anomalous reflectance values and corrupted geocoding), the process of quality control of the input data has been adapted. For the subsequent classification algorithm it is preferable to avoid not detected cloud pixels, even for the price of losing some bright land surfaces which are wrongly classified as a cloud. Although the final cloud screening does not completely solve the problem of remaining clouds, the production of the L2 and L3 products for the first epoch could be re-processed.

In order to find out whether our dataset contains all data available from MERIS the team compared the data inventories of the ESA MERCI catalogue and its own local archive for RR. They compared EOLI and their local archive for FRS. There are differences in both directions and the team is investigating whether they can complete the FR and RR data by retrieving missing orbits.

Product Generation

Production is split between pre-processing and classification chains. The pre-processing transforms the daily satellite L1b data into global mosaïcked times-series

of surface reflectance values. These data are then fed into the classification chain to produce the land cover maps.

The first land cover map (corresponding to the epoch 1 from 2008 to 2012) will be delivered to the climate modeller group by September 2012 for internal testing. Epoch 2 (2003-2007) and Epoch 3 (1998-2002) will be delivered by December 2012. The end of the *Landcover_cci* Phase 1 is scheduled for August 2013.

Main issues encountered during production consist in choosing appropriate cloud screening algorithm and manipulating the large volume of data generated by the pre-processing chain.

12.5 Product Validation and User Assessment

Product Validation (plans)

The overall validation process of the product relies on 4 complementary pillars: (i) the confidence building procedure (systematic quality control of the CCI land cover products integrated into the classification procedure), (ii) the statistical accuracy assessment (based on a validation database and expert interpretation), (iii) the comparison with other global land cover products (most recent global land cover products, including the GlobCover products and the MODIS derived land cover products will be used for comparison) and (iv) the temporal consistency assessment between the three CCI land cover products.

In the framework of the statistical accuracy assessment, the following products will be used to generate reference data:

- The Landsat Global Land Survey (GLS) database.
- Data derived from other moderate or higher resolution satellite imagery: "TropForest" dataset covering sample units over South America and South East Asia for epoch 2010, and complementary SPOT imagery to be acquired through Third Parties Missions. Google Earth imagery and multi-temporal NDVI profiles will also be used during the interpretation phase.
- The GLC2000 and GlobCover reference validation databases. These datasets will be used for the comparison with other global products.

Uncertainty Characterization

Both the pre-processing and the classification chains generate quality flags which characterize the performance of their algorithms. The way these flags will be combined into an uncertainty index which is relevant for users has not yet been precisely defined.

ECV Data Access and exploitation

The different land cover products (corresponding to the different epochs) will be made available to the CRG at different periods in time through a tool developed specifically for this purpose. This tool will be made available to the CRG for area

selection and for data aggregation. The assessment of the first epoch is scheduled to start in October 2012.

12.6 System Specification

The CCI phase 1 prototype system for the generation of the land cover climate data record is composed of a pre-processing subsystem located at Brockmann Consult GmbH and a classification subsystem located at Université Catholique de Louvain. In addition, validation is done in a distributed manner. The pre-processing system is based on a 72 nodes cluster running Calvalus/Hadoop with 34 nodes (136 cores) dedicated to LC-CCI. The classification subsystem is based on the UCL infrastructure for land cover. The algorithm implementations are for the most improvements of existing processors with specific configurations for land cover. The pre-processing processors are plug-ins for the ESA BEAM framework.

The input data for MERIS FR and RR and SPOT VGT comprises about 150 TB. Intermediate pre-processed outputs are about 50 TB, and the final land cover maps and condition products are considerably smaller. Half of the input data, i.e. the data for the epoch 2008-2012 has been completely pre-processed, and classification processing is on-going.

A sustainable system shall cope with an extended input data set into the past with AVHRR data, and into the future with data from Sentinel 3 and maybe 2. This comes with data quality and alignment issues, and with an order of magnitude larger data volumes for the Sentinels. A second requirement for a sustainable system are improvements in algorithms to make the results even more stable. The system shall support the development of such improvements by having the capacity and structures for faster and repeated reprocessing.

12.7 Plan to complete Phase 1

The main activities left to complete the *Landcover_cci* Phase 1 are:

- The finalization of the production:
    - On the pre-processing side, pre-processing of MERIS RR, SPOT VGT and MERIS FR time series reflectance data need to be produced for epochs 2 and 3
    - On the classification side, Epoch 1 is being processed and Epoch 2 and 3 still need to go through the classification chain.

- Product validation by experts:
    - Development of validation tool: the validation tool will be updated and provided to the experts to collect data and further enhance the accuracy of the available reference dataset
    - Validation exercise: validation of the products based on the reference is an important step to assess the quality and the accuracy of the product, which will be carried out in parallel to the product assessment made by the CRG.

- Assessment by CRG: Starting from September 2012 and until the end of the project, the quality of the different *Landcover_cci* products will be assessed products by the CRG. The relevance of the product for their respective model and the impact on their model predictions will be thoroughly analyzed.

12.8 General comments/feedback to ESA

General feedbacks to ESA on CCI phase 1 from the CCI land cover project are:

- there are two many deliverables in this phase 1. More time should be dedicated to research rather than to documents writing;
- the time needed to access MERIS archive was rather slow;
- conversely, we would like to thank ESA for the large amount of high spatial resolution imagery allocated to our project for the validation.

12.9 Relevant Scientific Publications

Bontemps S., Herold M., Kooistra L., van Groenestijn A., Hartley A., Arino O., Moreau I., Defourny P., Revisiting land cover observation to address the needs of the climate community, Biogeoscience Journal, vol.9, pp. 2145-2157, 2012

Defounry P. et al., Revisiting land cover mapping concepts, in: Remote Sensing of Land Use and Land Cover: Principles and Applications, Ed: Chandra P. Giri, May 02, 2012 by CRC Press, 477 Pages

Herold, M. et al., : Building saliency, legitimacy, and credibility towards operational global and regional land cover observations and assessments in the context of geo and observing essential climate variables (ECV's), Proceedings ESA Living Planet Symposium, ESA Special Publications SP-686, Bergen, Norway, 28 June - 2 July 2010.

13 FIRE_CCI *(GCOS T.9)*

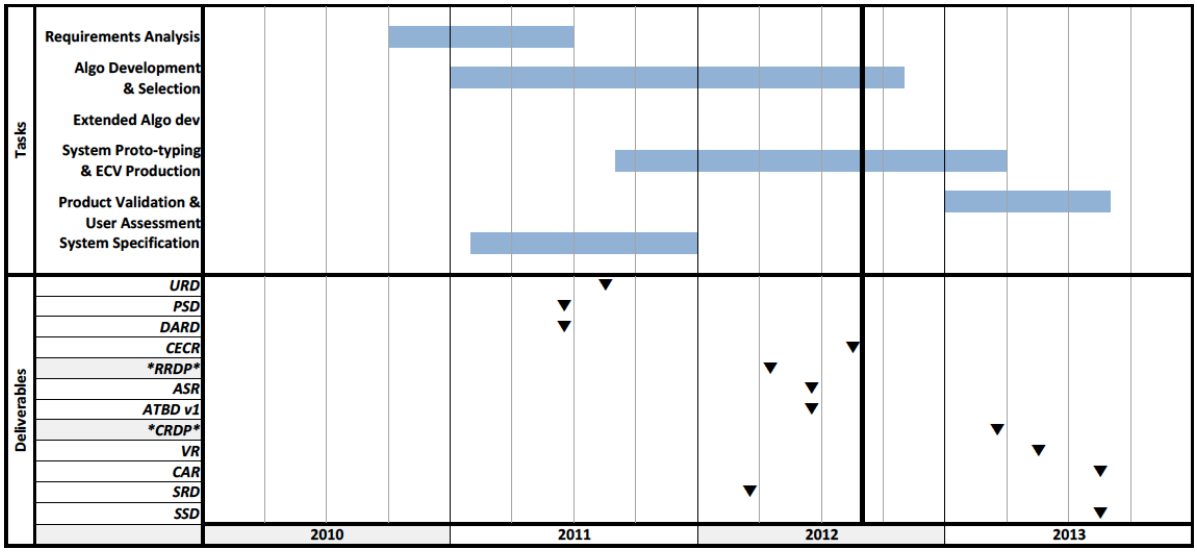
13.1 Overall Project Status

Summary of Overall Progress to date

The *Fire_cci* project has developed a time series of study sites to test the spatial and temporal consistency of burned area (BA) algorithms being developed. Algorithms are adapted to three European sensors (ATSR, VGT and MERIS), including merging them into pixel and grid BA products. An extensive validation dataset has been generated, both covering spatial and temporal consistency. The project is in close connection with international research communities on global fire issues.

The project has faced difficulties in accessing L1b data for algorithm development and producing corrected reflectances (after geometric and radiometric corrections and cloud-water-haze masking). Mobilization of additional processing resources has been necessary, but generation of global products remains very demanding in the short time available.

Overall Project Schedule



Team Composition

Prime/ Scientific Lead	UAH - University of Alcalá de Henares (Spain)
Project Management	GAF AG (Germany)
System Engineering Partners	GMV - Aerospace & Defence (Spain) DLR - German Aerospace Centre (Germany)
Earth Observation Partners	ISA - Instituto Superior de Agronomia (Portugal) UL - University of Leicester (United Kingdom) DLR - German Aerospace Centre (Germany)
Climate Modelling	IRD-CNRS - L'Institut de Recherche pour le

Partners	Développement - Centre National de la Recherche Scientifique (France) JÜLICH - Forschungszentrum Jülich GmbH (Germany) LSCE - Laboratoire des Sciences du Climat et l'Environnement (France)

13.2 Requirements Analysis and Product Specification

User Consultation

The specifications for the BA product to be generated within the *Fire_cci* project were based on an extensive literature review, as well as on user consultation. A total of 193 referenced scientific papers were analyzed to assess the use of BA and other fire products during the last 10 years. The user questionnaire was drafted within the consortium and consulted to CMUG fire experts. We collected 47 user responses modelling (MOD), data assimilation (DA) and Earth observation (EO). Users showed preference for gridded and burned patches and burned pixel products. They stressed the lack of accuracy in the existing fire products and the difficulties to meet the standard GCOS (2006) requirements. There was a consensus as well about the need of unbiased product that balances omission and commission errors. Above all, a clear understanding and description of fire types missing (understorey fires, surface/intensity thresholds for small fires) seems to be the common requirement among users. The URD was reviewed by the international office of the Global Carbon Project.

International Scientific coordination

GOFC-GOLD Fire IT participated actively commenting the product specifications, including formats and distribution. Also CEOS-LPV commented on the Product Validation Plan that aims to comply with standardized validation procedures. The project was presented to the international science fire community to obtain feedback for designing the Round Robin exercise. The team has also interacted with climate modellers interested in fire issues through the internal partners (JULICH for the atmospheric modelling community) and LSCE-IRD for the carbon modellers). Links with Global Carbon office have also been established. Interaction with CMUG has focused on the MPI modelling activities.

Relations with other ECVs of the CCI program have been fostered through the CMUG integration meetings (Reading, Toulouse, Frascati). Particular collaborations have been established with the land_cover_cci, defining common projections and geographic tiles for product distribution.

The *Fire_cci* project was presented in the ESA Side Event held during the COP 15 climate change conference in Cancun (Mexico), at the European Geophysical Union meeting in Vienna and at the NASA Science Meeting, GOFC-GOLD Workshop, and Regional Conference on 17 – 22 June 2012 at Yoshkar Ola, Mari El, Russia

ECV products description

Two different BA products will be offered:

- Pixel product, where burned pixels will be offered at the highest spatial resolution available (300-1000 m depending on the input sensor). This product will be primarily used by the modellers interested in regional analysis.
- Grid product, at 0.5 degree resolution, where total Burned area, cloudiness, burned land cover types, fire size patch distribution will be offered for each cell.

