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DOCUMENT

Seventh CCI Collocation Meeting Report

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1 SCOPE

This document summarises the outcomes of the seventh Collocation meeting of the ESA Climate Change Initiative, held at ESRIN, Frascati, Italy from 4-6 October 2016.

The Collocation meeting brought together representatives of all fifteen CCI project teams, as well as the Data Portal and Toolbox projects, and Visualisation activities. The main focus of this Collocation meeting was to assess the legacy achievements of the CCI projects and programme as a whole, as well as look towards how this legacy can be used to shape the programme for CCI+.

The output of the Collocation meeting is recorded within this report as a collective assessment of the status of the CCI and a series of key actions, as formulated by the colocation participants, drawing upon the collective expertise of all CCI project teams.

This report is intended to assist the CCI teams to pursue their projects and generate operational ECV data products in a consistent manner during Phase 2, as explicitly required by GCOS.

2 INTRODUCTION

The CCI programme objectives and scope are described in the document, "ESA Climate Change Initiative: Description [EOP-SEP/TN/0030-09/SP]".

The work to be carried out on each ECV is specified in the Statement of Work for the CCI, "ESA Climate Change Initiative Phase 2 Statement of Work" [CCI-PRGM-EOPS-SW-12-0012].

The project scope and team composition for each of these projects is described in the document "ESA CCI Projects Description" and key documents can be found on the CCI website: cci.esa.int

At the time of the 7th Colocation meeting the following fourteen ECV projects were in place:

GCOS ECV	CCI Project	Science Leader
A.6	Cloud_cci	Deutscher Wetterdienst (*R.Hollmann)*
A.7	Ozone_cci	BIRA-IASB (*M. Van Roozendael*)
A.8	Aerosol_cci	DLR / FMI (*T. Popp / G.De Leeuw*)
A.9	GHG_cci	U.Bremen IUP (*M. Buchwitz)*
O.1	Sea_Ice_cci	NERSC, *(S. Sandven)*
O.2	Sea_Level_cci	LEGOS-CNES (*A. Cazenave*)
O.3	SST_cci	U. Edinburgh (*C. Merchant*)
O.4	Ocean_Colour_cci	Plymouth Marine Laboratory (*S. Sathyendranath)*
T.2.1	Glaciers_cci	U. Zurich (*F. Paul)*
T.2.2	Greenland_Ice_Sheet_cci	DTU Space *(R. Forsberg)*
T.2.2	Antarctic_Ice_Sheet_cci	U. Leeds *(A. Shepherd)*
T.5.1	Landcover_cci	Université Catholique de Louvain (*P. Defourny*)
T.9	Fire_cci	U. Alcala (*E. Chuvieco)*
T.10	Soil_Moisture_cci	TU Vienna *(W. Wagner)*

Through a separate ITT, the cross-cutting project, the 'Climate Modelling Users Group (CMUG)' was set up with the aim of ensuring integrated feedback between the ECV projects and the global climate modelling community. The CMUG provide a structured forum for guiding the ECV projects on the use of the data sets, discussing intercomparison methods, error characterisation, etc. and helping the projects to achieve the set performance targets for each ECV.

Each CCI project team typically includes experts from ten or more research organizations, including a Science Leader and a Project Manager, and contains three sub-groups. The sub-groups are organised into: specialist scientific expertise in EO; a Climate Research Group, including climate modellers; and system engineering experts.

Each science leader ensures the overall scientific integrity of the project throughout its lifetime. The science leader also ensures that each CCI project maintains effective working links to the appropriate international climate science programmes, initiatives and projects, and to other CCI project teams. Each science leader is directly supported by a project manager who ensures communication within the project team, maintenance of schedule, tracking of actions, deliverables and reporting to ESA.

The Open Data Portal and Toolbox projects, together with the work on Visualisation are cross-project activities that help people use and understand the CCI data. The Open Data Portal project covers the development, implementation and operation of an online single point of access for the CCI ECV datasets, while the Toolbox will enable users of the data to more easily manipulate the CCI datasets and look at multiple ECVs together. The Visualisation activities include a Visualisation Tool for exhibitions and a Tablet App, Climate from Space, and the development of animations, which enable a less-expert audience to understand the work of the CCI programme and how satellites contribute to climate science.

The projects are at varying stages. The CCI project deliverables for Phase 1 and Phase 2 have been specified in accordance with the "Guideline for the Generation of Satellite-based Datasets and Products meeting GCOS Requirements" (GCOS-129, March 2009). All completed documents and data products can be found on the project websites, accessible via the main CCI programme homepage.

3 UPDATE ON THE CCI PROGAMME

3.1 Activities of the CCI Programme

The seventh CCI Collocation meeting was opened by Maurice Borgeaud, who gave an update on the progress and achievements of the CCI programme. This is the last Collocation meeting of the present format, as the implementation of the CCI+ extension will have begun by the time of the 2017 Collocation meeting.

3.1.1 Living Planet Fellowships

Each of the Living Planet Fellows (LPF) presented their research in a quick-fire session that gave every LPF two minutes to introduce their research. An overview table of all the LPFs awarded in the CCI programme is included below. Presentations were made by all LPFs who attended, and those who couldn't make it in person (Povey, Hieronmyi) sent in slides to be presented on their behalf. A presentation was also made by Anna Maria Trofaier, the ESA Research Fellow at the Climate Office, using her experience working on permafrost to put permafrost measurements forward as an example of a cross-ECV project.

This session was followed up by poster presentations from the LPFs, with a dedicated session on the evening of the 4th October.

Name	Year	Country	KO Date	Project Title
Jens Heymann	2014	DE	Mar 2015	CARBOn dioxide emissions from FIRES' (CARBOFIRES)
Adam Povey	2014	UK	Jun 2015	The Environmental Response to Aerosols observed in CCI ECVs (ERACE)
Tero Mielonen	2014	FI	Mar 2015	Does Increasing Temperature Increase Carbonaceous Aerosol Direct Radiative Effect over Boreal Forests?'(ITICA)
Martin	2014	DE	Feb	Ocean Colour at low sun and high waves' (LowSun-OC)

Hieronmyi			2015	
Omar Bellprat	2014	ES	Feb 2015	'Verification of high-resolution climate forecasts on Intera-seasonal-to-interannual Timescales with Advanced Satellite datasets of the Climate Change Initiative' (hereinafter 'VERITAS CCI')
Simon Munier*	2014	FR	Mar 2015	Surface water and climate variability from a high-resolution GIEMS-SAR merged product' (GIEMS-SAR)
Anna Hogg	2014	UK	Feb 2016	CryoSat measurement of the Antartic Ice Shelf thickness change (CryoShelf)
Marie Fanny Racault	2014	UK	Apr 2015	Climate Impact on Marine Ecosystem State (CLIMARECOS)
Robert Parker	2014	UK	Mar 2015	ExpLoring thE Global cArbon CyclE through atmospheric GreenHouse Gas variability'(ELEGANCE-GHG)
Charles Robert	2015	BE	Feb 2016	EXtending the Performance of AerGom to explore New aerosol related Species and to Improve OzoNe retrieval "EXPANSION"
Sophie Vandenbussche	2015	BE	Feb 2016	MIneral DUst SOurces using vertical profile information retrieved from IASI radiances "MIDUSO"
Luca Lelli	2015	DE	Apr 2016	STatistics of AeRosol and CLouds INTeractions from satellite "STARCLINT"
Mathias Forkel	2015	AT	Feb 2016	CCI data for assessing SOil moisture controls on FIre Emissions "CCI4SOFIE"

* has now left the LPF scheme and was not present at the Collocation meeting.

3.2 Legacy from the CCI Projects

Each project was given the following questions to prepare for this session:

1. What was status of the [ECV] landscape at the start of the CCI programme?
2. What is the status of the [ECV] landscape at the end of 6 years of CCI?
3. What are the activities in CCI that have served to change from Status 1 to Status 2?
4. What are the lessons learned from CCI to provide to future projects?

CMUG: Initially climate model validation was simpler, it was mainly top of radiation budgets that were used but these gave varying and disparate results. Since the beginning of the CCI programme both the climate models and model validation process have become more sophisticated. Within the CCI, CMUG have been able to use the new ECV data sets to confront climate models, from which we now have produced better climate trends, better uncertainties, better consistency (as this is the first time satellite data products have been pushed to be consistent with one another), and better access to the data sets through Obs4MIPS. This has been a major effort of CMUG and a success story of the CCI.

Soil Moisture: A number of key outcomes of the project can be defined, starting with the number of users, which has increased with every new data release and is now over 2500. The project has made a significant science impact too, with annual contributions to the State of the Climate report and a large amount of publications now produced. Methods and techniques for obtaining soil moisture data from satellites have been developed over the life of the project, including using C and X band, and the advancement of triple collocation. There has been a more subtle achievement of integrating soil moisture information more firmly within the climate community. The move to full operational services will be a success for the CCI soil moisture project.

Fire: The European burned area products existing before the CCI programme were not consistent and not very accurate, and even the more detailed US products were not statistically validated globally and weren't well linked to the climate modeling community. The Fire project has now created a new MERIS based BA

product that has trends consistent with the MODIS product, and has been statistically validated globally. Regional differences show that the CCI products are more sensitive than GFED4, particularly in hotspot areas. There has been a strong emphasis on validation, for which the Fire team have generated their own database. There is now clear consistency in the CCI products, which have been used in models to simulate fire behaviour and estimate carbon emissions.

Land Cover: At the start of the CCI programme the link between climate modellers and the land cover community was weak; modellers would use any LC data to convert as input for their PFTs. And from a remote sensing perspective there were only single sensor – single year products available, with no compatibility between existing products and typology. A key outcome from the CCI LC project has been the iteration between the modelling and remote sensing community to establish what the LC description requirements are and what is the LC uncertainty. A key request from the climate groups was to have a consistent global land cover time series with added some land surface seasonality. Therefore, multi-sensor LC products were created, together with LS seasonality and a global inland water body mask. The CCI LC product will be used in the CMIP6 assessments, and there is now a joint climate modelling protocol and long-term commitment from the modelling and remote sensors to work together.

Glaciers: The Glaciers CCI project benefited from the team developed and work done by GlobGlaciers before CCI was set up. This work has been continued in the CCI Glaciers project, resulting in incredible jumps in knowledge and process understanding due to the use of remote sensing data. Key achievements for the project have been their contribution to the development of a global inventory of glaciers; the knowledge development, such as closing gaps in the mass changes in Asian high mountains; publications of both science results and papers on methods and standards; improvements in automated algorithms, and strong engagement in international activities.

Antarctic Ice Sheet: All AIS data products show a marked improvement from what existed before the CCI programme. Previous ice velocity products for Antarctica were mosaics that covered a 5-10 year period, which was not very helpful for ice sheet modellers. The ice velocity product developed from Sentinel-1 data is able to give a more useful snapshot in time. Progress has been made in developing the algorithms for grounding line location so that more frequent updates to the product can be made. It is hoped a legacy of the AIS project will be automated grounding line locations. The surface elevation change product has improved dramatically from a static product to a 25 year time series. In addition, the gravimetric mass balance product from GRACE is the first of its kind. All products have a dedicated data portal that's tailored to the community. The work done by IMBIE has been instrumental in bringing together the ice sheet mass balance community on an international level.

Greenland Ice Sheet: Previous to the CCI programme, all GIS data products were dominated by US groups but the CCI GIS project has been working with those groups to develop new European products. This has been helped by European missions like Cryosat. The radar elevation change product has developed and improved to capture the margins of the ice sheets. There is now a time series of 30+ retreating outlet glaciers from the CCI GIS project. Ice velocity products have improved dramatically with the introduction of Sentinel 1 A and B, giving systematic monitoring of Greenland's margins, with automatic processing and updates every 6 days. Grounding line location work has been developed for Greenland for the first time, also using Sentinel 1. There is also now a consolidated estimate of ice loss from GRACE, which has been a large success story. Collaboration with US groups has been important, in particular using their extensive airborne and in situ measurements for validation work, and collaboration with other ECVs has also been valuable.

Sea Ice: Work done by the CCI Sea Ice project has helped improve knowledge of climate processes such as the ice albedo feedback, using SST and sea ice data together. Updated algorithms have led to more accurate products with better spatial resolution and better uncertainty information for sea ice concentration. Here, collaboration with OSISAF has been key, with the two sea ice concentration products being developed closely. Good progress on sea ice thickness from radar altimetry has been made over the past 6 years and there is now one single processor for all the satellite archives, however validation is still a big issue. There are many upcoming activities, including C3S, an EU Arctic cluster and climate applications calls that can make use of the CCI Sea Ice data, showing there is clearly a need for the data.

Ocean Colour: OC-CCI was built on the GlobColour project, which helped to identify the scientific and technical challenges of producing an Ocean Colour ECV. These challenges were successfully tackled, and the project leaves behind a number of legacies including OC products that give better spatial coverage, and are validated, error characterised, and bias corrected. The integrated, open access dataset of in situ measurements has been vital for validating the products. Progress has been made in providing consistency of the sea ice mask across Ocean Colour, SST and Sea Ice CCI projects and looking at the consistency of Ocean Colour and Aerosol Optical Thickness. This has been a success of the CCI, the cooperation between projects and the community coming together to learn from each other. There is a large, active user group and good international collaboration with NASA, IOCCG.

Sea Surface Temperature: There was already a well-established SST community before CCI, which meant that there was a decade's worth of SST collaboration to inform and enable the development of improved user requirements. This has produced improved AVHRR reprocessing based on physics, linked to ATSRs for calibration, giving a less biased product, with credible uncertainties. There is now an integrated, pan-European team for SST R&D that has paved the way for operational and climate use, includes infra-red and microwave, spans L1 to L4, and links satellite and century-scale. Having a consistent set of different products has got good user feedback, plus the users are more engaged with uncertainty concepts. The inclusion of CCI SST in the last IPCC report has increased visibility and independent uptake of the data, although having an embedded Climate Research Group helped engage users. The improved SST product has led to closer interactions with the in situ community in order to improve accuracy across the board.

Sea Level: Satellite altimetry is a mature technique with good international links, although there were important differences between the products of the main groups developing SL datasets. Sea Level CCI has improved the data processing methodology by bringing a formal protocol for validation, allowing the evaluation of the numerous altimeter standards and algorithms. The selection of algorithms, through the round-robin process, were successfully obtained through a consensus between EO experts and climate scientists. The project has also developed links between European partners and initiated scientific collaborations between altimetry experts and modellers, as well as tackling grand science challenges such as the closure of the sea level budget.

Cloud: Cloud detection has a long history and is most likely the first ever satellite application. Previously to CCI, optimal estimation for cloud retrieval was not used in the generation of long-term cloud climate data records (only in research mode), there was no sustained initiative to perform algorithm inter-comparisons and no standard L1 dataset available for AVHRR. Cloud CCI has supported cloud assessments for new data records; made the first integration of AATSR (and to some extent MERIS) into a long-term cloud climatology; established joint AATSR-MERIS retrieval for ENVISAT and paved the way for the AVHRR FCDR. Multi institute collaboration on algorithm development has involved a lot of European expertise. [Done by cloud?] During the project new cloud properties were developed, e.g. spectral cloud albedo, and uncertainty information was produced and validated on all L2 products. Generation of OE based multi-satellite, multi-channel retrievals in operationalized environments

Aerosol: Although there was a growing community of aerosol remote sensing scientists there was little coordination between the groups doing this in Europe before CCI, and the algorithms being developed were not at a competitive level. Aerosol CCI has developed a consistent 17-year aerosol record with regionally consistent overlap biases. A big success was the initiation of AEROSAT, the international satellite aerosol science network, which has been running for x years now and coordinates its meetings with the AEROCOM modelling network. This has inspired international teams to re-think how they do retrievals and has borrowed the ensemble concept from the modelling world to apply to aerosol retrievals. The project has been able to start developing and evaluating new aerosol variables such as dust, absorption and layer height, after feedback from the GCOS and AEROCOM communities.

Greenhouse Gases: The SCIAMACHY sensor on Envisat enabled pioneering data on carbon GHGs from space to be made. The CCI GHG project has made significant progress in this relatively new area and improved and extended the XCO2 and XCH4 products. They have addressed significant bias issues and improved the accuracy of the data. A strong focus on publications throughout the project has brought much better visibility to these products in the scientific world. Cooperation across different expert groups has been really productive, both on the retrievals and with key users. Being part of the wider CCI programme and most

importantly having stable funding for a period of time has allowed Regular (annual) improvement, reprocessing and data analysis cycles, resulting in quasi-continuously improved data quality. It has also created standardisation and documentation, with good discussions and feedback from the CCI programme and better visibility through the ESA and CCI websites.

Ozone: Although ozone has been measured for a long time, and now has many different sensors available to measure it there had been no coordinated effort to harmonise data production across these sensors. The multiplication of data products left access difficult and confusing for the non-expert user. CCI has brought together a community of European satellite ozone experts to work together on a single project. They have produced a complete reprocessing of nadir UV sensors using a common algorithm, as well as the HARMOZ limb data sets, generated from 10 different ESA, ESA/TPM and NASA sensors. Extensive, coordinated, validation of the CCI products has taken place and data access has been made much easier. The data standards have been improved through the DSWG-SEWG, and access to high-performance processing systems (e.g. CEMS) have helped to enable the success of the project too.

4 COMMUNITY ACCESS

4.1 CCI Open Data Portal

Victoria Bennett: The Open Data Portal has been up and running since September and offers a number of different data search and download services: ftp, OPENDAP, HTTP, Wget, WCS, WMS. The catalogue search allows searches to be performed for ECV, frequency, platform, sensor, processing level, product string, institution, geophysical quantity. There are also catalogue records, which each project should check and let the team know about if there are any issues. Datasets in the portal are 'tagged' with vocabulary terms that are automatically extracted from the filenames and metadata.

Currently not all the services work for all the data, mainly due to compliance with data standards and vocabularies. There have been some formatting problems with the data when using WMS if the data is not CF compliant or isn't gridded. The Portal team are keen to hear feedback on catalogue records and the vocabulary contents and would like to be informed if there's upcoming CCI data releases. They encourage all teams to follow the agreed data standards.

Richard Lowe: The Portal aims to achieve the widest possible take up of CCI data across nations and sectors, beyond CCI members and the core climate community. The ways of accessing the data have been highlighted by Victoria but there is also a CCI Viewer that is on the way. Feedback from the projects would be appreciated to help develop the Help Desk and quicklooks. The Portal and Toolbox teams are working closely together to produce complementary access and tools to CCI data.

4.2 CCI Toolbox

The CCI Toolbox has been set up to help enable cross-ECV exploitation as there is currently limited means to ingest ECV data spanning different ECV types into a common data model, or to apply algorithms homogenously across different ECVs, and a lack of ways to conveniently analyse and visualise this data. The Toolbox will address these problems by ingesting different ECV products into a common data model, compute algorithms across this model and support analysis and visualisation with the user community. It will provide unified ECV data access and a number of different cross-ECV operations such as: ECV filtering, simple transformations, geospatial polygon filtering, temporal filtering, quality parameter filtering, analysis filtering, calculating anomaly information, ECV parameter filtering, gap filling, ensemble statistics calculations, time series analyses, ECV comparison, GeoTIFF layering and delta information between two data sets.

The Toolbox considers 7 different user types from the international climate research community to the knowledgeable public and has developed 22 different use cases from these, and will test the tools and software needed for each one. The basic toolbox design will include: a desktop application (GUI), web service

(WebAPI), Command-line application, and a python core library. The alpha release of the Toolbox is currently available to test; the team are looking for suggestions and bug reports. The Toolbox is designed to make use of cloud computing in the future, even though it's not part of the current contract.