ECV Product Name:						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Burned Area	VEGETATION AATSR Meris	Global	1000 and 300 m pixel size	1999, 2000, 2003, 2005 2008	Monthly files with Day of detected burning	(*)1000m: (5 x) 391,680 MB per year 300m: (5 x) 1,175,652 MB per year*
Burned Area	VEGETATION AATSR Meris	Global	0.5 degree grid	1999, 2000, 2003, 2005 2008	Monthly files	(*)385 MB per year
Burned Area	VEGETATION AATSR Meris	10 study sites of 500x500 km	From 1000 to 300 m pixel size	1995-2009 full time series	Monthly files with Day of detected burning	1000m: (15 x)572 MB per year 300m: (15 x) 17787 MB per year.
Explanatory text: The Burned area product will be a merged of three sensors. Each sensor has its own algorithm. Grid products are mostly intended for climate and vegetation modellers. Pixel products will be of use to modellers too, as well as fire ecologists, fire managers, and civil protection communities (*) For 360 by 170 degree global dataset						

13.3 Algorithm Development, Inter-comparison, Selection

Results of Round Robin inter-comparison

Within the inter-comparison step the following algorithms were compared and analysed: for AATSR two algorithms/products (1Fire_cci versus 1 ESA 2008), for VGT four algorithms/products (1Fire_cci – 1 UL – 2 ESA 2008), for MERIS no comparison was feasible since the MERIS *Fire_cci* BA output presented an unprecedented product. Four study sites were selected for two years (2005 and 2006). A validation and inter-comparison technique was developed. It was adapted to the pixel product (based on error matrix) and computed several indicators of accuracy, error balance and temporal stability. Based on high resolution reference and validation data sets, the outcomes revealed that the performance of BA detection between algorithms was highly differentiated, depending on sensor and geographical region. As the *Fire_cci* algorithms are continuously improved the inter-comparison stage is prolonged until the end of July 2012.

Expected Product Improvements

The *Fire_cci* BA products will include the first global evaluation of BA derived from integrating three different sensors and also the first BA product derived from MERIS sensor. The BA data validation will use the largest amount of validation data compared with all the previous BA products. Information on confidence level of the accuracy of BA data will provided for both grid and pixel data and this will facilitate the error characterization in the down-stream use of BA data. While it remains to be seen whether the new product can actually improve on the data quality that has been achieved from MODIS data, it will certainly lead to a better characterization of fire regions and a better understanding of uncertainties. In the mid-term this information is expected to improve the accuracy of fire emission estimates of trace gases and aerosols.

13.4 System Proto-typing and ECV Production

Data Gathering and Data Quality

For the BA product generation global data sets of AATSR, MERIS and VGT from the years 1999, 2000, 2003, 2005 and 2008 will be processed. All L1b data sets are already available and stored at the processing site. The global processor is actually being implemented for bulk processing.

- ATSR and AATSR L1b data were downloaded either from the DLR archive or distributed on tapes from GMV. The data were stored as full paths.
- MERIS L1B data (FR, FRS and RR) were distributed on hard disk by Brockmann Consult after agreement with ESA. No full paths were available for MERIS –FRS.
- VGT L2 data (atmospheric corrected) were ordered at VITO, Belgium. VGT data were distributed as daily composited.
- In total about 170 TB of data are transferred and handled for the development of the improved pre-processing chain.
- All pre-processed data were distributed to the BA-developers with quality flags. All masks were delivered as fuzzy masks for flexible use.
- Currently, the development of the global pre-processing is on-going in cooperation between DLR and GMV. The overall global BA-processor will be operated at GMV.

Product Generation

Global BA products from 2008 are expected for August/September 2012. The BA algorithms and the merging procedure will be revised and implemented until November 2012. After this date the operational production will follow prioritizing years 1999, 2000, 2003, 2005 and 2008.The main challenges are implementation of the global processor, and the short time window to develop, implement and test the complete system.

13.5 Product Validation and User Assessment

Product Validation (plans)

Two different validation datasets have been generated from multi-temporal analysis of Landsat images. The first one aims at validating the spatial consistency of the BA product for 2008 (100 scenes, selected by stratified sampling). The second is focused on the study sites and includes the full time series where BA products will be available. It is designed to validate the temporal consistency of the BA product. The BA reference data has been generated based on CEOS-LPV recommendations.

Uncertainty Characterization

A new method for validating and characterizing errors has been developed for this project. The users will have a confidence level layer for both the pixel and grid products that will make it possible to infer quantitative properties on BA. Since it is very complex to integrate error propagation throughout all stages of processing, uncertainty characterization will be based on the network of validation sites. Significant effort has been spent to define the uncertainty information in the merged gridded product that is useful and meaningful.

ECV Data Access and exploitation

The main challenges are the vast volumes of data and the time scales required to analyse all these data. The global data products will be provided via ftp and web services. The interface will provide instructions and guidelines for the accessibility, description and usability of data and metadata. The CRG will focus on the comparison of the BA products versus fire census data and validation of the global BA products with existing fire databases, including and integrating the information in relevant fire regime models and climate models. The exploitation of BA outputs will be concentrated in the first semester of 2013. An update of product specifications will be produced if needed as a result of interaction with users.

13.6 System Specification

Phase 1 proto-type processing system description
HPC cluster consisting on:

- 4 Twin Blade servers Dual Xenon 5600 2.4GHZ with 96 cores total and 64Gb per server (total 512 Gb Ram).
- 3 Dell Super Server 4 x 2.4 GHz AMD opteron with 8 Gb RAM per Node

The processing system used (CATENA) can be considered cluster solution for distributed processing. We are using Xen Server virtualization technologies to ease administration management and deployment.

The storage system comprises a set of NAS servers connected to the processing nodes by gigabit Ethernet cards. This is a heterogeneous storage solution as some of its components come from previous projects:

- 12 NAS units for a total raw capacity of 48 TB

- Pool storage composed by 22 hard disks for a total capacity 58Tb

Major SW components: For obtaining corrected reflectances, the main inputs are BEAM, GDAL, XDIBIAS processing system, AMORGOS and ATCOR, along with dedicated software for masking procedures. To generate the BA products dedicated algorithms are being developed.

The main concerns are the bulk volume of data, both for the input and intermediate products. These are forcing to create policies for removing temporary space when needed and increase local storage in the processing nodes.

As far as processing loads, since this is a distributed system the main concern is to reach the maximum processing power from the hardware. The goal is processing as much products in parallel as possible without impacting the by-product delayed time. Current experience shows the main bottleneck as I/O bandwidth. Processing performance scales well, even when forcing the hardware to operate at twice nominal capacity.

The three priority system requirements for a sustainable system are: storage (Size), I/O Bandwith, and processing power (number of cores)

13.7 Plan to complete Phase 1

The first global products representing the 2008 (golden year) observations are planned to be delivered by August 2012. In order to generate and provide a reliable and consolidated ECV product, the BA and Merging Algorithms will be streamlined until November 2012, followed by the implementation into the processing chain and the global production.

13.8 General comments/feedback to ESA

We found that the number of deliverables and the processing tasks were extremely ambitious for the time available and resources of this phase of the project.

13.9 Relevant Scientific Publications

Hantson, S., et al., (2012): A Global characterization of MODIS hotspots using high resolution burned area data, International Journal of Wildland Fire (in review).

Padilla, M., etl al., (2012): Metrics for validation and comparison of global burned area products, Remote Sensing of Environment (in review).

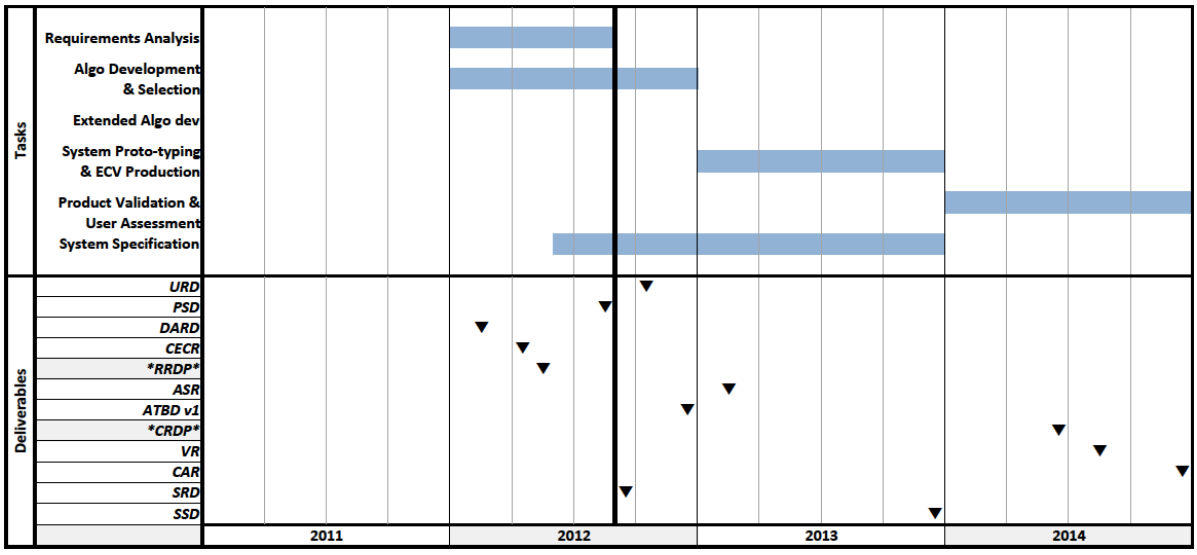
14 SOIL_MOISTURE_CCI *(GCOS T.10)*

14.1 Overall Project Status

Summary of Overall Progress to date

Soil moisture was recently included in the list of Essential Climate Variables (ECVs) deemed essential for IPCC and UNFCCC needs and is feasible for global observation. ECVs data records should be as long, complete and consistent as possible: for soil moisture the data record is based on both active (scatterometer) and passive (radiometer) microwave observations. The objective of the SoilMoisture_cci project is thus to produce the **most complete and most consistent global soil moisture data record based on active and passive microwave sensors.** The project kicked off be done in January 2012 and builds upon the heritage of the WACMOS Project. By June 2012 a first prototype ECV soil moisture product was released.

Overall Project Schedule



Team Composition

Prime/ Science Lead	TU Wien - Wolfgang Wagner (Austria)
Project Management	GeoVille – E. Haas (Austria)
EO Science Team	TU Wien – (Austria) Vrije Universiteit Amsterdam (VUA) - (The Netherlands) University College Cork (UCC) - (Ireland) Finnish Meteorolocial Institute (FMI) - (Finland) GeoVille - (Austria)
Climate Research Group	Eidgenössische Technische Hochschule Zürich (ETH) - (Switzerland)

	Norwegian Institute for Air Research (NILU). (Norway).
System Engineering Team	AWST GmbH (Austria)

Key Science Bodies (GEWEX and ISWG) are actively involved, and mechanisms for scientific exchange of the core project partners and the Key Users have been established.
A Visiting Scientist Programme (VSP) for the SoilMoisture_cci project was established. The goal is to facilitate the scientific exchange between the CCI project and Key Science Bodies and Key User organisations.

14.2 Requirements Analysis and Product Specification

User Consultation

User consultation is on-going and the URD will be available by October 2012. Targeted audience are remote sensing experts interested in understanding user requirements related to the use of surface soil moisture products derived from microwave earth observation. The eight societal benefit areas as defined by the group on earth observation (GEO) are used to broadly categorise stakeholders. A complete scientific literature review will be carried out and initial user requirements are taken into account. User consultation will be carried out by sending a questionnaire to three groups: the identified stakeholders, to researchers who requested the ECV soil moisture dataset and participants of the ECV soil moisture workshop that will be held in Vienna on 20 – 21st September 2012. There, the user requirements will not only be collected but also discussed in detail.

The most important user requirements currently foreseen are
- Spatial and temporal characteristics,
- Units of measurement
- Depth represented
- Physical consistency
- Uncertainty/error of estimate

International Scientific coordination

The *SoilMoisture_cci* scieince leader co-chairs the CEOS Land Product Validation (LPV) team on soil moisture and become member of the Terrestrial Observation Panel for Climate (TOPC) in February 2012. This ensures strong linkage to the different scientific bodies interested in soil moisture (incl. GEWEX, WCRP, GEO, etc.). The project also has close links to the EUMETSAT H-SAF and the GMES project geoland2. There is also close interaction with CMUG is given thanks to long-established cooperation with ECMWF, Met Office, Max Planck, and others.

ECV products description

At the end of the project, three surface soil moisture data sets will be made available to the users: a merged active microwave ECV, a merged passive microwave ECV and a combined active/passive ECV. CMUG advised to make available also the intermediate single sensor group products in order to establish the impact of the various merging stages.

ECV Product Name:						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Surface Soil Moisture	SMMR, SSM/I, TMI, AMI-WS, ASCAT, AMSR-E	Global	0.25 by 0.25 deg	Active: 1991-present passive: 1979-present merged: 1979-present	Daily	220 Meg Per Year (uncompressed)

A first version of the combined product was recently released in NetCDF file format.

14.3 Algorithm Development, Inter-comparison, Selection

Round Robin inter-comparison

The Round Robin exercise aims at identifying the most appropriate algorithms for soil moisture retrieval. Two separate Round Robin exercises are currently being carried out. One is for algorithms to be applied to the scatterometer measurements and the other one is for passive algorithms. The two Round Robins will be based on ASCAT (scatterometer) and AMSR-E (passive) Level 1 data sets from the 5-years period 2007 to 2011 respectively. Any conclusions that can be drawn from these two round robins can also safely be assumed to apply to the predecessor instruments.

The result of the round robins for ASCAT and AMSR-E will, with all likelihood, not present a clear winner. Only for some algorithms, or parts thereof, the failure to represent particular physical processes correctly will become apparent. These instances of a clear identification of a model failure are expected to be the most important outcomes of the round robin exercises as they will allow improving the affected algorithms in the long run, provided that new algorithms can be found that can solve these problems.

Expected Product Improvements

The CCI soil moisture dataset is an observation-based soil moisture dataset and has already shown its value in climate research. For example Bisselink et al., 2011 demonstrates in a study that satellite soil moisture can improve temperature predictions in regional climate models, and Jung et al 2010 shows how satellite soil moisture captures the vulnerability of our global water resources. With the current availability of our 30+ year dataset more applications are expected, especially in climate research. There is a considerable uncertainty in how soil moisture affects convective storms across the world, due to both lack of observational evidence and

uncertainty of large-scale models (Koster et al. ,2004). With the availability of the CCI soil moisture in place we will be in a good position to detect and understand the impact of soil moisture feedbacks within the climate system.

14.4 System Proto-typing and ECV Production

Data Gathering and Data Quality

Input EO Products from the following sensors are being used:

Principle Purpose	Agency Producer	Satellite	Sensor	Period	Products	Data Licensing
Production	ESA	ERS-1 ERS-2	AMI-WS	1991 - 2001 2003 - 2010	L1b	Free
Production	ESA	ERS-2	AMI-WS	1997 - 2003	L1b-HR	Free on request
Production	ESA	ERS-2	AMI-WS	2003 - 2011	L1b-HR	
Future Prod.	ESA	SMOS		2009 – on going	L1c	Free
Future Prod.	ESA	SMOS		2009 – on going	L2	TBC
Validation	ESA	ENVISAT	ASAR	2004 – on going	L1b	Cat 1 users
Validation	ESA	ENVISAT	ASAR	2004 – on going	L1b	Cat 1 users
Production	EUMETSAT	METOP-A	ASCAT	2007 – on going	L1b	Free
Future Prod.	JAXA	GCOM W	AMSR 2	Launch in 2012		Free
Production	NASA	NIMBUS 7	SMMR	1978 - 1987	L1b	Free
Future Prod.	NASA	SMAP		Post 2014		TBC
Future Prod.	NASA	Aquarius		2011 – on going	L2	Free
Validation	NASA	GRACE		2002 – on going	L2	Free
Production	NASA, JAXA	TRMM	TMI	1997 – on going	L1b	Free
Production	NASA, JAXA	Coriolis	Windsat	2003 – on going	L1	Free
Production	Naval Research Laboratory	AQUA	AMSR	2002 - 2011	L2a	Free
Production	NOAA	DMSP	SSM/I	1987 – on going	L1	Free
Validation	NOAA/GLCF	NOAA	AVHRR	1981 - 2006	L3	Free
Validation	NSIDC	DMSP	SSM/I	1995 – on going	L2	Free

In terms of data availability there are no operational constraints to the production of the soil moisture ECV. AMSR-E failed in October 2011 but AMSR-2 has already been successfully launched on May 18, 2012.

The team members of the CCI soil moisture participate to several CCI quality working groups such as the ECV data standards working group.

Product Generation

Three ECV soil moisture products are envisaged:

- A merged product created from all active data sets
- A merged product created from all passive data sets
- A product created from merged active and merged passive products

The Product Specification Document (PSD) will be compiled and finalised by August 2012. This will be traceable to the UYRD and strongly on the heritage of the WACMOS project.

Data standards will be defined in accordance to best practice resulting for CCI SM project participation in the ECV data standards working group. These standards will be based upon best community practice undertaken with the Climate Forecast community, (i.e. NetCDF CF best practice) and will support INSPIRE standards for access to and use of geospatial data within Europe.

A set of metadata are provided with the data products in accordance with the user requirements, product specifications and relevant metadata standard as promoted and accepted within the ECV data standards working group. Also, a report detailing error-characteristics of each of the processing steps will be provided with the data.

14.5 Product Validation and User Assessment

Product Validation (plans)

For a complete validation of the final CCI ECV soil moisture product on different spatial and temporal scales several data sets will be used including the in-situ measurements from the ISMN, SAR-based soil moisture retrievals, estimates of total water storages changes, soil moisture output from multi-model analysis and land assimilation systems as well as evapotranspiration and precipitation data sets. The data sets are partially available over longer time periods and in near real time, which enables a validation of soil moisture characteristics important for climate research, e.g. inter-annual variability, seasonal characteristics and trend analysis. The product validation will include validation of several soil moisture characteristics, i.e. the absolute and relative values of surface soil moisture and the profile soil moisture as well as their short- and long-term anomalies, over different spatial and temporal scales. The characterization of the errors and uncertainties will be carried out using methods which are frequently and successfully applied in previous studies, i.e. the conventional measures bias, root mean square difference and correlation as well as triple collocation and R metric technique.

Uncertainty Characterization

Uncertainty is addressed at two levels: error propagation accounts for uncertainty in the parameterization and calculation of the input soil moisture product retrievals. In addition, relative sensitivity of individual input products to vegetation density is used as a basis for the merging scheme. Each observation is accompanied by an error estimate and a flag indicating which input product(s) was/were used. Main challenges are to optimize the propagation of input product uncertainty to the merged product and to characterize additional uncertainties resulting from the merging process.

ECV Data Access and exploitation

In June 2012 the team released the first ECV soil moisture data set generated within the WACMOS and CCI Soil Moisture projects. This global soil moisture data set has been generated using active and passive microwave space-borne instruments and covers the 32 year period from 1978 to 2010. Users can obtain the data after registration on the CCI soil moisture website www.esa-soilmoisture-cci.org. Since its release more than 100 users from various scientific fields have downloaded the ECV dataset and the number of interested users is continuously growing. This ensures the exploitation of the dataset beyond CMUG and CRG that will exploit the ECV data to investigate land-climate interactions, to analyse the related feedbacks and validate climate models. Moreover, critical feedback was already received in the development phase, and can be used to improve the algorithms.

Parallel to the ECV production it is foreseen to revise, where necessary, the new algorithms developed within the first year of the project. This revision will on the one hand be based on the understanding of the data producers where problems still exist. On the other hand, critical feedback will come from the other project partners and manifold users. This will lead to a close feedback loop between the data producers and the rest of the CCI project. The major outcome of this close interaction in year 2 will be Version 2 of the Algorithm Theoretical Baseline Document (ATBD Version 2).

14.6 System Specification

Analysis of requirements for the ECV Production System started in July 2012. System requirements will be based on the first (internal) version of the URD, which is the prime supplier of source requirements. Since September 2011 a stock of additional requirements sources was built up in the course of the participations of the System Engineers in workshops and meetings (ASCAT workshop, Collocation2, SEWG) and an analysis of one of the scientific software prototypes available at TU Wien. The team plans to issue the first veriosn of the the SR in, 2012 and nd the final version by September 2013.

14.7 Plan To Complete Phase 1

The ECV production system will be set up to allow the integration of other soil moisture products, such as provided by the new Soil Moisture and Ocean Salinity (SMOS) mission, in the next phase(s) of the CCI programme. The project will also broadly involve the international community to make sure that that the project lives up to the highest scientific standards, respectively contributes to defining these standards itself.

This will lead to novel, internationally coordinated validation efforts and a comprehensive documentation on best practices and easy-to-read user guidance.

14.8 General comments/feedback to ESA

The data release in the early stage of the project guarantees a timely and very extensive user feedback.

14.9 Relevant Scientific Publications

Liu, Y.Y., et al., (2012). Trend-preserving blending of passive and active microwave soil moisture retrievals, Remote Sensing of Environment, 123, 280-297, doi: 10.1016/j.rse.2012.03.014.

Wagner, W., et al. (2012) Fusion of active and passive microwave observations to create an Essential Climate Variable data record on soil moisture, Proceedings of the ISPRS Congress 2012, Melbourne, Australia, August 25-September 1, 2012

15 CLIMATE MODELLING USERS GROUP

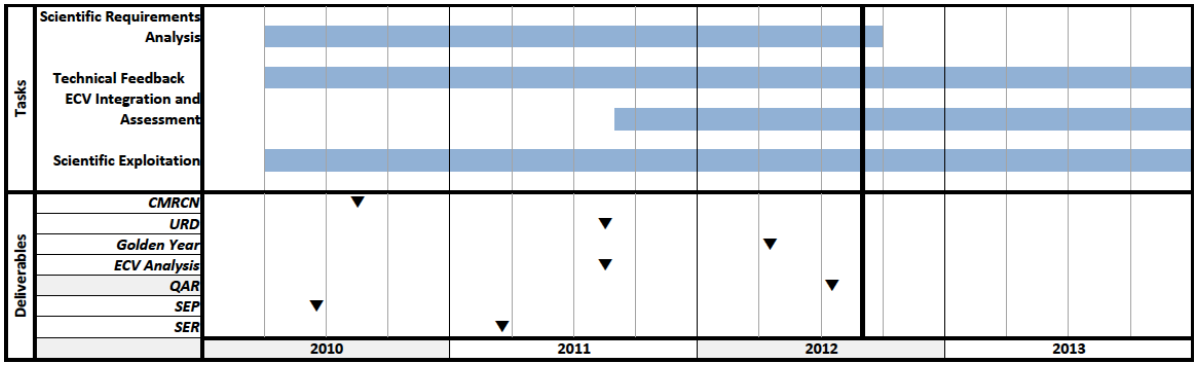
15.1 Overall Project Status

The "Climate Modelling User Group" (CMUG) aims to support integration across the CCI projects, by providing (i) requirements and assessment of the Climate Modelling Community & Re-analysis Community and (ii) independent feedback from a "climate system & modelling perspective" on the CCI data sets and documents.

Summary of Overall Progress to date

Activities related to user requirement are fully schedule whereas the assessment of CCI data sets has been extended by one year, to accommodate the staggered implementation of the first ten ECV projects, and the start of three new ECV projects in 2012. CMUG has been highly flexible in adapting its work-plan to accommodate changes in availability dates of documents and data from the thirteen different ECV projects.