5 COPERNICUS SENTINELS AND DATA ACCESS

5.1 Data Access

The EO data policy at ESA (ESA policy and Copernicus policy) is free of charge and open (and as full as possible). For all missions, operations concept is based on all data being systematically acquired, downloaded and processed to generate and disseminate core products. The volume of EO data is increasing fast, although there are many other challenges including data continuity, diversity, quality, timeliness, synergy, uniqueness and innovation. As well as the ESA EO missions of the current Earth Explores and heritage missions, there are 3rd party missions, Proba and the Copernicus Sentinels available at ESA. There are stringent near-real time requirements for accessing Sentinel data and the data access infrastructure has been tailored to various users: the open access Data Hub for anyone, along with redistribution of Sentinel products via large and small private companies using free and pay-per-use schemes. Collaborative mirror sites directly serve many ESA member state users, plus international partners now have mirror sites to disseminate to their own national communities. Alongside these are the Copernicus services, providing high-level products. Nearly 50,000 self registered users on the Copernicus data access hub. Looking to expand use of EO data and products through the ESA Thematic Exploitation Platforms.

5.2 Sentinel 1

Sentinel 1 is nearly at full routine operations for both satellites; the data flow for S1A was opened to all users worldwide at the end of September 2016 and the S1B products will be operationally qualified at the end of 2016. Sentinel 1B launched successfully and the first acquisitions were available less than three days after launching. The inclusion of S1B with S1A now gives 3-day routine mosaics for sea ice monitoring.

The use of S1B and S1A gives double the coverage of observations, and specific strategies are being implemented to increase the global land mapping frequency. This will be enhanced in 2017 with the integration of EDRS service and a 4th X-band station. There will be an increase of revisiting frequency for operational monitoring services, in particular CMEMS and maritime surveillance. European coverage will increase by a factor of 2, and interferometry will be available every 6 days for critical areas, such as fast moving glaciers and areas of subsidence. Complementarity of observations will be implemented between S1A and S1B, while there will be an increase of global land mapping frequency. There will be specific campaigns for Antarctica and Greenland, with continuous monitoring of the margins and ice sheet-wide acquisition campaigns.

Backwards processing of IW SLC over areas not included in the SLC processing scenario since 2014.10.06 has just started. Missing IW SLC for all areas in the past will be gradually available to users from May 2016 starting with Europe. Weekly mission status reports are published online to keep users up to date. The allocation of S1 resources need to be considered as the user requirements from different areas evolves.

5.3 Sentinel 2

S2A is operational and S2B is in the lead up to routine operations, which should be complete in autumn 2017. The baseline observation scenario covers all land surfaces between 56° south and 84° north, including major island and the whole Mediterranean Sea. There will be 10 days visit time across all land masses by quarter 1 of 2017. The acquisition plan is available online and small evolutions are under assessment. A Global Reference Image from S2 is in development; the European one should be completed by end 2016, and globally by 2017. Data quality aspects are being addressed and the first Validation team meeting is taking place in November 2016. The pilot production of L2A over Europe is to be released soon through the SciHub. L1C products over mountainous areas have poor geolocation accuracy due to the DEM resolution so a pilot project with Norway is addressing this with a higher resolution DEM. Data are ready to download on average

4-5 hours after sensing, but this will be improved to less than 2 hours with EDRS and/or the 4th X-band station.

5.4 Sentinel 3

ESA and EUMETSAT share operations for Sentinel 3, with ESA responsible for LEOP and commissioning phases, CSC shared multi-mission services and the S3 land payload data ground segment. EUMETSAT covers the S3 marine payload data ground segment. The optical mission provides: Sea and land color data, through OLCI (Ocean and Land Color Instrument) and sea and land surface temperature, through the SLSTR (Sea and Land Surface Temperature Radiometer). Sea surface topography data is provided, through a Topo P/L including a Ku-/C-band Synthetic Aperture Radar Altimeter (SRAL), a bi-frequency MicroWave Radiometer (MWR), and a Precise Orbit Determination (POD). In addition, the payload design will allow data continuity of the Vegetation instrument (on SPOT4/5), and enhanced fire monitoring capabilities, river and lake height, and atmospheric products. Since launch the satellite and all instruments are in nominal operational mode and functioning well with much of the level 1 and 2 data released at the end of the year.

5.5 Sentinel 5p

The ESA Sentinel-5 Precursor (S-5P) is a pre-operational mission focusing on global observations of the atmospheric composition for air quality and climate. The TROPOspheric Monitoring Instrument (TROPOMI) is the payload of the S-5P mission and is jointly developed by the Netherlands and ESA. Enhanced radiometric sensitivity & spatial resolution enabling sampling of small-scale variabilities specifically in the lower troposphere. The planned launch date for S-5P is during 2017 with a 7-year design lifetime. The mission will make measurements of: Total column O_3, NO_2, CO, SO_2, CH_4, HCHO, Tropospheric column O_3, NO_2, O_3 profile, UV Aerosol Index & Aerosol layer height and clouds. S-5P is planned to observe within 5 minutes of Suomi-NPP and will use VIIRS cloud mask for S-5P methane observations.

5.6 Heritage data

ESA has been dedicated to observing Earth from space ever since the launch of its first meteorological satellite, Meteosat-1 in 1977. There is now more than 25 years of continuous measurements from space are available for many geophysical parameters. There is a need to preserve, keep this data discoverable & accessible with latest technology, as well as to continuously improve to ensure fitness for purpose and continuity/comparability with present and future missions data (e.g. Sentinels). ESA's focus is on: preventing the unrecoverable loss of unique ESA heritage data holdings; performing data consolidation & valorisation activities for a selected subset of Earth Observation data; and providing basic access and maintaining international cooperation on data preservation at a collaborative level.

5.7 Thematic Exploitation Platforms

While the availability of the growing volume of environmental data from space represents a unique opportunity for science and applications, it also poses a major challenge to achieve its full potential in terms of data exploitation. In this context ESA has started the EO Exploitation Platforms (EPs) initiative, a set of R&D activities that in the first phase (up to 2017) aims to create an ecosystem of interconnected Thematic Exploitation Platforms (TEPs) on European footing, addressing: Coastal, Forestry, Hydrology, Geohazards, Polar, Urban themes; and Food Security (under definition). The TEPs are a collaborative, virtual work environment providing access to EO data and the tools, processors, and Information and Communication Technology resources required to work with them, through one coherent interface. As such the EP may be seen as a new ground segments operations approach, complementary to the traditional operations concept.

6 INTERNATIONAL CONTEXT

6.1 3rd GCOS Implementation Plan

GCOS were encouraged by the UNFCCC's SBSTA to consider the outcomes of COP21, and to collaborate with relevant partners when preparing the GCOS IP 2016. The implementation plan has a number of goals, including to: ensuring that the climate system continues to be monitored and improving global, regional and local long-term climate forecasts by: filling gaps in network coverage, refining ECV requirements, improving techniques and addressing global cycles. The 2016 IP provides continuity from the previous IP, but with some updates to the ECVs and the ECV products. The IP has been expanded to include observations for climate adaptation, mitigation and climate indicators. It also considers the broader relevance of climate observations in related activities such as the CBD, SDGs, UNCCD and the Sendai framework and addresses how to make consistent observations across the Earth system cycles of carbon, energy and water. Part 2 of the IP considers overarching and cross-cutting actions, requirements for Climate Observations, planning, review and oversight, data management, stewardship and access, production of integrated ECV products, ancillary and additional observations.

It is intended to reduce the time-lag between the IP report and the subsequent satellite supplement by providing the Satellite Supplement as an Appendix to this Implementation Plan. The plan is to extend the ECV product requirements provided in satellite supplement to all observations (incl. those based primarily on in-situ observations) and there is an action to define the review process in 2017 and provide periodic updates.

6.2 Space Agencies contribution to the IPCC, COP and UNFCCC

The Paris Agreement, the historic outcome from the UNFCCC's COP21, aims to hold the increase in global warming to "*well below 2°C above pre-industrial levels*" and to "*pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels*". The space agencies main contribution to COP21 was through the Subsidiary Body for Scientific and Technological Advice (SBSTA) report, where positive feedback was received from statements by GCOS, IPCC, WMO, CEOS and CGMS. The space agencies are supporting the Paris Agreement through programmes such as CCI, which support fundamental climate science. They can also respond directly to key aspects of the Paris Agreement, such as the need for observations to support REDD and climate adaptation. ESA has long term commitments that contribute to the response to the Paris Agreement, through partnerships with the EU, EUMETSAT, scientists, users, CEOS, its Member States, etc. An effective international framework also helps strengthen the impact of the space agencies response.

6.3 Joint CEOS/CGMS Working Group on Climate

WGClimate helps to coordinate activities to develop the Climate Monitoring Architecture and ECVs, reporting to the space agencies and to the UNFCCC and GCOS. A key part of its objectives is the development of the ECV Inventory, with each chair obliged to complete one inventory development cycle.

WGClimate coordinates input from the space agencies to the UNFCC's Subsidiary Body for Scientific and Technological Advice (SBSTA). Last year, for SBSTA-43, the SBSTA invited GCOS to collaborate with relevant partners in the development of its work, and urged Parties to work towards addressing the priorities and gaps identified in the GCOS SR 2015, as well as inviting Parties and relevant organizations to provide inputs to, and contribute to the review of, the GCOS IP 2016. The SBSTA also encouraged Parties and relevant organizations to enhance systematic observations related to the understanding and prediction of extreme events. This is a new area of emphasis, and one where WGClimate needs to work with GCOS on specific requirements.

WGClimate will be present in Marrakech, at COP22 for the SBSTA 45 and will present a statement on behalf of all the space agencies. Here, there will be an Earth Info Day, which aims to be a reoccurring day, to provide an up-to-date picture of the status of the climate and current future outlook at COP22.

6.4 WGClimate ECV Inventory

The goal of WGClimate is to improve the systematic availability of Climate Data Records [CDRs] through the coordinated implementation, and further development of the architecture for climate monitoring from space. Therefore the ECV Inventory was designed in response to the climate monitoring needs as formulated by GCOS. The aims for the ECV Inventory are to:

- Capture the largest possible number of quality controlled current and future CDRs responding to requirements for GCOS ECVs.
- Get the most accurate information concerning the data records.
- Ensure completeness and consistency of information provided.

The ECV Inventory is intended to be a thorough and reliable source of information.