Overall Project Schedule



Team Composition

Prime Contractor/ Scientific Lead	Met.Office Hadley Centre - (United Kingdom)
Climate Modelling	Met.Office Hadley Centre - (United Kingdom) MeteoFrance - (France), MPI-M - (Germany)
Re-Analysis	European Centre for Medium-Range Weather Forecasting - (United Kingdom)

The team includes the major centres in Europe for climate modelling, and Re-Analysis, having significant contribution to international climate networks and activities (e.g. IPCC WG, EUMETSAT SAF, AEROCOM, MACC, FP7 projects, IS-ENES). The team has therefore direct access to a wide and diverse modelling capability, including three of the leading global climate models (e.g. Met Office /

Hadley Center, MPI-M, Meteo France) and Re-analysis (e.g. ERA-Interim) contributing to the IPCC assessment, as well as individual Earth System model components for land (JSBACH), atmosphere (ECHAM, MOCAGE), and ocean (MERCATOR).

15.2 Requirements Analysis & Product Specifications

CMUG has been gathering the observational & data requirements of the climate modelling community & Re-analysis community via a questionnaire from 34 experts which covers a dozen climate models and represents a wide range of model complexity (regional and global) and applications. This survey was also refined via discussions with modellers, email/phone campaigns, and promotion at various meetings including a dedicated CMUG splinter session at the "European Geophysical Union"(EGU) (Vienna, 2010) with participation of 29 climate modellers.

User Consultation

CMUG produced a complete mapping of the modelling community, describing their key actors and models. This elaborated upon the GOCS requirements with specific needs of the climate and Re-analysis communities. These needs were articulated in terms of 4 categories: prediction, assimilation, model development, and trend monitoring. Not all the ECVs attract the same interest for climate modelling. For example, glaciers are not well represented in global climate models, while clouds and aerosols are a major source of uncertainty, for which extensive observations are needed to validate and improve models.

A key message from modellers is that multi-decadal time series of ECVs together with their error characterization are crucial for long-term monitoring of "climate trends". This imposes stringent requirements on the stability and time-span of observations in order to capture relatively small climate signals. There is a strong requirement for comprehensive characterization of the uncertainty of the measurement, per sensor and per pixel (more difficult for merged products), and its spatial correlation (co-variance matrix), in particular for assimilation (e.g. reanalysis).

Another important message is that for each ECV, different communities & applications have different needs. For example, a many climate modellers focus on "model development", which has requirements for process-study somewhat different from long-term monitoring,. Similarly re-analysis applications are more likely to use Level 1, rather than the high-level gridded products (Level 2/3) preferred for other climate applications.

International Collaboration & Outreach

Connecting to International Climate Activities
CMUG has been active in international cooperation providing a gateway to a variety of international initiatives, including for example:

- WCRP (World Climate Research Programme), including GEWEX (CMUG linked with their Cloud Assessment group), WOAP (CMUG participated in the workshop hosted in ESA and contributing to their report), CLIVAR (CMUG contributed to the newsletter dedicated to CMIP5) and WGCM (The Met Office hosted the 14th Session of the in Exeter (6-8 Oct) and presented the CCI).

- ENES (European Network for Earth System Modelling), which represents the majority of climate modelling centres in Europe now taking part in the FP7 Research Infrastructure project IS-ENES. ENES provided CMUG with a coordinated reply to the CMUG survey, with particular focus on data format and meta-data. CMUG participated in IS-ENES meetings, general assembly and working groups.

- FP7 projects, including projects on climate & re-analysis, such as EUCLIPSE "European Union Cloud Inter-comparison, Process Study and Evaluation Project", EMBRACE & SPECS.

- EUMETSAT. CMUG regularly attends the EUMETSAT satellite conference (Cordoba, Spain, Oslo, Norway) and leads a climate session in which issues of interfacing models and satellite observations were discussed.

- GCOS (Global Climate Observing System), where CMUG participates in the "Atmospheric Observations Panel for Climate" (AOPC).

- CMIP5 (Coupled Model Inter-comparison Project) is the network in charge of managing the climate data and model experiments in support of the IPCC next assessment. CMUG partners are contributing to the CMIP5 simulations with their models (e.g. HadGEM, COSMOS, MétéoFrance model). CMUG also contributed to building bridges with the NASA-JPL initiative "Obs4MIPS" aiming to build model-equivalents of the observational EO data sets for use within the next IPCC assessment. In particular, it is planned to put some precursor European ECV data sets (e.g. GlobVapour, ARC SST) as part of this initiative.

Promoting CCI
CMUG has been active in outreach, including presentations / or posters at MACC Assembly (Toulouse, Oct 2010), Euronews Space (Nov 2010), UNFCCC COP-16 (Cancun, Nov 2010), EGU ILeaps (ESRIN, Nov 2010), AGU (San Francisco, Dec 2010), EGU (Vienna, Apr 2011), WCRP Open Science Conference (Denver, Oct 2011), Re-analysis conference (Washington, May 2012), and Planet Under Pressure (London, March 2012).

15.3 Interactions with CCI teams

CMUG has continuous interactions with CCI projects, through phone calls, joint seminars, participation in dedicated progress meetings (e.g. Aerosol, Land Cover,

Ozone) and organization of integration meetings. Feedback is passed to the teams through technical notes available on the CMUG web site.

Feedback to the CCI teams

CMUG provided early feedback to the ECV teams on their product portfolios. This analysis highlighted some CCI products with high potential for direct use or assimilation within climate models (e.g. SST, Sea Level), while others would need tailoring to be fully exploited in a model or reanalysis context (e.g. Cloud "heritage" products not optimal for cloud feedback radiation studies & model development, Burned Area products generated by CCI need to be combined with ancillary data to generate the biomass products needed by models).

It was recognized that a hierarchy of requirements, highly dependent on the type of modelling applications (e.g. model development, monitoring, initialization of decadal prediction), should be captured and managed as a basis for definition of the ECV products. CMUG has set-up a wiki page to manage this information in a flexible & traceable way. This provided the teams with a first independent appraisal of their planned products, created a good basis for discussion, and led to actions within CCI projects to improve products or their description.

A joint requirement for CCI products, is the need for common overlap of data sets in order to perform a cross-consistency study. However, the CCI products at the end of Phase 1 will cover different time spans. Some are multi-decadal (e.g. Sea level, Ocean Colour, SST), while others are restricted to a few years (e.g. Cloud, Aerosol). At the integration 1 meeting, it was proposed to generate a so-called "Golden Year" for which data for all of the CCI datasets would be processed. The year 2008, was chosen as a "quiet / typical" year (no major climate phenomenon), which benefits from availability of Envisat, ERS, Metop and ECV pre-cursor data (e.g. ISCCP, GLORYS reanalysis), and is part of the CMIP5 exercise.

Integration Meetings

CMUG organized two integration meetings in order to address specific issues and facilitating the interactions between CCI teams.

Integration Meeting 1 @ ECMWF
The meeting at ECMWF, on 14-16 March 2011 was well attended with 44 experts from CMUG, ESA, all the CCI projects, and researchers from international organisations and projects. The objective was to check "How ECV project URDs are consistent with the needs of Climate Research Groups in the context of CMUG needs and GCOS requirements". The meeting included a mix of presentations by CCI teams & external experts addressing various scientific challenges, such as Climate modelling, Reanalysis, CMIP5 model assessment, IS-ENES network and SPARC Chemistry Model Assessment. The main recommendations were to identify a "golden year" for re-processing all ECVs, ensure consistency via the use of common data, both from EO sensors and ancillary data, and to clearly describe the added-value of their products compared to existing products, in order to foster their exploitation.

Integration Meeting 2 @ MeteoFrance
The meeting, in MeteoFrance (Toulouse, 14-16 May 2012), with 41 experts from CMUG, ESA, and CCI projects, had the objective to "Explore the over-arching scientific challenges for research and identify how the CCI contributes to meeting them". Invited experts addressed major scientific challenges for the carbon cycle (University of Sheffield), oceanography (NERSC) and cryosphere (University of Leeds). Preliminary results of CMUG assessment and utilization of pre-cursor ECV data sets within a model context were presented. The key outcome was to identify opportunities for exploiting the ECV data sets, for potential sharing of IT infrastructure for ECV production, for better quantification of added-value of CCI products, and team aspirations for CCI Phase 2.

Access to Re-analysis data for the CCI teams

CMUG has provided the ECV teams access to the ERA-Interim reanalysis datasets from ECMWF. Most teams (except Fire and Glaciers) need some reanalysis data to support retrieval and round robin activities (e.g. Ozone, Water Vapour). A web-based data server has been implemented for on-line access. It has been proposed use of a common "Climate Data Operator" package for interpolation of ECMWF data at satellite location, to ensure consistency. CMUG is developing synergy with the "Earth System Grid" (ESG) which is widely used by climate modellers to access, store and explore the CMIP5 simulations for the IPCC AR5.

15.4 Confrontation of Data & Models

CMUG has performed preliminary work using "pre-cursor" ECV data sets. The aim is to "now" develop methodologies and tools useful to "later" assess the CCI data sets. This work also provides insight into the potential incremental "added value" of CCI data sets over precursors being currently used by the community.

The pre-cursor data cover a restricted set of ECVs: (i) SST (ARC SST [1991-2010], p-HadISST2 [1899-2010]), (ii) Ocean Colour (GlobCOLOUR [1995-2010]), (iii) Clouds (ISCCP [1982-2010]), (iv) Ozone (EUM IASIS L2 [2008-2009], MIPAS [2008-2009]), (v) Land Cover (GlobCOVER[2005,2009]) and (vi) Fire (GFEDv3 [1997-2010]). The assessment is performed in different ways, in the context of models - available within CMUG (e.g. HadGEM, JSBACH, MOCAGE, FOAM), re-analysis (e.g. HadSST, ERA-Iterim, GLORYS), or by simple comparison with existing climatologies.

Various methodologies have been used to assess SST pre-cursors. UK Met-office has developed a three-way matchup technique - comparing 3 independent estimates - (using in-situ data) and applied to the ARC data set in order to gain better insight into the quality of "uncertainty" and how to "validate" it. This technique was shown to be very powerful to better understand the SST bias and could be applied to multiple CCI data sets.

ECMWF has started to develop a “Climate Monitoring Facility” (CMF) tool to quantify the quality of a climate data set in the context of the ERA-Interim reanalysis. The tool has been applied to each of the “ensemble members” of the pre-HadISST2 data set. By automatically assessing “homogeneity” of time series and their “consistency” with other variables, the CMF tool has rapidly highlighted some anomalies in the data set (not detected before). The GlobCOLOUR data set has been assimilated in the UK-Met-Office FOAM model, showing some encouraging improvement in the performance of the biological model but also revealing its weaknesses.

Ozone data sets have been integrated into the MOCAGE model, showing an impact on the representation of the annual cycle and regional variations such as the polar vortex. The value of Cloud observations for climate model development has been highlighted through a study of the ISCCP data by use of cloud simulator COSP.

For surface datasets - land cover and fire -, the assessments are made by direct comparison between the model and new satellite derived fields. It is critical here that all the surface variables are consistent with each other between datasets as the models with otherwise struggle to provide consistent surface analyses.

15.5 Plan to complete Phase 1

CMUG activities will enter a new phase when the ECV products start to become available for all projects from late 2012 onwards.

15.6 Relevant Scientific Publications

Hollmann, et al., 2012: The ESA Climate Change Initiative: satellite data records for essential climate variables. Submitted to BAMS.

Lean, K. et al. 2012: Validation of the ATSR Re-processing for Climate (ARC) dataset using data from drifting buoys and a three-way error analysis. Submitted to J. Climate.