A questionnaire has been developed in order to develop the fields of the inventory. It covers stewardship of ECVs, the generation process, record characteristics, documentation, accessibility and the type of applications and users. Feedback from the CCI has been good, with feedback from most projects. Any CCI teams that haven't yet filled in the Inventory with their own data are encouraged to do so. Access to the inventory and the related guidance is via the WGClimate website, the ECV Inventory website is in development. Globally, the ECV Inventory is approaching 300 entries and is still growing. This includes ongoing contributions from EUMETSAT, ESA, NASA, NOAA, UKSA, USGS, as well as upcoming contributions from CNES, EC, JAXA, CSA, UK Met Office, KMA, and more. 80% of the entries are 'current' (i.e. already produced, based on past/present missions), with 20% 'future' CDRs (i.e. planned and committed but not yet produced, based on past/present/future missions). All three domains are covered: atmosphere, ocean, and land. Around 5% entries have been verified, with ~10% under verification. The Inventory has over 120 responders registered, around 40% of which are active.

The CCI have 34 entries so far from:

- GHG, Aerosol, Sea Level: process almost complete
- Fire, Glaciers, SST, Clouds: ongoing
- Sea Ice, Ocean Colour, Ice Sheets, Soil Moisture: upcoming
- Land Cover, Ozone: TBD

6.5 Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6): Experimental design and organization

CMIP defines common experiment protocols, forcings and output; it has developed in phases, with the simulations of the fifth phase, CMIP5, now completed, and the planning of the sixth phase, i.e. CMIP6, well underway. CMIP model simulations have also been regularly assessed as part of the IPCC Climate Assessments Reports and various national assessments.

A common suite of experiments for each phase of CMIP provides an opportunity to construct a multi-model ensemble using model output from various phases of CMIP. Currently there are 21 CMIP-6 endorsed model intercomparison projects, all of which have to fulfil some key criteria to gain endorsement. Within the wide variety of models in CMIP6, some main tools are used to broadly characterise the model behaviour: tools such as the community-developed Earth System Model Evaluation Tool (ESMValTool, *Eyring et al., ESMValTool, GMD (2016b)*) that includes other software packages such as the NCAR CVDP *(Phillips et al., 2014*)) and the PCMDI Metrics Package (PMP, *Gleckler et al., EOS (2016)*) produce well-established analyses as soon as CMIP model output is submitted.

The Observations for Model Intercomparison Projects (Obs4MIPs) was developed as a well to bring observational scrutiny to as much of the CMIP/IPCC process as possible, and to utilize the wealth of satellite observations available. Obs4MIPs has defined a set of technical specifications and criteria for developing observational data sets that are technically aligned with CMIP model output (with common file format, data and metadata structure). Over 50 datasets that conform to these standards are now archived on the ESGF alongside CMIP model output (Teixeira et al., 2014), including ESA CCI data. Users have enthusiastically received these Obs4MIPs data. Further information on Obs4MIPs is given in the following presentation.

6.6 Obs4MIPs overview

There was a dataset call last spring for CMIP6, from which over 175 datasets were submitted and about 50 are complete. There has been a good response from the CCI teams. The proposed submissions must have a short user guide document for each dataset, all of which needs to undergo a peer review process, which is taking a bit of time to complete. There are monthly teleconferences to update the Obs4MIPs coordination team on the status of the submitted datasets. To update the status of datasets that have been submitted, contact Roger Saunders or Veronika Eyring.

7 BREAKOUT SESSIONS

7.1 Consistency and Stability

A Climate Data Record (CDR) is defined as "*a time series of sufficient length, consistency, and continuity to determine climate variability and change*" [NRC, 2004]. Consequently, consistency and stability are fundamental concerns to CDR production, and have been rigorously treated in the CCI programme. The Consistency and Stability session of the Seventh CCI Colocation continued dialogue on the matter, in the form of an introductory scoping of the session by its Chair (Simon Pinnock), seven presentations spanning CCI ECV projects, discussion and subsequent reporting to plenary.

7.1.1 Consistency

The Agency and climate data community would like ECVs to be easy to use and for there to be no conflicting results. ECVs can be designed to be consistent in various ways, including (i) the form of their output formats, metadata standards, and dissemination mechanisms, (ii) their product specification, (iii) use of the same auxiliary data across CCI ECV data production (e.g. land/sea mask, meteorology), (iv) use of the same input data, calibration data, orbit models, etc., spanning CCI ECV projects, (v) consistent coverage (and sampling) in time and space, and (vi) where there are common retrieval models/assumptions, using the same ones.

There are often good reasons for inconsistency, including (i) different input data requirements for different ECVs, (ii) different retrievals suited to different ECVs, (iii) and it not being clear which auxiliary data or retrieval models/assumptions are best.

A data assimilation perspective of consistency (Rossana Dragani).
Consistency does not have a unique definition. Nevertheless, consistency does depend on the property of interest and on the reference to its evaluation. In this context, assessing consistency in a Data Assimilation System (DAS) is not trivial, and this largely due to the size of the problem (e.g. 100+ fields). Examples of a data assimilation perspective to consistency were presented, derived from (i) consistency between two or more datasets representing the same ECV, (ii) cross-ECV consistency, and (iii) internal consistency of the DAS. Moreover, consistency in the information provided by two datasets can eventually be translated to redundancy within the DAS, and to robustness in the DAS.

Consistency between CCI Sea Ice and CCI SST (Dirk Notz).
Using examples of CCI Sea Ice and CCI SST data sets in assessing consistency, Notz presented that (1) inconsistencies between observations and model can indicate shortcomings in the model *and* in the observations; (2) Consistency across data sets is not necessarily a value in itself. In particular, model physics can often deal well with inconsistencies. ; (3) Consideration is needed to the prize to pay for getting rid of inconsistencies, for instance the compromise on reliability.

Cross-assessment of ECV's for global climate variability study (Ulrike Willen).
Willen presented an evaluation of Pacific Ocean variability, the El Niño Southern Oscillation (ENSO) pattern in observations and climate models, and took the form of investigation of known relationships, climate indices, e.g. Niño3.4 SST time-series, and correlation with rainfall (clouds) globally. The evaluation was undertaken with the aim of deriving new metrics/ observational constraints to evaluate climate models.

Particular examples in this activity included evaluation of the physical relationships between different ECV's in observations and climate models.

Cross-consistency of marine ECVs (Roger Saunders).
Saunders presented on cross-consistency of marine ECVs (ocean colour, SST, sea level, sea ice concentration) based on current CCI ECV products OC V2, SST V1.1, SL V1.1, SIC: OSI SAF. The experiments took the form of (1) a statistical assessment of observations, (2) model runs assimilating ECVs individually and in combination (1°: 1998-2010, and ¼ °: 2008-2010), and (3) an assessment of consistency of spatial features, temporal variability, and climate indices. Results were presented for illustration, with full results to follow over the coming months, and which will include an inter-comparison with ECMWF.

Consistency for the Sea Level CCI (JF Legais).
In an analysis of *homogeneous sea level estimations for all altimeter missions*, it was found that (i) exactly the same geophysical corrections for all altimeter missions, and (ii) altimeter corrections (sea state bias, ionosphere path delay) and orbit solutions can change from one mission to another but the consistency has been improved. Moreover, in the case of *biases*, an accurate estimation of global and regional sea level biases is such that Global and regional biases are accurately estimated thanks to verification phase of few months during which both satellites measure the same ocean, (i) between TOPEX and Jason-1 in 2002, and (ii) between Jason-1 and Jason-2 in 2008. Moreover, global biases are such that the accuracy is lower than 1 mm and the impact on the Global MSL trend (from 1993) is lower than 0.1 mm/yr (Zawadzki et al., 2016). Additionally, the estimation of regional biases are also very accurate: lower than few mm at oceanic basin scales, and impact of regional sea level biases correction (TOPEX/Jason-1 & Jason-1/Jason-2) on regional MSL trends from 1993 to 2010 was presented. On the matter of *Along-track long wavelengths errors reduction* the cross calibration process insures that L2 data flows from all satellites see consistent and accurate information by correcting Geographically Correlated Errors. Additionally, The orbit error reduction is based on dual crossover minimization of all the satellites using the concept of reference mission, leading to Homogenization between altimeter tracks.

Consistency between AATSR Aerosol CCI and Cloud CCI products (C.Poulsen).
The motivation behind the work is to (1) *correctly identify cloud or aerosol*, impacts the global radiative effects, (2) *increase coverage*, reduce biases in climate record associated with incorrectly identified or missing retrievals, (3) *enable better science*, through more accurate cloud aerosol interaction analysis. An Aerosol and Cloud consistency analysis was presented, Comparing cloud masks of aerosol and cloud, 2008 June/July/August. Consistency dilemmas comprised (1) *Cloud Mask*, more consistency is possible but 'perfect' solution is a way off, (2) *Auxiliary files trade offs*. (ii) *Stability vs Accuracy of product*. (iii) *Consistency with AATSR aerosol product vs CCI Cloud products*, e.g current Ice and land masks. By conclusion, a side to side comparison between *Aerosol-ORAC* (Optimal estimation algorithm, Similar forward model to cloud retrieval - Dual view algorithm & Visible channels only, NN + Independent cloud mask, 1km retrieval→ 10km product, Auxiliary files the same Thomas et al. 2010) and *Cloud-CC4CL* (Optimal estimation algorithm, Similar forward model to aerosol - Single view algorithm; Visible and IR; Uses 3.7 to retrieve effective radius, NN cloud mask, 1km retrievals, Auxiliary files the same, Poulsen et al 2012) was provided.

7.1.2 Stability

Stability of the Sea Level CCI (JF Legais).
Altimeter standards have been improved, supported by the formal protocol to evaluate new standards, namely the "Round Robin exercise". An example is provided by the impact of using new orbit solutions (CNES POE-D/POE-C; Couhert et al, 2015). Additionally, characterization of errors and uncertainties are such that uncertainty in GMSL trend is ±0.5 mm/yr over 1993-2010 and ±0.36 mm/yr over 2000-2010, and Uncertainty in GMSL variations is ~±2. mm. Altimetry measurement errors at climate time scales were presented (Ablain et al., 2015). On the matter of future work on Sea Level CCI stability, the project team aim to (i) continue to improve MSL calculation and processes to reach GCOS requirements, by way of new altimeter standards, and new altimeter missions; (ii) better characterize MSL uncertainties to validate the MSL content and to better know sea-level rise components, at global, regional & inter-annual scales and for each MSL estimation, and (iii) continue to improve MSL stability in non-optimal areas for altimeters: coastal areas, Arctic Ocean.

Ozone_cci experience on producing and assessing harmonised long-term ECV series (Van Roozendael).
The GCOS requirements for stability of Ozone products are < 1%/decade. The approach by the Ozone ZZI project team to meeting these are to (1) use single retrieval baseline applicable to all sensors; direct-fitting scheme selected based on Round-Robin conducted ahead of CCI programme, (2) apply level-1 corrections on individual sensors before level-2 processing (soft-calibrations), and (3) further adjust (small) inter-sensor residual bias before merging. It is found that the tracking drift and bias sources is an essential part of the work for scientists working on CDR generation. In conclusion, there is generally not one single and generic approach to drift and bias minimisation, instead a combination of different 'good practices', including (i) algorithm harmonisation and FCDR (level-1) understanding should always be the first step where possible, (ii) data set customisation can be useful for trend analysis (cf. bias-removal through use of ozone anomalies), (iii) to not stick to one method but think about multiple ways to assess drifts and biases.

7.2 Education and Visualisation

The aim of this session was to help develop a plan for Education, Visualisation and Communication activities within CCI+. Pascal Lecomte gave an overview of the current work that's being done in the CCI and a list of questions for the audience to give feedback on:

Visualisation
During the CCI, an effort has been made to promote the CCI products through the development of a visualisation tool (0.6 %) through: the Exhibition version (OS and Windows), Climate from Space App (OS and Android), as well as a series of animations. Alongside this there are also more scientific visualisations in the Toolbox and projects' own visualisations (e.g. Land cover, Ocean Colour).
Key questions: *Are the above sufficient to achieve our intended objective? How should our objective evolve in CCI+? Do we need other types of visualisations?*
Proposed ideas for discussion include the development of further features on the laptop/tablet visualisations, putting the visualisations we have on different media. The suggestion for putting them on a web interface was well received by the audience.

Education and outreach
Regarding education (including the public and schools) the key questions were: *how do we achieve a broad impact across different countries? What materials are most useful to develop?*
Suggestions for materials involve a "Recipe book", i.e. using the Exhibition version of the Vis Tool to tell stories; the evolution of fact sheets and another MOOC (e.g. Climate from Space follow-on).

Outreach to decision makers, such as via the media briefing held at the Royal Society in June 2015. Key question: *should we organise similar events in the future?*

Outreach to new CCI users – from EO expert to wider global change scientists, covers a wide range of potential users of CCI data. Currently, CCI has been targeted towards modellers but we want to enlarge the user base to others.
Key question: *how best should we expand the user base of the CCI data?*
Example ideas were to continue and expand the LP Fellowships, potentially to be more involved in the core activities of the CCI. Summer school involvement or running – the idea of extended summer schools was raised by the projects. Engaging wider global environment change researchers is an area where 'outreach' activities crossover with the Toolbox, so we should be coordinated.

Communication and media material
Key question: *Should CCI+ develop a Communication Strategy?*
The activities that would evaluated under the strategy would include managing and promoting the CCI website, Twitter, the potential of blogs, etc. Plus the development of a "Starter Pack" easily available in order to be CCI branded (to include logos, fonts, templates, etc.), and a standard set of CCI slides at the disposal of

the whole programme kept up to date. The usefulness of the newsletters should be assessed and if implemented as part of CCI+, should be more consistent.

7.2.1 ESA Education Activities

The three key objectives of ESA Education are to:

- Motivate and enable young people to enhance their literacy & competence in sciences and technology (STEM disciplines)
- Inspire and enable young people to consider pursuing a career in the STEM field, in the space domain in particular
- Contribute to increase youngsters' awareness of the importance of ESA (European space programme), space research, exploration and applications in modern society and economy

Education should not be confused with outreach, they are different things that need to be addressed differently.

ESA Education target ages 4-28 years old over 22 ESA member states, covering 18 languages, aiming to address the lack of interest in STEM, from girls in particular, and the shortage of specialized workforce in the space sector. ESA Education address both school pupils and teachers, and up to university level. Research shows that a child will establish whether they are interested in science or not before the age of 11. In the former, space is the context for formal education, covering teacher training, classroom activities to support the curriculum in an innovative way, and European project-like challenges: learning to think, learning to do, learning to collaborate.

The European Space Education Resource Office (ESERO) is ESA's main project in support of school education. They target the teaching community as the key actors to make a real change in STEM education, the most effective multiplying factor and because inspired teachers make engaged students. Space is used as a theme/context to teach the STEM school curriculum, providing access to space content, data, facilities, methodology, expertise and role models – a key value in modern pedagogy of Sciences.

ESERO is based on national synergies with national Space Agencies, Ministries of Education, national space sector, renowned educational partners. They establish and maintain the institutional framework to operate in the territory, tracking the evolution and trends of national curricula. ESERO provide pedagogy and didactics expertise, which aim to successfully design/produce classroom activities with ESA and national partners, and successfully deliver accredited pre-service and in-service teacher training, and training of trainers. This gives them large scale reach across each country. ESERO has an over-arching space portfolio that covers Earth and climate sciences, life sciences, satellites and rockets, etc.

There is a current active thematic working group on observing the Earth, which addresses a lot of topics that are relevant for the CCI programme, at different levels of detail for primary and secondary schools. Some examples of classroom resources developed by ESERO pedagogical experts are:

Primary school level:

- Observe Earth from the ISS
- See your school from space, From the ground and from the sky
- The magic of light + Secret messages + Daily devices
- Watching a glacier + The ice is melting + The green house effect + Global issues from above

Secondary school level:

- Case studies based on EO data (Sarepta, Leoworks and other SW)
- Webcam hack + Global issues from above + EO and GPS
- Complementing apps: vegetation (Proba-V) + environment (Copernicus/Sentinels) + ice (Cryosat)

A new topic on Earth Guardians: European school challenge, is where the CCI work could contribute. It is aimed at primary and secondary levels, project-type activity. It uses progressive learning to investigate:

- Understanding the science behind Earth phenomena (e.g. ice melting, change of state, green-house effect, the water cycle)
- Select a theme: Climate, Land & cities, Forests, Seas and Oceans, Rivers & lakes, Atmosphere
- Make and present a group project: identify a problem/environmental issue and propose a solution; use of EO data/products; citizen science approach?

7.2.2 Using the CCI Visualisation tool in teaching school groups and the public

A team of researchers at University College Cork in Ireland at the Marine Renewable Energy Ireland institue have been using the CCI Visualisation Tool for educational purposes, in conjunction with the CIT Blackrock Castle Observatory (BCO), which supports programmes that strengthen communities. BCO aims to increases interest in STEM-related careers, develop inquiry-based education and improve the baseline understanding and acceptance of scientific methods amongst the public. BCO work closely with ESERO Ireland and Science Foundation Ireland as a funded strategic partner to achieve ESA Education objectives. As part of this they have developed a National Space Week and will host the International Space University Space Studies Programme in 2017.

A number of capacity building collaborations have been set up at BCO, which has established a reputation of leading, hosting, and co-organising high quality, focused, and effective training courses and events. In these, the practioners often deploy a successful consultation process whereby trainees shape the courses. Training events often balance capacity building with space for networking and collaboration building. UCC and BCO collaborate to teach students, and the public about Climate Change, and more recently Climate Adaptation, and for this they have used the CCI Visualisation Tool.

CCI Visualisation Tool
The benefits:
- Easy to use – zoom in, zoom out, pan etc.
- Supports telling the story, examining the different points in the Earth system, and relating it to the audience
- Excellent visual support for the educator

The shortcomings:
- Limited time (have to download data)
- Need an EO specialist to translate it…. There are not many EO specialists in Ireland who teach…
- Need data packages pertaining to specific Climate/Weather narrative case studies (e.g. N. African crop failure – Syrian crisis)

The opportunities for development lie within the fact that ESA has a reputation for cutting-edge science, accountability, traceability, and reliability. Therefore data from the CCI teams carries this weight. There are case studies in climate events already held in the data, which could be extracted and prepared as narratives for teaching. Then produce the materials and tools for educators to use, and the knowledge to use them effectively.
Challenges for enacting this:
Educators cannot incorporate new working practices, tools, or innovations unless: it genuinely makes their job easier, it is easy to incorporate into their routine and it addresses their KPI's and goals. The need for outreach on climate change and adaptation needs to be clear, concise and targeted, and preparations for outreach on CC&A need to be of the same high standard and quality. Outreach and education are generally considered nice-to-have, not need-to-have, and are funded accordingly. There will be an iterative development process to discover what educators need, and what CCI+ can provide.

Recommendations from the UCC/BCO work done already:
- Targeted, professional, rewarding Educator Engagement
- No workshop for workshops sake
- Deploy professional facilitators

- Reward attendees (e.g. support their travel)
- Align with Users schedules (e.g. training periods, or holiday periods with teachers)
- If targeting teachers and their holiday periods, ensure participation is better than a holiday!
- Advance planning, and notice is essential.
- Engage, and keep engaged!!!
- Demonstrate listening, understanding, and responding
- N.b. the Human Factor

To enable educators:
Key recommendations are to support the provision of tools to teach, e.g. pre-prepared lesson plans which address National Curricula. For more advanced students, this might include template lectures and learning topics with the links to data, tools, and toolkits. Provide Europe's educators with the material to inform, and inspire (e.g. social media posts etc.) and develop this material iteratively with educators, to ensure usability.

For public outreach and education:
Key recommendations are to ask the people doing public outreach some main questions, e.g. what fora are they teaching in? What information do they need to support teaching? And what tools would help them teach? It is beneficial to expose the public outreach folks to current tools, and explore how they can be adapted, allowing the educators the flexibility to be very creative. Support the targeting of educating to disadvantaged areas / regions / social groups in order to widen the reach of science.