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ANNEX 1: DRAFT AGENDA: MID TERM REVIEW

Villa Tuscolana, Frascati
27 September 2012

0900 – 0915 **Introduction** (Director)

0915 – 0945 **CCI Programme Status** (ESA)
- *25 min presentation, 5 min Q&A*

0945 – 1020 **Ocean ECVs** (science leaders)
- SST, Ocean Color, Sea-level, Sea-ice
- *25 min combined presentation, 10 min Q&A with science leaders*

1020- 1055 **Terrestrial ECVs** (science leaders)
- Land cover, glaciers, fire, soil moisture, ice sheets
- *25 min combined presentation, 10 min Q&A with science leaders*

1055 – 1110 COFFEE

1110 – 1145 **Atmospheric ECVs** (science leaders)
- Cloud, aerosol, ozone, GHGs
- *25 min combined presentation, 10 min Q&A with science leaders*

1145 – 1200 **Confronting observations and models**
- *CMUG presentation*

1200-1230 **Early Science Results** (science leaders)
- Inter-comparison of Ice Mass Balance Estimates (A. Shepherd)
- Glaciers as Climate Indicators (F. Paul)
- Assessing Global Sea-level Budget (A. Cazenave)

1230 – 1300 **System Aspects** (ESA / project teams)
- Data Requirements & Quality
- Data Standards
- System Requirements

1300 – 1400 LUNCH

1400 – 1600 **Key Challenges for CCI Phase 2**
- International Climate Research and Monitoring Perspective (Panel: *CSAB Members, ESAC Chair*)

- Discussions, Q&A

1600 Conclusion

ANNEX 2: CLIMATE SCIENCE ADVISORY BODY

Recommendations and advice from the third meeting of the ESA Climate Science Advisory Body

The Climate Science Advisory Body (CSAB) was established by the European Space Agency (ESA) in 2009 to provide scientific advice on the conduct and outcomes of the ESA Climate Change Initiative (CCI) programme. CSAB membership include representatives from European and international bodies and programmes related to climate, namely ECMWF, FAO, GCOS, IPCC, JCOMM, WCRP and the ESAC[1].

At its third meeting held on Tuesday, 5 June 2012, at ESRIN, Frascati, Italy, the CSAB was informed on the programme status and progress over its Phase 1 and the roadmap toward Phase 2. The following conclusions were drawn by the CSAB members present, namely Ghassem Asrar (WCRP), Adrian Simmons (GCOS, also representing ECMWF), Jean-Louis Fellous (JCOMM), and Alan O'Neill (ESAC).

- **CCI objectives**:
  The CSAB highlighted the fact that the CCI objective "to realise the full potential of the long-term EO archives that ESA together with its Member states have established over the years" represents a remarkable contribution of the European Space Agency and its member states to GCOS, the UNFCCC and the IPCC process. This objective is and remains more than ever a valid goal. It appears as a prominent contribution to the response of the space agencies, working together in the context of CEOS, to the GCOS Implementation Plan. The ESA CCI should be seen as a beginning, and a critical one, in laying the foundation for a long-term activity, spreading over several decades to fulfil long-term and high quality observational records required for use in climate research, modelling and prediction. Though still in its early stage the programme is already delivering significant outputs.

- **CCI progress and achievements**:
  The CSAB noted that the CCI has already gained a lot of attention in bodies related to climate research, such as the AOPC and TOPC of GCOS, which have devoted special sessions in their agendas to information on the CCI and presentation of specific CCI projects of interest in their respective domains. The CCI has also been presented and acknowledged as an exemplary endeavour in the framework of the recently-established Working Group on Climate of the CEOS. Of particular merit is the interaction developed within the CCI to determine specific user needs, including the involvement of user communities

[1] ECMWF – European Centre for Medium-Range Weather Forecasts; FAO – Food and Agriculture Organization; GCOS – Global Climate Observing System; IPCC – Intergovernmental Panel on Climate Change; JCOMM – Joint (WMO/IOC) Commission on Oceanography and Marine Meteorology; WCRP – World Climate Research Programme; ESAC – Earth Science Advisory Committee of ESA.

well beyond European climate research groups. The CSAB encouraged ESA to exploit all possible ways to stimulate innovative use of CCI products by the science community, as has been done with the Ice sheets mass balance inter-comparison exercise. The CSAB also encouraged ESA to work with the EC in order to include the use of CCI products in future calls for proposals for research, analysis, modelling and assessment projects.

- **CCI programme evolution in Phase 2 and beyond**:
  The CSAB expressed the view that it will be critically important in Phase 2 to keep pace in all ECV teams, to trigger more intense cross-collaboration between them, and to encourage them to join forces. The CSAB suggested that some seed funding be spared in the margins of the programme to encourage cross-cutting, creative and innovative, forward-looking activities among ECV teams. The CSAB considers that the main drivers for the continuation of the programme beyond Phase 2 will likely be the preparation of a 6th IPCC assessment report (AR6) and the progressive implementation of climate services. The necessary confrontation of modelling and observations will require the continuation of a Climate Modelling User Group. Keywords will be *continuity*, as the richness of the programme lies in the complementarity and maturity of the current core set of ECVs, *innovation*, as additional efforts should be made to improve treatment of current ECVs and include new ECVs in the programme, in pace with the progress of research and data acquisition, and *integration* at a higher level. The CCI should find its ultimate home in the framework of GMES and the most advanced use of many of its products will be in analysis and reanalysis. Future activities should continue to benefit strongly from ESA's leadership. The data gap between the ERS/Envisat missions and the Sentinels (data of which will have to be incorporated) will represent a serious challenge. In addition to incorporating the Sentinel data there will be opportunities to expand the set of ECVs with the data from several Explorer missions, and perhaps in cooperation with European national programmes, and other international partners through mechanisms such as CEOS.

- **Mid-Term Review**:
  The CSAB confirmed interest in contributing to the CCI mid-term review, and advising the Executive and delegations of member states on the best ways to structure the MTR agenda, encourage furtherer cooperation between individual ECV CCI teams, appreciate the complementarity between each team's work through a set of broader themes, and lead the whole activity to its expected successful completion

ANNEX 3: CCI USER REQUIREMENTS VERIFICATION

A3.1. Scope

This annex provides verification tables by which the current performance of the CCI data products for ECVs may be traced back to the user requirements. The primary source of requirements is the GCOS satellite supplement, GCOS 107 and its update, GCOS 154. These are supplemented by specific requirements gathered from the end users communities with which each CCI team is interacting. These are further supplemented by requirements for the global climate modelling user community expressed by the Climate Modelling Users Group (CMUG). Current performance reported for each ECV is based on the results of the round-robin algorithm inter-comparison and initial results for the first CCI products generated.

A complete, independent validation of each product will be conducted in the coming year, based on validation against *in situ* data, models, re-analysis data and confrontation with climate models. End users will exploit the data products for a variety of applications and will provide their independent assessments. This user feedback will be fed into improvements to be made in the next stage of the programme.

Section A3.2 provides traceability for all CCI products with respect to GCOS Product Guidelines.

The remaining tables provide traceability at the level of each individual data product and parameter.

A3.2 All CCI Products: Compliance with GCOS Product Guidelines

GCOS Guideline Number	Guideline Text	CCI ITT Req. No.	CCI Requirement
1	Full description of all steps in the generation of datasets and products, including algorithms used, specific FCDRs used, and characteristics and outcomes of validation activities	R-14	• 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 • 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 IODD, version 2 • D4.1 Product Validation and Inter-comparison Report (PVIR) • D4.2 Climate Assessment Report (CAR)
2	Information on publications in peer-reviewed journals, covering both the description and the application of datasets and products	R4	Each CCI project team shall publish its results in world class, peer-reviewed scientific journals that are cited by the IPCC assessment reports
		R7	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.
3	Statement of expected accuracy, stability and resolution (time, space) of the product, including, where possible, a comparison with the requirements stated in the Satellite	CR2	Develop and validate algorithms to meet GCOS ECV requirements for (consistent, stable, error-characterized) global satellite data products from multi-sensor data archives

	Supplement (or any subsequent revision)		
4	Arrangements for access to the datasets, products and all documentation	See 2.6, p. 10	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.
5	Version management of datasets and products, particularly in connection with improved algorithms and reprocessing	R14	• D1.2 ECV Product Specification Document (PSD) Version identifiers for: all CCI ECV data products; algortihms; source data; and auxiliary data; will be written into the headers of all CCI data products
6	Long-term stability and homogeneity of the product	CR1	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
7	Full application of all appropriate calibration/validation activities that would enhance product quality	R3	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
8	Global coverage where appropriate	CR2	Overall requirement for global products.
		Annexes A-K	Specify explicit global coverage requiremens for each ECV data product
9	Timeliness of data release to the user community to enable monitoring activities	See 4.8.2	Explicit schedule for all data and documents (over 3 year period).
10	Facility for user feedback	R14	• D4.2 Climate Assessment Report (CAR)
		R11	systematic user feedback for annual planning of CCI projects
		Climate Modelling User Group 2.2(1)	Support integration within the CCI programme by providing ESA and CCI Projects with (i) requirementsand user assessment from the Climate Modelling Community and (ii) feedback from a “climate system” perspective (e.g. examining consistencies across ECVs, synergies / overlap within production system, climate constraints to be ensured)
		Climate Modelling User Group 2.2(2)	Foster the exploitation of Global Satellite Data Products within the Climate Modelling Community by (i) promoting the use of CCI data sets to climate modellers and (ii) by building partnership and links with existing research organisations, networks and scientific bodies of the Climate Modelling Community.
		Climate Modelling User Group	Assess quality and impact of individual/combined Global Satellite Data Products in Climate Model and Data Assimilation context by (i) assessing suitability of products for climate applications (e.g.

		2.2(2)	climate modelling, decadal prediction, reanalysis, etc), and by (ii) quantifying their incremental value on model performances in an objective manner.
11	Application of a quantitative maturity index if possible		Maturity of retrieval methods, length of available observation records, and continuity of future observations, were taken into account when prioritizing ECVs to be addressed by the ESA CCI
12	Publication of a summary (preferably on-line) documenting point-by-point the extent to which this guideline has been followed	N/A	ESA will publish this table on-line

A3.3. Cloud_cci: User Requirements Verification

Cloud Cover (CC)				
ECV Parameter Requirement	G / BT / T[1] MD / TM / DA[2] G / BT / T	Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution [km]	50 10 / 30 / - 50 / 85.5 / 250	GCOS 154[3] CMUG WCRP	50	
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution [h]	3 / 4 / 6 1 / 3 / - 3 / 4.8 / 12	GCOS-107 CMUG WCRP	10/day	Baseline product with polar satellites
Accuracy	10% / 15% / 20% 5% / 5% / - 5% / 7.9% / 20%	GCOS-107 CMUG WCRP	10% bias 20% bc-rms	
Stability	<0.03/dec	Ohring et al.[4]	N/A	Initial assessment for baseline 3 years
Format	netCDF	User survey	netCDF	
Update frequency	TBD	TBD	Three years	
Temporal extent	TBD	TBD	2007-2009	
Geographic Coverage	Global	GCOS-154	Global	

[1] G, BT, T refer to goal, break through and threshold requirements
[2] MD, TM and DA refer to different application areas: model development, trend monitoring, data assimilation
[3] The requirement already matches the latest update of GCOS-107 (GCOS-154).
[4] Ohring, G., et al., 2005: Satellite Instrument Calibration for Measuring Global Climate Change (Report of a Workshop), Bull. Amer. Meteorol. Soc., 86(9): 1303–1314.