Throughout the development of educational material it is essential to keep doing the CCI data science that ESA are funding through the CCI projects. Without the data, we have no information to teach, no tools to support our education efforts. Existing tools form an element of what educators need but it is not yet the perfect package. Understand, that good outreach cannot be done on a shoestring, and develop your CCI-education support plans strategically, by having a plan for educators to follow.

Key stakeholders to engage initially should be determined, which in the case of UCC/BCO is conditional to Ireland.

8 MOVING FROM CCI TO CCI+

8.1 Splinter reports and discussion

8.1.1 Consistency and stability

Based on presentation and discussion in the Consistency and Stability session, the following concluding points were presented to plenary.

Consistency is a broad topic. Nevertheless, there is an overall need for ECVs to have no conflicting results. ECV data records can be designed to be consistent in various ways, including (1) Output formats, metadata standards, dissemination mechanisms; (2) Product specification (snow vs. glaciers vs. ice sheets vs. land cover); (3) Use the same auxiliary data (e.g. land/sea mask, meteorology); (4) Use the same input data, calibration data, orbit models; (5) Coverage (and sampling) in time and space; (6) common retrieval models/assumptions, using the same ones.

Perfect consistency probably cannot be achieved, given (1) Different input data requirements for different ECVs; (2) Different retrievals suited to different ECVs; (3) Not clear which auxiliary data or retrieval models/assumptions are best. Nevertheless, consistency is not an end in itself. Striving for consistency can allow us to learn a lot about our data and models, even if we finally don't achieve consistency.

Treatment of **Stability** has progressed, given (1) altimeter standards have increased (e.g. round robin, formal protocol to evaluate new standards) and apply to corrections due to orbit, wet troposphere, and atmosphere correction, and (2) Characterisation of errors and uncertainties; statistical significance sea level trends.

Stability is not only a problem of Level-2 and algorithms, but also Level 1 data. Orbital drift and Slit function changes with time (e.g. for GOME-2) are therefore relevant.

8.1.2 Education and visualization

A person's attitude to science is formed when they are 10 years old. Therefore we recognize in the CCI programme that we want to encourage the education and to nurture the enthusiasm of a new generation of young scientists. Two key recommendations from the ESA Education office were to develop any educational material through the framework of the successful European Space Education Resource Office, as they have offices and links to 22 ESA member states. And that a new "Earth Guardians" theme in ESA Education could provide a role for CCI+ to help develop projects to understand the science behind Earth phenomena.

In order to develop new projects within ESA Education, help is needed from the CCI community to:

- Access to space themes, content and expertise, e.g: 'Internal' thematic consultancy and workshops; suggestions for typical real science cases; historical perspective → modern challenges and trends; thematic webinars for teachers and/or students; dedicated MOOCs, YouTube videos
- Teacher/student-friendly access to data (over space and time)
- Audiovisuals/visualisation tools
- Role models
- Direct insight and access to real space events & opportunities
- European overview, coordination, facilitation
- Smart funding

In using the CCI Visualisation Tool for teaching, the team from Blackrock Castle Observatory and University College Cork developed the following recommendations:

- CCI data use can be expanded into the realms of education and societal capacity building.
- The fundamental tools are there to support ad-hoc events, and Climate Change & Adaptation narratives.
- There are collaborative arrangements and infrastructures in place in member states to respond to calls and initiatives.
- Each member state's education system is the same, but different.
- Capitalise on building bridges between science outreach centres, and the science institutes

In the following discussion a communication strategy was recommended – to identify the CCI assets and tools. There are lots of tools that are currently available, the Vis Tool, iPad App, MOOC, could develop more stories for them. There was support from the audience for a web version of the Vis Tool, to avoid downloading it.

Further suggestions were for Youtube videos/explainers and games, the idea being 'education without knowing you're doing it'. At the moment there's not many people doing this for climate.

For collaboration through ESERO, the CCI should select key topics; get some people together for workshop, introduce climate change as a key topic and identify requirements through a proper planning process.

There is potential overlap between the CCI Toolbox and Vis Tool that we may want to develop, or at least be aware of while both are developed. There was a concern from some CCI scientists that education is very far removed from what CCI scientists do in their daily life and what CCI currently does.

8.2 Exploitation of CCI data sets

8.2.1 Science Leaders' Feedback

Update on OBS4MIPs (R. Saunders)

Roger is part of the Obs4MIPS oversight panel which meets virtually once a month to decide on which datasets are to be approved for inclusion on the Obs4MIPS dataset. Most CCI teams have submitted their datasets to Obs4MIPS and the mature end of CCI phase 2 datasets will be accepted for inclusion in Obs4MIPS.

Update on SAF-CCI interactions (R. Hollman)
EUMETSAT has agreed the next phase of SAFs. CM-SAF mainly covers climate. The Ozone SAF is now AC-SAF with CDRs generated; H-SAF is doing CDRs for soil moisture and J. Schulz is the main interface between the CCI and SAFs.

CCI Portal (V. Bennett)
The Open Data Portal is now live on cci.esa.int with a working dashboard. Various options are available to search the datasets, on variables, time periods, faceted search also on categories. The next step is to have tags that are recognised and show up in a search. The data can also be downloaded on the ESGF, which climate modellers will use. All are encouraged to play with it and give feedback.

There was a question over what download access is required and the contact details given, if any. Concerns were expressed over the terms and conditions on the use of datasets and the need to give citations. Various options were proposed to help this. Forums and Wiki sites may also help communication with users. The future users of CCI data in the CCI+ era needs to be defined with ESA as some of the teams may be disbanded. There is no plan to make available old versions of the data, which is still a requirement and was a concern expressed by the group to be raised with ESA.

CCI Tool Box (C. Brockmann)
The toolbox makes it easy to work with different ECV datasets. CCI teams can use it but there are many other researchers who could also make use of it. Clouds, Glaciers and SSTs are champions of Toolbox and represent different types of data. Other non-CCI datasets can also be configured to combine with the CCI data. There will be new releases on the open data portal every 3 months for users to provide feedback. There was a question on how access to pre-operational and operational datasets should be enabled and how it will be different. The former is like having beta testers for datasets.

CCI+ Discussion (All)
The key points are a general concern if ESA abandons current CCI projects as for prospective users it doesn't give the new users the right message. There needs to be seamless access through C3S for users and there shouldn't be gaps in the data or service.

Papers Status
CCI uncertainty paper (C. Merchant)
Good progress has been made since last autumn but some ECVs have not responded and we need clarity on this. There is a draft text already but differing views in some cases so it will be a generic paper. Chris will make a google doc of what he has from each team to make it clear which contributions are needed. *Action: Chris Merchant*

Special CCI issue on EO data for global climate observation in Remote Sensing of Environment (Emilio, Michael)
Deadline for submitting papers was end of September but there were a lot of last minute emails requesting an extension and 15 October is now the official deadline. There are 42 accepted abstracts covering all ECVs. Eight papers are already uploaded. It was suggested end of October should be an extended deadline if the journal agrees (papers need to be very good).

Potential topics of collaboration between ECVs for cross-related papers (Emilio)
One aim of CCI is to bring together cross disciplines and some publications in this area should be encouraged. The sea level project is a good example of cross ECV work and a collection of papers from the ISSI meeting in 2015 will be published and many papers are directly related to CCI datasets. There will also be a book. It

seems a dedicated workshop is a good way to initiate this kind of activity. Could plant seeds for this at the next Integration meeting.

Exploitation of CCI datasets (All)
1. As we move from CCI to CCI+ what mechanisms would you suggest are put in place to ensure the teams who generated the CCI datasets have the opportunity to exploit these data to answer scientific questions. This should consider existing ECV projects and those potentially in CCI+.
Teams of course need funding but many have ideas on how to exploit the datasets as not only data provider but exploiter. There is a need to advertise datasets to national and European funding agencies to increase funding. Deliverables should also be submitted papers to peer reviewed journals. Living Planet fellowships are another mechanism. Once the Toolbox is available, more can be done with less effort. CCI internships might be another mechanism. Scientists move from one ECV to another perhaps. CCNs on existing projects is another way if there is a defined project and remaining budget.

2. *Since one of the proposed CCI+ themes is dedicated to Cross-ECV activities can you please provide suggestions (ideally specific) of the types of projects that should be supported here - typical examples include CMUG, Sea Level Budget Closure, and a potential activity in support of RECCAP-2 (regional carbon cycle budgets). Such projects/suggestions should be multi-ECV, linked to a major international exercise or international research programme and/or aimed at tackling a key scientific question on climate/climate change.*
Anny gave an overview of the sea-level budget closure project proposed to ESA with 8 teams for 1M€ which is not CCI+. Ice mass balance (IMBIE), carbon budget (GHG, fire, soil moisture, etc.) and aerosol/clouds/ radiation closure are other potential topics. Contribution to the State of Climate Report from CCI datasets could be expanded. NOAA lead this at present through NCEI. *Action: Roger to inform group on how to publish within the BAMS state of the climate and give points of contact.*

3. During CCI an additional mechanism for exploitation was developed through the CCI Living Planet Fellowship scheme. It is intended that this scheme will form part of CCI+ so please can you consider what changes if any you would like to see in how this scheme works (required funding, project types, call frequency, length of contract).
Need flexibility here, would like to open it to non-Europeans to apply. Internship as mentioned above is another proposal.

Proposals for CCI+
Proposal for CCI+ cross-ECV activity / activities:

Improved quantification of land and ocean carbon sources and sinks
The goal would be improved quantification of regional land & ocean carbon sources and sinks using satellite ECV data products and inverse modelling / assimilation / CCDAS. It would involve the ECVs: GHG (CO_2, CH_4), fire, SM, LC, OC, SST, (Biomass, FAPAR additional to CCI). It links well to the WCRP Grand Challenge "Carbon feedbacks in the climate system", addressing the following questions and research areas: Q1: What are the drivers of land and ocean carbon sinks? Contributions to Q2 (feedbacks) and Q3 (vulnerable reservoirs). Research areas: R3 (learning from the existing record; satellite data explicitly mentioned), contributions to R1 (process understanding land), R2 (process understanding ocean) and R4 (improved projections). The idea would include integrated analysis/assessments via (inverse) modelling / assimilation; will highly benefit from improved satellite data (accuracy, spatio-temporal coverage, new ECVs,) and be relevant for CEOS Carbon from Space; can be one or several projects.

CMUG-CCI Integration Meeting in Paris 13-14 Feb 2017
Some discussions were had on the planning of the CMUG meeting addressing the questions: what are our expectations? (e.g. format) for CMUG Meeting, given that less than half of ECVs in phase 2 will be finished. It may be a good time to discuss CCI+. Good time for inputs to 'State of the Climate' discussion. Other potential topics: Cross ECV issues; demonstrations of usage of datasets; meeting of Science Leads; request for talks on sea-level comparisons with climate models at the meeting.

8.2.2 Exploitation – a Living Planet Fellowship view

8.2.2.1 Mechanisms to ensure the teams exploit the CCI data to answer scientific questions

This was a big issue and was done too well in CCI. Data providers need the chance to exploit the data or we end up as co-authors on a large number of papers using our data but rarely had the chance/time to do that exploitation ourselves.
Mechanisms for making this happen:

1) Have a climate data provider group (CDPG) (similar to CMUG) to orient funding to current and future CCI groups to explore or improve CCI datasets and future cross-cutting CCI projects
2) Encourage Cross-ECV exchange – ideally atmosphere-ocean-land-cryosphere interactions in context of CCI+, model-data interfaces, National/EU funding opportunities outside CCI+.
3) Exchange between these projects by a separate CCI data exploitation meeting
4) Producer driven ideas (generators of data sets know best the product quality)
   - The generators of the data sets identify a scientific question to be addressed (GCOS reports or IPCC or WCRP challenges).
   - The generators reach out to those colleagues who can contribute to the scientific reasoning.
5) Annual CRDPs WAS a good thing and drove improvements to the data (as did the competitive round-robin).
6) Fellows attached (embedded in) CCI teams is a huge bonus and allows some data exploitation. Consider more of this.
7) More emphasis on publications as a driver rather than documentation would encourage exploitation.

Funding
Allow the data providers to propose exploitation projects which they then undertake themselves or propose to any interested researcher. There should be funding of exploitation projects of the teams in addition to the Living Planet Fellowship projects. Funding for these exploitation project studies should be applied from outside ESA, like EU. If the products are good enough, this shouldn't be a problem.

There should be long-term, stable, dedicated funding for a) continuous generation of state-of-the-art ECVs product; b) for climate science and exploration of the CCI and CCI+ variables/products – the latter funding would allow research time to work with the ECVs that have been generated and would drive some of the science generated by the research community. Some funding/time for “science", separated from the data production but involving the same teams would be ideal (maybe under the “optional work packages” framework).

8.2.2.2 Proposed cross-ECV activities

Global carbon cycle re-analysis
For this we need consistent data-based quantification of the global carbon cycle (Fig. 6.1 of IPCC AR5 is mostly based on models!). It would need to consider both stocks and fluxes. The approach could be to use data driven using empirical modelling or model-data integration approaches, and process models only where necessary (in case of un-observables). This idea relies on several existing CCI datasets as predictors for C fluxes: Ocean: SST, ocean colour, ice sheets, sea ice, sea level; Land: land cover, soil moisture, fire, clouds (for radiation), (biomass, FAPAR); GHG as atmospheric constraint. It includes inverse modelling e.g. use of the fire, land cover and ocean data to constrain/inform inversions. There would also be outputs for CMUG as benchmark datasets and for IPCC to improve the physical science basis. Links to GCP’s RECCAP focus.

Hotspots of Change
Intensive analysis in response to hotspot of change identification – keeping the focus regional and smaller, using multiple ECV datasets to understand Earth system processes e.g.

1. Dramatic loss of sea ice: wind, SST, circulation and impacts in atmosphere through feedbacks.
2. Soil moisture anomalies – long term changes and relation to other ECVs – air temperature, human influences (LCLU, water use), circulation patterns (El Nino/La Nina)

Process Understanding - Interactions between ECVs

1. Focus on process understanding and potentially on tele-connections (space-time analysis), e.g. how is atmospheric CO2 related/responding to soil moisture and vice versa (Water-Carbon Cycle interactions) or ECVs that vary across seasonal time-scales, hence SSTs, sea-ice, soil moisture, sea-level, clouds.
2. Cross-ECV studies should probably expand the horizon of CCI. E.g. to study the soil-moisture precipitation feedback (which includes clouds) or the links of soil-moisture and snow on the Indian monsoon onset.
3. Permafrost would be a good example where we can feed in CH_4 data and perform some important studies that have climate relevance.
4. Separation of the anthropogenic and biogenic effects on climate change

Targeted Satellite-In situ Efforts

Need for a focus on in-situ measurements. In situ measurements are useful for validation of long-term data set generation and needs support. They also offer insights for local-to-regional chemical and physical processes and offer new ways to further exploit the data sets. An example of a past successful initiative has been the VOCALS-Rex (https://www.eol.ucar.edu/projects/vocals/rex.html).

Product Tailoring and Exploitation

Explore the use of CCI datasets to support other ESA (and non-ESA programmes) e.g. Support to Science or Value Added programmes (inc World Bank). Joint Collocation/ESA meeting to coordinate ESA Programmes (i.e. under Block 4). This could include tailoring of CCI datasets for specific more policy oriented use, for example, formatting of data in appropriate manner (e.g. sea level coastline protection responsibility – but are we close enough to the coast?).

Data maturity is a big issue for exploitation. CCI needs to ensure all datasets are available before cross-ECV activities are started (and ideally all data to same resolution in space and time). Dedicated projects (or dedicated cross-ECV fellows) on specific themes might make the joining-up of the data easier. Need to encourage C3S/CAMS data inclusion not limit to CCI ECVs.

CMUG Role

Could there be a dedicated person in CMUG to get to grips with specific data and be responsible for more useful engagement between CMUG and the ECVs? Having data in OBS4MIPS was always pushed as a massive deal from the CCI side BUT from LPF experience many ESM/climate modelling people, only seemed vaguely aware of what OBS4MIPS was and had little intention to use it if it wasn't something automatic in their analysis tools. Need more dedicated work and meetings to make sure that climate modellers want our data and are aware of its value. Publishing the data better (citable DOI datasets, etc) rather than "projects". There could be a "CCI4CMIP6" or similar beyond Obs4MIPs.

8.2.2.3 CCI Living Planet Fellowship scheme approach

Overall, the LPF has worked really well and the Fellows are happy to be part of CCI. Suggestions for improvements for CCI+:

Funding/Contract

Fellowships should be 100% funded in order to allow them to focus on the work and not funding (difficult to achieve across member states – different costs). Co-funding implies that other projects are followed concurrently BUT 'full-funding' does not necessarily alleviate this. Funding should be in line with National Programmes e.g. NERC (3 years) but at same time also 2-year and 2-year call (shorter but more frequent). Opportunities for Fellowship extension associated to other project opportunities would be welcome. More fellowships would be good, as well as a network/mailing list to continue links with past fellows (ELP Fellowship Alumni?). More money or longer time would both be great but it was enough time to dedicate to doing some science and the reporting/meetings weren't too onerous.

Current conditions are quite difficult and the travel budget is too small to fund participation in all meetings. For travel, LPFs do not receive a fixed travel budget, but get travel money for the mandatory meetings, and

may apply for travel money for at least one additional scientific meeting each year. Reporting shouldn't be done for the sake of reporting but to guide the project to the best possible outcome.

Cross-ECV/collaborative aspects
Tandem-fellowships should be encouraged to improve collaboration (i.e. 2 fellows working on a common project in two countries/preferably also from central-eastern European countries to activate human resources). Multiple science locations should be offered with sufficient support (this was in the call last time but no take up - this should be continued). A co-funding mechanism could be designed, perhaps together with a local host institution and their needs (this would give closer cooperation with universities and research centres toward a consolidated network of researchers. Is an "ESA-sponsored professorship" a realistic and feasible concept in the future? Generally, cross-ECVs fellowship projects should be encouraged.

9 CCI+

9.1 European provision of ECVs and climate services: roles and relationships

A panel discussion was held with representatives from Copernicus C3S, EC and CCI (EUMETSAT were also invited but unable to attend) to discuss the role of each institution in the provision of ECV datasets, and to help clarify the roles for each organisation, and potential gaps and areas for mutual collaboration in their work.

The European Space Council commissioned report in 2010(?) on the European capacity for climate observations and reanalysis, which helped to consolidate the need for Copernicus climate services, put in place leadership mechanisms on climate, and increased the profile of reanalysis. An updated report is planned for 2017. This could be a vehicle for some coordinated messages from these groups.

9.1.1 What Level of Coordination exists between European Institutions involved in Climate Observations (primarily satellite)?

- Is the current level of coordination adequate?

This is an active area of development - European institutions (including ESA) will invest more than 200 MEuro in the next 5 years. There is good coordination already between the institutions, partly due to the GCOS IP, defining common goals to work towards. However, at the moment, any cooperation is informally agreed, e.g. the process of delivering state of the art products through C3S involves a chain of work that relies on organisations outside of the C3S programme. This includes the research and development aspects of ECVs done in the CCI.

Therefore we need to make sure that these processes of interaction are improved. At the moment the current feedback mechanisms are too slow: requirements from C3S made to H2020 are fed in once a year, recommendations come out in call up to 2 years later, then results are delivered a few years later again – taking up to 6 years in total.

The relationships need to be formalised, whilst maintaining a level of flexibility. Discussions should also happen more multilaterally, bringing in entities responsible for data provision and research agencies in the member states.

There is some concern from the CCI scientists about how Copernicus provides feedback to the H2020 research agenda, this has been weak in CAMS, would like to see robust feedback in C3S. This process exists in ECMWF but needs to be developed in ESA.

There is a clear (if slow) communication avenue from Copernicus services into H2020 but how do the results of the research in H2020 flow back into Copernicus services? IPR problems could arise.

9.1.2 Are there well understood roles and responsibilities?

- Is it necessary to be prescriptive – is it even possible?

There is a need to be prescriptive to some degree, in terms of implementing delegation agreements for Copernicus. The same is true with ESA in terms of the programme proposal. There is some opportunity to be more flexible outside of this.