Cloud Top Pressure (CTP)				
ECV Parameter Requirement	G / BT / T MD / TM / DA G / BT / T	Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution [km]	50 10 / 30 / 5 100 / 171 / 500	GCOS-154 CMUG WCRP	50	
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution [h]	3 / 4 / 6 1 / 3 / 1 12 / 15.1 / 24	GCOS-107 CMUG WCRP	10/day	Baseline product with polar satellites
Accuracy	15 – 50 hPa	GCOS-154	TBD	
Stability	3 hPa/dec - 15 hPa/dec	Ohring et al	N/A	Initial assessment for baseline product of 3 years
Format	netCDF	User survey	netCDF	
Update frequency	TBD	TBD	Three years	
Temporal extent	TBD	TBD	2007-2009	
Geographic Coverage	Global	GCOS-154	Global	

Cloud Top Height (CTH)				
ECV Parameter Requirement	G / BT / T MD / TM / DA G / BT / T	Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution [km]	50 10 / 30 / 5 100 / 171 / 500	GCOS-154 CMUG WCRP	50	
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution [h]	3 / 4 / 6 1 / 3 / 1 12 / 15.1 / 24	GCOS-107 CMUG WCRP	10/day	Baseline product with polar satellites
Accuracy [km]	0.5 / 1.0 / 2.0 0.1 / 0.2 / 0.1 0.5 / 0.63 / 1	GCOS-107 CMUG WCRP	0.3 / 0.3 / 0.8 1.5 bc-rms	
Stability	TBD	TBD	N/A	Initial assessment for baseline 3 years
Format	netCDF	User survey	netCDF	
Update frequency	TBD	TBD	Three years	
Temporal extent	TBD	TBD	2007-2009	
Geographic Coverage	Global	GCOS-154	Global	

Cloud Top Temperature (CTT)				
ECV Parameter Requirement	G / BT / T MD / TM / DA G / BT / T	Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution [km]	50 10 / 30 / - 50 / 85.5 / 250	GCOS-154 CMUG WCRP	50	
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution [h]	3 / 4 / 6 1 / 3 / - 3 / 4.8 / 12	GCOS-107 CMUG WCRP	5/day	Baseline product with polar satellites
Accuracy [K]	1 - 5 0.1 / 0.2 / 0.1 0.5 / 0.63 / 1	GCOS-154 CMUG WCRP	0.3 / 0.3 / 0.8 1.5 bc-rms	
Stability	TBD	TBD	N/A	Initial assessment for baseline 3 years
Format	netCDF	User survey	netCDF	
Update frequency	TBD	TBD	Three years	
Temporal extent	TBD	TBD	2007-2009	
Geographic Coverage	Global	GCOS-154	Global	

Cloud Optical Thickness (COT)				
ECV Parameter Requirement	G / BT / T MD / TM / DA G / BT / T	Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution [km]	50 10 / - / - 50 / 85.5 / 250	GCOS-154 CMUG WCRP	50	
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution [h]	3 / 4 / 6 1 / - / - 12 / 15.1 / 24	GCOS-107 CMUG WCRP	5/day	Baseline product with polar satellites
Accuracy	10 % - / - /- 15 / 18.9 / 30	GCOS-154 CMUG WCRP	>= 25 g/m² or 25% bias 40% rmse	
Stability	5 %/dec	Ohring et al	N/A	Initial assessment for baseline 3 years
Format	netCDF	User survey	netCDF	
Update frequency	TBD	TBD	Three years	
Temporal extent	TBD	TBD	2007-2009	
Geographic Coverage	Global	GCOS-154	Global	

Liquid Water Path (LWP)				
ECV Parameter Requirement	G / BT / T MD / TM / DA G / BT / T	Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution [km]	50 10 / - / - 50 / 85.5 / 250	GCOS-154 CMUG WCRP	50	
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution [h]	3 / 4 / 6 1 / - / - 3 / 4.8 / 12	GCOS-107 CMUG WCRP	5/day	Baseline product with polar satellites
Accuracy [g/m²]	25 % - / - /- 10 / 12.6 / 20	GCOS-154 CMUG WCRP	>= 25 g/m² or 25% bias 40% rmse	
Stability	5 %/dec	Ohring et al. GCOS-154	N/A	Initial assessment for baseline 3 years
Format	netCDF	User survey	netCDF	
Update frequency	TBD	TBD	Three years	
Temporal extent	TBD	TBD	2007-2009	
Geographic Coverage	Global	GCOS-154	Global	

Ice Water Path (IWP)				
ECV Parameter Requirement	G / BT / T MD / TM / DA G / BT / T	Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution [km]	50 10 / - / - 50 / 85.5 / 250	GCOS-154 CMUG WCRP	50	
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution [h]	3 / 4 / 6 1 / - / - 3 / 4.8 / 12	GCOS-107 CMUG WCRP	5/day	Baseline product with polar satellites
Accuracy [g/m²]	10 / 15 / 20 - / - /- 10 / 12.6 / 20	GCOS-107 CMUG WCRP	20% bias 40% rmse	
Stability	5 %/dec	Ohring et al	N/A	Initial assessment for baseline 3 years
Format	netCDF	User survey	netCDF	
Update frequency	TBD	TBD	Three years	
Temporal extent	TBD	TBD	2007-2009	
Geographic Coverage	Global	GCOS-154	Global	

Effective Radius				
ECV Parameter Requirement	G / BT / T MD / TM / DA G / BT / T	Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution [km]	50 10 / - / - - / - / -	GCOS-154 CMUG WCRP	50	
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution [h]	3 / 4 / 6 1 / - / - - / - / -	GCOS-107 CMUG WCRP	5/day	Baseline product with polar satellites
Accuracy [m]	5 - 10 % 1 / 1 / 1 - / - / -	GCOS-154 CMUG WCRP	N/A	
Stability	1 – 2 %	GCOS-154	N/A	Initial assessment for baseline 3years
Format	netCDF	User survey	netCDF	
Update frequency	TBD	TBD	Three years	
Temporal extent	TBD	TBD	2007-2009	
Geographic Coverage	Global	GCOS-154	Global	

A3.4. Ozone_cci: User Requirements Verification

Total ozone				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	50-100 km 20-50 km	GCOS-107 CRG	40-320 km (level-2) 100 km (level-3)	- GCOS requirements for the stratosphere - CRG: Ozone_cci user requirements
Vertical Resolution	N/A			Vertically integrated quantity
Temporal Resolution	3 hours 3 days	GCOS-107 CRG	1-6 days (level-2) 1 month (level-3)	Dependent on individual sensor coverage
Accuracy	5% 2%	GCOS-107 CRG	3%	For clear-sky conditions
Stability	0.6%/decade 1-3%/decade	GCOS-107 CRG	1-2%/decade	After bias correction
Format	NetCDF-CF	CRG	NetCDF-CF	All data products
Updating frequency	N/A			Not specified in Ozone_cci URD
Temporal extent	1980-2010	CRG	1996-2011	GOME, SCIAMACHY and GOME-2
Geographic Coverage	Global	CRG	Achieved	

Ozone Nadir Profiles				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	50-100 km 20-200 km	GCOS-107 CRG	200 km	CRG: Ozone_cci user requirements for the lower stratosphere
Vertical Resolution	0.5-3 km 3-10 km	GCOS-107 CRG	5-10 km	Vertical resolution is best in UT/LS
Temporal Resolution	3 hours 3 days	GCOS-107 CRG	1-6 days	Dependent on individual sensor coverage
Accuracy	5% 8%	GCOS-107 CRG	8-15%	Best accuracy obtained in the middle stratosphere around ozone maximum
Stability	0.6%/decade 1-3%/decade	GCOS-107 CRG	3%/decade	After bias correction
Format	NetCDF-CF	CRG	NetCDF-CF	Level-2 in HDF5
Updating frequency	-			Not specified in Ozone_cci URD
Temporal extent	1980-2010	CRG	1997; 2007-2008	Demonstration data set GOME, GOME-2
Geographic Coverage	Global	CRG	Achieved	

Ozone Limb Profiles				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	50-100 km 100-300 km	GCOS-107 CRG	250-500 km	CRG: Ozone_cci user requirements for the lower stratosphere
Vertical Resolution	0.5-3 km 3-5 km	GCOS-107 CRG	2-4 km	All limb sensors have similar vertical resolution in the lower stratosphere
Temporal Resolution	3 hours 3 days	GCOS-107 CRG	1-6 days	Dependent on individual sensor coverage;
Accuracy	5% 8%	GCOS-107 CRG	10-15%	Best accuracy in altitude range 20-50 km
Stability	0.6%/decade 1-3%/decade	GCOS-107 CRG	1-2%/decade	After bias correction
Format	NetCDF-CF	CRG	NetCDF-CF	Level-3 products only
Updating frequency	-			Not specified in Ozone_cci URD
Temporal extent	1980-2010	CRG	2007-2008 2002-2011	- Merged ENVISAT data set - Level-3 from individual sensors
Geographic Coverage	Global	CRG	Achieved	

A3.5. Aerosol_cci: User Requirements Verification

Aerosol Optical Depth				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	5-10km 1°	GCOS-154 User survey	10km, 1°	
Temporal Resolution	4h 500 obs./day	GCOS-154 MACC	1 to 6 days	- Depends on sensor swath; data availability limited by presence of clouds - MACC requirement for data assimilation
Accuracy	Max (0.03, 10%) 0.05 (model 1° grid)	GCOS-154 User survey	0.08 0.10	4 months ACCI round robin data compared to AERONET; for comparison 12 months: MODIS (MISR): 0.10 (0.13)
Stability	0.01	GCOS-154	Not yet assessed	Baseline product only 1 year
Temporal extent	Minimum 3-10 years	User survey	2008	Option to produce 1995 – 2012 could be activated in phase 1
Uncertainty	on single pixels	User survey	Provided per pixel	Validation is ongoing
Spectral coverage	4 AODs (VIS/NIR)	User survey	For several sensors	- To allow derivation of size information - Sensor and algorithm dependent

Absorption: Absorbing aerosol index				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	5-10km	GCOS-154	13x24km	OMI pixel resolution
Temporal Resolution	4h	GCOS-154	Near-daily	
Accuracy	0.03	GCOS-154	N/A	For single scattering albedo (SSA)
Stability	0.01	GCOS	N/A	For single scattering albedo (SSA)
Temporal extent	Minimum 10 years	User survey	2008	Potential time series 1979-2012
Best suited absorption parameter	Absorption Aerosol Optical Depth (AAOD)	User survey		- AAOD is under development over ocean - GCOS-154 requires SSA (difficult for low AOD); under development as a research product (land & ocean)

Stratospheric Extinction Profile				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	200-500km	GCOS-154	2.5° x 10°	
Vertical Resolution	1-2km	GCOS-154	1-3km	Additional: integrated stratospheric column AOD for discrimination stratospheric and tropospheric AOD
Temporal Resolution	Weekly	GCOS-154	Monthly	Determined by occultation principles and available data points
Accuracy	10%	GCOS-154	20%	Comparison to SAGE-II
Stability	20%	GCOS	Not yet assessed	Baseline product only 1 year
Temporal extent	Minimum 10 years	User survey	2008-2010	Potential GOMOS time series 2003-2012

All aerosol products				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Format	NetCDF	User survey	NetCDF	Metadata and filenames following CCI guidelines / CF1.4 convention
Updating frequency	Annual	User survey	Two years	According to system specification document (phase 2)
Geographic Coverage	Global	GCOS-154	Global	Except polar latitudes

A3.6 GHG_cci: User Requirements Verification

Methane (XCH_4)				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	10-250 km Sensor	GCOS-107 CRG	10-60 km Achieved	- GCOS requirements & performance - GHG_cci CRG req. & performance - Sensors: SCIAMACHY/ENVISAT & TANSO/GOSAT
Vertical Resolution	N/A	-	-	XCH_4 is column-averaged quantity
Temporal Resolution	3 hours Sensor	GCOS-107 CRG	6 days Achieved	SCIAMACHY nadir neglecting clouds, etc.
Accuracy	20 ppb <10 ppb	GCOS-107 CRG	Achieved: 3-8 ppb	Exception to CRG req.: SCIAMACHY after 2005 due to detector degradation (here: 8-13ppb)
Stability	- <10 ppb/yr	GCOS-107 CRG	- TBD	Assessment not yet possible due to too short time periods (SCIAMACHY degradation, GOSAT launch)
Format	- NetCDF	GCOS-107 CMUG	- NetCDF & other	RRDP: Some products still in other formats (hdf, ASCII)
Updating frequency	- -	GCOS-107 CRG	Monthly-annual	Depending on algorithm & sensor, e.g. SCIAMACHY monthly for MACC-II
Temporal extent	- >1 yr	GCOS-107 CRG	Achieved: 2003-2010	GOSAT: since mid 2009; SCIAMACHY: 2010 low quality due to degradation
Geographic Coverage	Global Global	GCOS-107 CRG	Achieved Achieved	Gaps due to sensor sampling and quality filtering