Is the current loose structure that operates between the organisations the right structure to begin with? Do the R&D projects always have to be finite? There is an argument that it's not making optimal use of EO satellites, as the Sentinels won't be explored in a climate sense without good links between the critical reprocessing infrastructure and how it connects to the R&D. This is easier to manage in one organisation such as ECMWF but now across multiple organisations it's more complicated.

It is not currently clear to everyone who is responsible for Level 3 & 4 products between ESA and the operational services. CSS will provide some L3 products but the research involved in joint development of level 1-3 products is critical. Within the broad boundary conditions of each organisation – ideally the products would be developed in CCI, transfer across to Copernicus and at the same time, research continues in CCI, e.g. on algorithm development.

Cloud-providers like Amazon are driving the agenda for platform processing but they are expensive and should not be used. The science community needs to find something else, as we are not commercial. A dedicated science platform to advance state of the art scientific products should be taken into consideration. This is starting to be discussed at a higher level but need to raise more awareness on this with the colleagues working on this.

9.1.3 How do we best ensure continued research and development?

- Are there gaps in opportunities and mechanisms (e.g. time span between for research to impact operations)?
- What aspects are best done under H2020 and what are best done under Space Agency programmes?
- How do we ensure that transfer to routine (op.) production (e.g. Copernicus/C3S, SAF) free up resources for continued research but without completely eliminating the R&D investment on a specific product?
- Which feed back mechanisms and interfaces are needed?

That Copernicus does not foresee any R&D in the programme is a problem. Improving quality control of the datasets is an R&D issue.

There is a gap we should look at how to fill: if Copernicus identifies a specific research need, as the feedback mechanisms to H2020 are too slow, and ESA has limited ability to fund ad hoc projects. What is needed is an 18-24 month project, with a 6-month start up that can react the research needs. There isn't currently a mechanism for doing this – we all need to push for this.

There might be a need for this type of project if, for example, there was feedback from users such as CMUG, who recommended some small improvements. Although, depending how minor the changes, there should be enough flexibility in the Copernicus contracts to do reprocessing, small algorithm updates, etc.

There is an issue from the scientists' perspective with the continuity of teams from the R&D to the operational domain, if they don't remain the same. However, having competitive tenders for operational aspects mean that there is no guarantee the same teams will remain but will make the transition as smooth as possible. There is a need to better describe the feedback mechanisms that this would involve, in case the teams are not the same. Each organisation has their own remit and the objective of CCI is to develop ECVs, not maintain them, therefore there might well be a gap in funding for the team producing the ECV for CCI

and then for C3S. This may mean a change in the personnel of the team and we may need to look for ways of lessening the impact of this gap – there is little CCI and C3S can do, they are at the limit of their boundary conditions.

One of the key successes of CCI is the community that's been built, which sparks new research ideas together. Not yet sure if this will develop as organically in C3S; it's a much bigger programme than CCI. However, it is in everyone's interest to keep the community built up in CCI, so the scientists, together with the organisations involved should look for ways of sustaining it beyond CCI. Options include H2020 space and geo pillars (but this could exclude some countries who are part of ESA but not the EU), national funding agencies, or European Science Foundation CAS money.

There are different links with ESA and C3S if the data involves the Sentinel satellites or not. If C3S or other services identify problems with e.g. the calibration than it can interact with either the CCI and place a CCN or through the ESA ground segment to make a request to reprocess the data. That is part of the Copernicus overall picture. But this agreement only works with the Sentinels.

More can – and is – being done to coordinate the long-term availability of fiducial reference measurements.

One area to consider in CCI+ is to look at streamlining the common aspects of the ECV projects that are using the same infrastructure. This was considered in CCI but with more ECVs in CCI+ it may be good to revisit.

In the long term – there is a need to make sure ESA engage member states efficiently. This process seems to work well now but we should aim to keep up the successes the CCI programme has managed so far. The focus will vary for each country – e.g. the UK is interested in jobs and revenue. Commercial impact on national infrastructure is really important and should be used to lobby on the national level.

9.2 CCI+

A recap on the CCI extension status was given, as CCI+ is classed as an extension of the current programme, rather than a new one. It is planned that over the period 2017-2024, CCI+ will enable EO and climate research communities in Member States to develop the ECV data products required by climate science (e.g. IPCC, CMIP, CoP-21) and for use in climate services (e.g. C3S). It will take account of: the new GCOS Status Report (2015) and new GCOS-IP (2016), the new EO capabilities (e.g. Sentinels, Earth Explorers) and the new programmatic landscape (e.g. C3S, H2020, EUMETSAT CDOP-3, CMIP-6).

The CCI+ scope will encompass four main streams:

i. Development of new ECVs (i.e. ECVs that were not started in CCI so far)
ii. New R&D on ECVs that were started in CCI
iii. Cross-ECV scientific exploitation (demonstration)
iv. Outreach and Communication

New ECVs in CCI+
The selection will be based on criteria already defined by Member States [ESA/PB-EO(2009)32, rev. 1], including the response to GCOS requirements (to be revised in 2016); availability, quality, uniqueness and importance of the satellite data; maturity of retrieval algorithms; ability to capitalise on European scientific expertise; prospects for transition to an external operational context. The ECVs under consideration are: long lived greenhouse gases, precursors (for aerosol and ozone), water vapour, sea state, sea surface salinity, high resolution land cover, snow cover, lakes, above ground biomass, land surface temperature.

It will take into account the overall level of Member States contributions and the need for complementarity with other ECV activities in Europe (C3S, CDOP-3, H2020, etc.). A list of new ECVs will be selected in early 2017, after CM-16 (2 Dec 2016), to facilitate this there will be a CCI Climate Science Advisory Body (CSAB) meeting in early 2017 to support ESA in formulating an implementation plan, then the CCI+ Implementation Plan to be presented to PB-EO in Feb 2017.

New R&D on existing ECVs
Further R&D on ECVs is needed in CCI+ to improve a number of aspects including the quality of ECV products, in order to get closer to meeting GCOS goals (e.g. accuracy, spatial resolution, long term stability), and improve cross-ECV consistency. The development of algorithms for "difficult" ECV variables required by GCOS, e.g. regional sea level, coastal ocean colour, aerosol type, sea-ice drift. The ECV can be lengthened by developing methods to bring older less well-calibrated satellite instruments into the time series (e.g. AVHRR), and develop corrections for future instrument degradation. New capabilities of Sentinel and Earth Explorer instruments should be fully exploited, e.g. new types of measurement, new spectral bands, wider swaths, higher resolution. Climate-quality methods could be developed to join-up multi-mission time series, especially where there are gaps, e.g. Envisat to Sentinel-1/3/5P. Also the increase in maturity of ECV product uncertainty estimates, improvement of merged ECV products and algorithm round-robins to assess promising new ECV retrieval techniques could form part of the work.

Cross-ECV activities
These activities are a key strength of CCI and CCI+, as CCI has succeeded to build an active multi-disciplinary community fostering dialogue and cooperation between the EO and climate science – as recommended by both CSAB and ESAC. The following three main streams are being considered:

1. CCI+ CMUG-type activities to provide an integrated climate user perspective across all ECVs, demonstrating exploitation of the CCI+ ECV products, giving feedback to the CCI+ teams on ECV quality and consistency and providing outreach to the wider climate modelling and climate service community.
2. CCI+ Cross-ECV targeted scientific studies that demonstrate the value of the CCI and CCI+ ECVs and to strengthen uptake by the wider climate community. E.g. assembly and analysis of multiple ECVs for sea-level budget closure, permafrost, air-sea mass and energy fluxes, etc.
3. CCI+ Young Scientist Research Fellowship Scheme to stimulate exploitation of CCI ECVs by the next generation of climate scientists.

Outreach and Communications
This would continue the CCI activities on the Open Data Portal, in order to provide open, free, and easy access to the CCI+ ECVs via multiple standard climate community interfaces. The software Toolbox to equip users at all levels with the tools they require to visualise, analyse and manipulate the ECV data. Alongside this Visualisation Tool will continue to provide interactive visualisations of the ECVs to help communicate the types of climate information satellites can provide. New activities on Education are being discussed at the splinter session this morning.

CCI+ will continue to work with related European activities on ECVs, as discussed in the panel session beforehand. These organisations include H2020, on R&D to exploit ECVs and complementary research on developing ECVs (e.g. FIDUCEO, EUSTACE, GAIA-CLIM). The Copernicus Climate Change Service on operational production of ECVs (but no R&D on ECVs). There was a first call for 9 ECVs announced on 13 Jan 2016 (sea ice, sea level, sea surface temperature, ozone, aerosol, CO_2 and CH_4, soil moisture, glaciers and ice caps, albedo-LAI-FAPAR) and further C3S calls can be expected for operational production of ~20 more ECVs by end 2017. ESA works closely with ECMWF for the transfer of CCI R&D into C3S operations and with EUMETSAT Satellite Application Facilities on a number of activities. The new SAF CDOP-3 programme starts 2017 and ESA is working closely with EUMETSAT to ensure full complementarity on the development of ECVs, on a case-by-case basis (WG-DRG and WGClimate).

ESA are working on getting the ITTs for CCI+ out as soon as possible but a number of formal procedures have to be followed first. The Critical Path includes the Ministerial (Dec 2016), IP approval by PB-EO (Feb 17) and AC/IPC approval (Jun 2017).

In summary, CCI+ is a proposal for the evolution of CCI over the period 2017-2024 to develop new ECV data products required by climate science and climate services. As for CCI, the objective is to transfer the R&D results into an operational context outside ESA once the ECV algorithms and pre-operational processing

systems are sufficiently mature. CCI+ will enhance the contribution of European EO science to future UNFCCC IPCC assessments, as part of the international coordinated action on climate observations through CEOS and GCOS. Both new ECVs as well as new R&D on ECVs already started in CCI are included, complemented by supporting activities providing an integrated climate user perspective, on cross-ECV exploitation, communications and outreach. CCI+ activities will be complementary to other activities on ECVs in Europe (e.g. C3S, H2020, EUMETSAT SAFs), and will be closely linked with international climate science programmes.