Carbon Dioxide (XCO_2)				
		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	10-250 km Sensor	GCOS-107 CRG	Achieved: 10-60 km	Same as XCH_4
Vertical Resolution	N/A	-	-	XCO_2 is column-averaged quantity
Temporal Resolution	3 hours Sensor	GCOS-107 CRG	6 days Achieved	SCIAMACHY nadir neglecting clouds, etc.
Accuracy	3 ppm <0.5 ppm	GCOS-107 CRG	Achieved: ~1 ppm	GHG_cci requirements stricter than GCOS
Stability	- 1 ppm/yr <0.5 ppm/yr	GCOS-107 CRG	Probably achieved: <0.5 ppm/yr	- SCIAMACHY: See Schneising et al., 2011, on CO_2 annual increase. - GOSAT: Time series too short
Format	- NetCDF	GCOS-107 CMUG	- NetCDF & other	RRDP: Some products still in other formats (hdf, ASCII)
Updating frequency	- -	GCOS-107 CRG	Monthly-annual	Depending on algorithm & sensor, e.g. SCIAMACHY monthly for MACC-II
Temporal extent	- >1 yr	GCOS-107 CRG	Achieved: 2003-2010	GOSAT: since mid 2009; SCIAMACHY: 2010 full time period not yet covered by a single algorithm
Geographic Coverage	Global Global	GCOS-107 CRG	Achieved Achieved	Gaps due to sensor sampling and quality filtering

A3.7. SST_cci products: User Requirements Verification

Sea Surface Temperature				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	10 km	GCOS-154	0.05°	0.05° corresponds to roughly 5 km (variable)
Vertical Resolution	SST_{skin}	GCOS-154	SST_{skin} and SST_{20cm}	- SST_{skin} : temperature at the air-sea boundary - SST_{20cm} : temperature at a depth below the surface representative of drifting buoy measurements - <50% users are satisfied with only SST_{skin}, whereas >75% are satisfied by SST_{skin} and SST_{20cm}
Temporal Resolution	Daily	GCOS-154	Daily, day and night	SST CCI users survey finds that "daily, day and night resolution" is required to satisfy most users
Accuracy	0.1 K	GCOS-154	0.1 K	- GCOS-154 requires that bias <0.1 K be demonstrated on 100 km scales; with present in situ network, the demonstrable scale is ~ 1000 km - Biases may exceed 0.1 K for the post-Pinatubo aerosol period (1991 – 1993)
Stability	0.03 K / decade	GCOS-154	0.05 K / decade	There are significant challenges in demonstrating these levels of stability due to lack of stable in situ reference
Format	netCDF	User survey	netCDF	Also compliant with community standards from Group for High Resolution SST
Frequency of update	1 to 2 years	User survey	Once in 3 years	Update means improved version of full time series made available. Can be addressed in Phase 2.
Timeliness	1 day to 1 week	User survey	No routine production	Seamless weather forecasting and climate services require timely delivery of newly observed SST. Can be addressed in Phase 2.
Temporal extent	>30 years	User survey (objecti ve)	Aug 1991 to Dec 2010	20-year record from SST CCI phase 1 meets "breakthrough" level requirement. Can be addressed in Phase 2.
Geographic Coverage	Global	GCOS-154	Global	
Uncertainty information	Need to develop methods	GCOS-154	Total and component uncertainties	- Improved uncertainty information also was a key requirement from SST CCI users survey. - Individual uncertainty estimates will be

				provided with each SST in SST CCI products
Independence	Pref. - essential to ~15% of users	User survey	Independent	- Independence means that satellite SSTs are not tuned empirically to in situ observations - SST CCI and its precursors are the only SST time series with this property

A3.8. Ocean_Colour_cci: User Requirements Verification

Water Leaving Radiance				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	4km	GCOS-154*	4km	- GCOS requirement will be met. - Note this was 1km in previous issues of the GCOS requirements and follows our User Requirements survey that the Users only require a 4km horizontal resolution
Vertical Resolution	N/A	N/A	N/A	N/A for Ocean Colour
Temporal Resolution	1 day	GCOS-154*	1 day	- Daily products will be generated, but there will be gaps in the data: the coverage will not be complete globally - It would be interesting to see whether two OLCI sensors in orbit, in combination with POLYMER processing capability, will be able to provide global coverage daily.
Accuracy	5%	GCOS-154*	2.34%	Estimate based on bias computed from global annual composite of R_{rs} at 443 nm for 2003. Reported value is the median. Preliminary results to be verified. Computations underway for the other wavebands
Stability	0.5% per decade	GCOS-154	yy	TBD
Format	Net CDF	User survey	Net CDF	User requirement met
Updating frequency	TBA	N/A	TBA	Still to be agreed on the update cycle, likely every 1 year
Temporal extent	1997-2012	User survey	1997-2012	User requirement met
Geographic Coverage	Global	GCOS-154*	Global	GCOS requirement met

Chlorophyll-a concentration				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	30km	GCOS-154*	4km	GCOS requirement exceeded
Vertical Resolution	N/A	N/A	N/A	N/A for Ocean Colour
Temporal Resolution	Weekly	GCOS-154*	1 day	- Daily products are being generated, but there will be gaps in the data: the coverage will not be complete globally - It would be interesting to see whether two OLCI sensors in orbit, in combination with POLYMER processing capability, will be able to provide global coverage daily.
Accuracy	30%	GCOS-154*	17.25%	- Estimate based on bias computed from global annual composite of chlorophyll for 2003. Reported value is the median. Preliminary result, to be verified.
Stability	3% per decade	GCOS-154*	TBD	TBD
Format	Net CDF	User survey	Net CDF	User requirement met
Updating frequency	TBA	N/A	TBA	Still to be agreed on the update cycle, likely every 6 months
Temporal extent	1997-2012	User survey	1997-2012	User requirement met
Geographic Coverage	Global	GCOS-154*	Global	GCOS requirement met
* As defined in Systematic observation requirements for satellite-based data products for climate 2011 Update, December 2011, http://www.wmo.int/pages/prog/gcos/Publications/gcos-154.pdf				

A3.9 Sea_Level_cci: User Requirements Verification

Regional Mean Sea Level				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	¼ degree	GCOS & SLCCI URD	¼ degree	
Temporal Resolution	Monthly	GCOS & SLCCI URD	Monthly	
Accuracy	1 cm	GCOS & SLCCI URD	<2 cm	Over a grid mesh of 50-100 kms
Stability	1 mm/yr	GCOS & SLCCI URD	<2 mm/yr	Over a grid mesh of 50-100 kms
Format	Net CDF	User survey	Net CDF-CF	
Updating frequency	-	User survey	Every 2 years	
Temporal extent	-	User survey	1992-2010	
Geographic Coverage	Global	SLCCI URD	Global	Latitudes >82° are not observed

Global Mean Sea Level				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	Scalar	SLCCI URD	Scalar	
Temporal Resolution	10 days	SLCCI URD	10 days	
Accuracy	2-4 mm	GCOS & SLCCI URD	<5 mm	Over an orbital cycle (~10 days)
Stability	0.3 mm/yr	GCOS & SLCCI URD	<0.5 mm/yr	Over a grid mesh of 50-100 kms
Format	Net CDF	User survey	Net CDF-CF	
Updating frequency	-	User survey	Every 2 years	
Temporal extent	-	User survey	1992-2010	
Geographic Coverage	Global	SLCCI URD (*)	Global	Very high latitudes >82° are not observed by altimeter satellite missions.

A3.10 Sea_ice_cci: User Requirements Verification

Sea ice concentration				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	10-15 km	GCOS-154	25 km	Most of the users require resolution better than 20 km as a minimum and better than 10 km as a target requirement.
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution	Weekly	GCOS-154	Daily	Most of the users require daily sampling.
Accuracy	5 – 20 %	GCOS-154	< 10 %	Accuracy during summer conditions is lower, but not well quantified.
Stability	5 % per decade	GCOS & user survey	TBD	Stability must be better than 5 % per decade since the reduction of Arctic ice extent since 1979 is 3 - 4 % per decade
Format	Net CDF	User survey	NetCDF	
Updating frequency	Daily	User survey	Daily	
Temporal extent	1979-present	Available data	1979-2008	User survey shows that 37 % need data prior to 1979
Geographic Coverage	Arctic and Antarctic	GCOS-154	Arctic and Antarctic	
Trade-off between resolution and length of time series				There is a trade-off between the length of the time series and the resolution. The oldest data have coarser resolution than the newer data. Data from AMSR-E from2001 to 2011 have higher resolution than SSMI and SMMR data

Sea ice thickness				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	25 km	GCOS-154	100 km	Most users require better than 50 km resolution. Expected resolution of ECV from radar altimeter is 100 km. There is a trade-off between resolution and accuracy. Higher resolution means lower accuracy
Vertical Resolution	5 cm	GCOS-154	TBD	The GCOS requirement is a target requirement for monthly mean thickness.
Temporal Resolution	Monthly	GCOS-154	Monthly	ECV data for winter months only (October – April)
Accuracy	5 - 20 cm	User survey	TBD	Most users require bias and precision of thickness measurements in the range 5 – 20 cm.
Stability	< 20 cm	User survey		Most users require long-term stability of thickness better than 20 cm per decade
Format	Net CDF	User survey		
Updating frequency	Monthly	User survey		
Temporal extent	1993-2012	User survey	1993-2012	
Geographic Coverage	Arctic and Antarctic	GCOS-154	Arctic	Ice thickness in Antarctic is required, but studies are needed before a possible ECV can be provided.
Trade-off between accuracy and resolution		User survey		The user survey showed that 50 % of the respondents preferred higher accuracy and lower spatial resolution, while the other 50 % preferred vice-versa

A3.11. Land_Cover_cci: User Requirements Verification

Global Land Cover State Map				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	300m and coarser	Users survey	300m or 1km	- 300m (MERIS FR) or 1km (SPOT-VEGETATION), depending on the epoch for the LC map - An aggregation tool allows resizing the spatial resolution of the products according to the user needs
Vertical Resolution	N/A	N/A	N/A	N/A
Temporal Resolution	Best stable map & annual updates	Users survey	3 consistent products with a 5 years interval	- Three LC state maps are generated for 3 different epochs (2000, 2005, 2010) based on 5 years of satellite acquisitions (i.e. 2008-2012 for 2010, etc). - The LC conditions report the annual variability.
Accuracy	90-95%	Users survey	80%	- Expert-based statistical validation with a target at 80 % already beyond any existing global products. - Cross-comparison with other LC products
Stability	>85%	Users survey	>85%	Temporal consistency assessment from one epoch to the other is expected to be high.
Format	Net CDF GeoTiff	Users survey	Net CDF GeoTiff	- Net CDF is the standard requested by climate community - GeoTiff is the standard for the LC community and GIS users.
Updating frequency	Yearly	Users survey	5 years	Only 2 Sentinel-3 satellites or PROBA-V will acquire enough cloud-free observation over a single year.
Temporal extent	1991-2012	Users survey	1998-2012	- MERIS SR FR&RR time series: 2003-2012 - SPOT-VGT global time series: 1998-2002 - AVHRR data could allow to extend to 1992
Geographic Coverage	Global	Users survey	Global products	The LC state maps and conditions are produced at global scale, except the poles covered by other CCI components
Legend	LCCS, PFT	Users survey	LCCS	An specific aggregation tool allows the conversion from LCCS to PFT according to each model requirements

Global Land Cover Condition products				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	300m and coarser	LC_CCI users	300m, 500m, 1km	The horizontal resolution depends on the variable: NDVI (1km), Burnt Area (500m), Snow (1km), Water Bodies (300m)
Vertical Resolution	N/A	N/A	N/A	N/A
Temporal Resolution	5 years	LC_CCI users	15 years	- The LC conditions correspond to time series describing the yearly cycle of the land surface variables - Average and inter-annual variability are computed over the longest period as possible (up to 15 years)
Accuracy	N/A	N/A	N/A	They are not validated by independent reference dataset but the consistency across variables over space and time is already a major progress.
Stability	N/A	N/A	N/A	The consistency across variables and with the land cover state is the purpose of this new land cover concept.
Format	Net CDF GeoTiff	LC_CCI users	Net CDF GeoTiff	- Net CDF is the standard requested by climate community - GeoTiff is the standard for the LC community and GIS users.
Updating frequency	N/A	N/A	5 years	Only for the pixels experiencing change in land cover state.
Temporal extent	1991-2012	LC_CCI users survey	1998-2012	Varies according to the land surface variable
Geographic Coverage	Global	LC_CCI users survey	Global	Global coverage, except the poles characterized by other CCI components

A3.12. Fire_cci: User Requirements Verification

Fire Burned Area				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	250 m	GCOS-154	300-1000 m	- 300 m when MERIS data are available, 1000 m otherwise. - Users suggested resolutions at grid level (0.5 degrees)
Temporal Resolution	Daily	GCOS-154	1-5 days	The BA pixel product includes the date of detection but actual temporal resolution depends on orbital characteristics and cloud-obscuration.
Accuracy	± 5% error	GCOS-154	Not yet available	Preliminary estimations 20-30% error. Users pointed out the importance of balancing omission and commission errors.
Stability	± 5%	GCOS-154	Not yet available	Preliminary estimates from the Round Robin exercise indicate ±15%
Format	Geotiff NetCDF	User survey	Geotiff and NetCDF	- Geotiff for pixel products - NetCDF for grid products
Updating frequency	Monthly	User survey	Monthly	Monthly files with date of detection and the indicators suggested by the users
Temporal extent	1997-2009	User survey	1997-2009 2006-2008	- Full time series for the selected study sites - 3 consecutive years of global coverage
Geographic Coverage	Global	GCOS-154 User survey		- Selected study sites - Global
Indicators		User survey		- Pixel products: date of the first detection, sensor detecting the BA, confidence level, land cover of burned pixels. - Grid products: sum of burned area, proportion of cell burned, confidence level, % of cloud-free observations, mean fire size/total area burned, dominant vegetation burned.

A3.13. Soil_moisture_cci: User Requirements Verification

Volumetric Soil Moisture				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	50km	GCOS Target Requirements	Yes	For data acquired after 1991
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution	1 day	GCOS Target Requirements	Partly	Dependent on latitude, for data acquired after 2006
Accuracy	0.04 m^3m^{-3}	GCOS Target Requirements	Yes	- For grasslands, agricultural areas, and (semi-)arid land - Retrieval accuracy varies in space and time mainly depending on the vegetation density - Accuracy is specified through unbiased RMSE
Stability	0.01 m^3m^{-3} per year	GCOS Target Requirements		Lack of suitable reference data makes this difficult to ascertain
Format	Net CDF	User survey (CCI DSWG)	Yes	First release provided in NetCDF 3 (classic) conforming to NetCDF Climate and Forecasting community standard
Updating frequency	Annual	ASSUMED	Yes	
Temporal extent	1979-2012	User survey	Yes	Currently available up to the end of 2010
Geographic Coverage	Global	GCOS Target Requirements	Yes	Quasi-global, coverage limited to areas where retrieval is physically possible; over frozen ground, snow covered ground, densely vegetated areas, and open water surfaces retrieval is not possible

A3.14. Glaciers_cci: User Requirements Verification

Glacier area				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	30 m	IGOS-Cryosphere	30 m	Landsat type sensors
Vertical Resolution	N/A	N/A	N/A	But DEM accuracy plays an important role for orthorectification (SRTM partly not sufficient)
Temporal Resolution	Annual	Literature	Multi-year composites used	Each region should be covered each year around the time of minimum seasonal snow
Accuracy	3%	IGOS-Cryosphere	Clean ice: 3-5% Debris: >30%	Result of round robin: in case of debris cover higher resolution is not more accurate
Stability	N/A	N/A	N/A	Outlines are derived from raw DN, changes in sensor response are compensated by scene specific threshold for band ratio
Format	Shapefile	GLIMS	Shapefile	- Format specified by GLIMS - Any grid resolution can be derived
Updating frequency	Decadal	GTN-G Tier 5	N/A	- Refers to glacier inventory repeat interval - Only first inventory available yet
Temporal extent	1984-2011	Landsat archive	1984-2011	- Currently the entire archive is used - Landsat 5 stopped operation
Geographic Coverage	Global	GCOS-107	Achieved in RGI v2.0	Quality partly remains to be improved

Elevation Change: DEM differencing				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	1-100 m	IGOS-Cryosphere	1-100 m	Resolution depends on DEM source: from national LIDAR (1 m) to SRTM3 (100 m)
Vertical Resolution	0.1-1 m	Literature	1 m	DEMs: SRTM, GDEM, NED, CDED, national DEMs
Temporal Resolution	1 year	Literature	1 week (SRTM) 8 years (GDEM)	The entire region should have been acquired within the same year
Accuracy	0.1-5 m	IGOS-Cryosphere		Possible over glaciers with good optical contrast and not influenced by artefacts
Stability	N/A	N/A	N/A	Only created once
Format	Grid	Definition	Grid	GeoTiff, bil or ASCIIgrid
Updating frequency	Decadal	GCOS - 107	Decadal	Depends on accuracy and change rates
Temporal extent	1930s to 2012	Literature	1960s - 2008	- Some early DEMs from aerial photography - Satellite data more restricted
Geographic Coverage	Global	GCOS -107	Global	All DEMs have geographic limitations

Elevation Change: Altimetry				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	100 m - 10 km	DARD	170 m	Point data with a large foot print (ICESat: 170 m, RA/RA-2: 10 km)
Vertical Resolution	0.1 m	Literature	0.1 m	Theoretically even higher
Temporal Resolution	1 day	DARD	1 day	Each ground track is acquired at a specific day
Accuracy	0.2 m	IGOS Cryosphere	0.2 m	Slightly depending on surface slope and method (cross-over vs. repeat track)
Stability	N/A	N/A	N/A	Lasers changed
Format	Vector	PSD	Vector	Shape file format
Updating frequency	All tracks	Literature	All tracks	All tracks acquired over a certain period are used for trend determination
Temporal extent	2001-2011	DARD	2001-2011	ICESat only from 2003 to 2009
Geographic Coverage	Key regions	User reqs.	Key regions	- Denser coverage towards the poles - So far analysed: Himalaya and Greenland

Glacier Velocity				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	10-20 m	IGOS Cryosphere	10-30 m	Sensor dependent (e.g. Landsat Pan: 15 m)
Vertical Resolution	N/A	N/A	N/A	But DEM accuracy plays an important role for orthorectification (SRTM partly not sufficient)
Temporal Resolution	Annual to monthly	IGOS Cryosphere	Annual to monthly	- Optical: annual - Microwave: monthly
Accuracy	5%	IGOS Cryosphere	5-10%	Depends on velocity, reduced for slow movement
Stability	N/A	N/A	N/A	- Product is not measured directly but computed - Proper orthorectification is most important
Format	Vector and grid	PSD		Vector: shapefile format, grid: GeoTiff
Updating frequency	Annually	URD, literature	N/A	Only for trend detection, not yet performed
Temporal extent	1991-2011	DARD		Archives with optical and microwave data
Geographic Coverage	Key regions globally	User reqs.	Key regions globally	See publication by Heid and Kääb (2010)

A3.15. Ice_Sheets_cci: User Requirements Verification

Surface Elevation Change				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	100 m	GCOS-154	5 km grids	Current satellite radar altimetry do not allow denser coverage due to gaps between satellite tracks
Vertical Resolution	N/A	N/A	N/A	Satellite altimetry must be averaged over larger regions to give meaningful results
Temporal Resolution	30 days	GCOS-154	4/year	To allow seasonal cycle detection
Accuracy	0.1 m/yr	GCOS-154	Down to 0.1 m/yr	Depending on location on ice sheets (center of ice sheet versus outlet glacier regions)
Stability	0.1 m/yr	GCOS-154	Down to 0.1 m/yr	TBD depending on mission cross-correlation
Format	Net CDF	User survey	NetCDF and simple grids	
Temporal extent	1991-2012	User survey	1991-2012	
Geographic Coverage	All Greenland	GCOS-154	All Greenland	Some data will be lost due to radar altimetry limitations near the coast

Ice Velocity				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	1 km	GCOS-154	500 m	Coverage limited to margin zones, northern interior basin and selected glaciers
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution and extent	30 days	GCOS-154	Snapshots or time series	- Time series on Upernavik and Jakobshavn glacier systems - Margin snapshots 1995/96 and 2008 - Northern interior basin 1991/92
Accuracy	10 m/yr	GCOS-154	<10 m/yr	Depending on availability of SAR data
Stability	10 m/yr	GCOS-154	< 10 m/yr	TBD
Format	NetCDF	User survey	NetCDF	

Calving Front Location				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	(1 km)	GCOS-154	250 m	For Iceberg Calving Rate; CFL is not a GCOS parameter, but can be derived from Calving Rate and Ice Velocity
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution	(1 year)		4 / year	Depending on data availability 19 selected major glaciers
Accuracy	(1 km)		250-500 m	Larger on glaciers with ice mélange in front
Stability	N/A	N/A	250 m	
Format	NetCDF	User survey	Shapefile	

Grounding Line Location				
ECV Parameter Requirement		Source	Performance CCI Phase 1	Explanatory Text
Horizontal Resolution	1 km	N/A	250 m	Only 3 floating glaciers (few floating glaciers in Greenland)
Vertical Resolution	N/A	N/A	N/A	
Temporal Resolution	1 yr	GCOS-154	1 yr	
Accuracy	1 km	GCOS-154	2-5 km	TBD – depends on glacier conditions
Stability	N/A	N/A	N/A	
Format	NetCDF	User survey	Shapefile	

16 ACRONYMS

For clarity, acronyms used in the status update are listed below:

AERONET	*Aerosol Robotic Network*
AIECAR	see CECR
AR5	*Fifth IPCC Assessment Report*
ATBD	*Algorithm Theoretical Baseline Document*
BAMS	*Bulletin of the American Meteorological Society*
CAR	*Climate Assessment Report*
CDR	*Climate Data Record*
CECR	*Comprehensive Error Characterisation Report (called AIECAR in the GHG_cci project - Algorithm Inter-comparison and Error Characterization & Analysis Report)*
CMIP	*Climate Models Inter-comparison Project*
CRDP	*Climate Research Data Package*
CRG	*Climate Research Group*
DARD	*Data Acquisition and Requirements Document*
DSWG	*Data Standard Working Group*
ECV	*Essential Climate Variable*
ERACLIM	*European Reanalysis of Global Climate Observations*
FCDR	*Fundamental Climate Data Records*
GHRSST	*Group for High Resolution Sea Surface Temperature*
IOCCG	*International Ocean Colour Coordinating Group*
IS-ENES	*InfraStructure for the European Network for Earth System Modelling*
JCOMM	*Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology*
MACC	*Monitoring Atmospheric Composition and Climate*
MARCDAT III	*Advances in the Use of Historical Marine Climate Data*
MTR	*Mid Term Review*
PSD	*Product Specification Document*
PVASR	*Product Validation and Science Report*
PVIR	*Product Validation and Intercomparison Report*
PVP	*Product Validation Plan*
RRDP	*Round Robin Data Package*
SEWG	*System Engineering Working Group*
TCCON	*Total Carbon Column Observing Network*
URD	*User Requirements Document*
WGMS	*World Glacier Monitoring Service*
WMO	*World Meteorological Organization*
WOAP	WCRP Observation and Assimilation Panel