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DOCUMENT

CCI System Requirements

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CHANGE LOG

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1 INTRODUCTION

1.1 Applicable and Reference Documents

1.1.1 Applicable Documents

- [AD-1] CCI Second Collocation Report available at <http://www.esa-cci.org/>
- [AD-2] ESA Climate Change Initiative Phase 1 Statement of Work CCI SOW v1.4.1_final, 09/11/2009, EOP-SEP/SOW/0031-09/SP
- [AD-3] “CCI Data Requirements Iss1.1_May 2013” by Victoria Bennett and Sarah James, reference CCI-PRGM-EOPS-TN-13-0009 issue 4 revision 0 available at <http://www.esa-cci.org/>.
- [AD-4] CCI Data Policy to be published

1.1.2 Reference Documents

- [RD-1] Systematic Observation Requirements for Satellite-based Products for Climate: Supplemental Details to the satellite-based component of the “Implementation Plan for the Global Observing System for Climate in support of the UNFCCC (GCOS-92)”, GCOS-107, September 2006 (WMO/TD No.1338). Available online at <http://www.wmo.int/pages/prog/gcos/index.php>
- [RD-2] Software Requirements Specification (SRS) – DRD ECSS-E-ST-40C (especially Appendix D) Software; available at <http://www.ecss.nl/>
- [RD-3] System Engineering General Requirements ECSS-E-ST-10C(6 March 2009) available at <http://www.ecss.nl/>
- [RD-4] The Earth System Grid Federation: Delivering Globally Accessible Petascale Data for CMIP5 ESGF_WilliamsEA_ESGF_for_IEEE_submitted_4sharing.pdf; available at <http://centaur.reading.ac.uk/26627/1/155-310-1-PB.pdf>
- [RD-5] “A Compilation of Requirements for Software and Tools for the Use of Sentinel_3/OLCI data at L1B and L2” S3OLCI_SoftwareTools_SummaryReport_v1.2_MAIN.pdf by Kevin Ruddick MUMM/RBINS available at ftp://ftp.mumm.ac.be/kevin/S3OLCI_SoftwareTools_SummaryReport_v1.2_MAIN.pdf
- [RD-6] “Engineering the Software for Understanding Climate Change”, IEEE Computing in Science and Engineering vol.PP, issue 99, p.s 65-74, Nov. 2009, DOI 10.1109/MCSE.2009.156, ISSN: 1521-9615 .
- [RD-7] “GCOS Climate Monitoring Principles”, November 1999, available online at http://www.wmo.int/pages/prog/gcos/documents/GCOS_Climate_Monitoring_Principles.pdf ;
- [RD-8] ESA Cloud CCI System Requirements Document, Cloud_CCI_D5_1_SRD_1_2.pdf, available online at <http://www.esa-cci.org/>



- [RD-9] Ozone_cci System Requirement Document, SRD_Ozone_cci_1.0.pdf, available online at <http://www.esa-cci.org/>
- [RD-10] ESA Climate Change Initiative aerosol_cci System Requirements document, SRD Version 1.1, Aerosol_cci_SRD_v1.6.pdf, available online at <http://www.esa-cci.org/>
- [RD-11] ESA Climate Change Initiative (CCI) System Requirements Document for the Essential Climate Variable (ECV) Greenhouse Gases (GHG), SRD_GHG_cci_1.0.pdf, available online at <http://www.esa-cci.org/>
- [RD-12] ESA Sea Level CCI System Requirements Document SLCCI-SRD-012 v1-0.pdf or Sea Level SRD v1.3 available at <http://www.esa-cci.org/>
- [RD-13] OC CCI System Requirements Document, OC_CCI-SRD-BC-1.0.2.pdf, available online at <http://www.esa-cci.org/>
- [RD-14] System Requirements Document (SRD) glaciers cci, Glaciers_cci-D5.1_SRD.pdf, available online at <http://www.esa-cci.org/>
- [RD-15] LC System Requirements Document, Land_Cover_CCI_SRD_1.1.pdf, available online at <http://www.esa-cci.org/>
- [RD-16] Fire_cci D5.1 – System Requirements Document (SRD), Fire_cci_Ph1_GMV_D5_1_SRD_v1_4.pdf, available online at <http://www.esa-cci.org/>
- [RD-17] CCI-SST System Requirements Document, issue 1.2, SST_CCI-SRD-BC-001, available online at <http://www.esa-cci.org/>
- [RD-18] “Analysis of How the CCI Data Sets will meet the Climate Modellers’ Needs” CMUG Deliverable TN D2.4 v1.2 available online at <http://www.esa-cci.org/>
- [RD-19] “ESA response to GCOS – Results of the CCI Requirements Analysis” ,DGH/2011/3007/ECO/dms/KW, ESA_Response_to_GCOS_v2_1.pdf available online at <http://www.esa-cci.org/>
- [RD-20] Systematic Observation Requirements for Satellite-Based Data Products for Climate - 2011 Update, GCOS-154, December 2011 available at <http://www.wmo.int/pages/prog/gcos/index.php?name=Publications>
- [RD-21] INSPIRE Infrastructure for Spatial Information in Europe D2.8.III.13-14_v2.0 Data Specification on Atmospheric Conditions and Meteorological Geographical Features – Draft Guidelines available at http://inspire.jrc.ec.europa.eu/documents/Data_Specifications/INSPIRE_Data_Specification_AC-MF_v2.0.pdf
- [RD-22] “Long Term Preservation of Earth Observation Space Data – European LTDP Common Guidelines” GSCB-LTDP-EOPG-GD-09-0002 issue 1.1 available at http://earth.esa.int/gscb/ltdp/EuropeanLTDPCommonGuidelines_Issue1.1.pdf
- [RD-23] QA4EO Guides (Quality Assurance for Earth Observation) QA4EO-QAEO-GEN-DQK-001 to 007 available at <http://qa4eo.org/documentation.html>



- [RD-24] CCI-SEWG-BC-DistributedEcvSystemApproach-1.0
- [RD-25] “Design Patterns” by Erich Gamma, Richard Helm, Ralph Johnson, John Vissides, Addison-Wesley 1994 ISBN 0-201-63361-2
- [RD-26] Software Product Assurance ECSS-Q-ST-80C available at <http://www.ecss.nl/>

1.2 Glossary of Acronyms, Abbreviations and Terms

- AR** – Adaptation and Installation Requirement
- BADC** – British Atmospheric Data Centre
- CCI** – Climate Change Initiative
- CF Convention** – NetCDF Climate and Forecast Metadata Convention
- CEMS** – Climate and Environmental Monitoring from Space
- CEOS** – Committee on Earth Observation Satellites
- CMIP-5** – Coupled Model Intercomparison Project Phase 5
- CORDEX** – COordinated Regional Climate Downscaling Experiment
- CR** – Configuration Control Requirement
- DARD** – Data Access Requirements Document (AD-2)
- DeR** – Design Requirement
- DKRZ** – Deutsches Klimarechenzentrum, German Climate Computing Centre
- DR** – Documentation Requirement
- DSWG** – CCI Data Standards Working Group
- ECV** – Essential Climate Variable
- ESGF** – Earth System Grid Federation
- ESSP** – Earth System Science Partnership
- FCDR** – Fundamental Climate Data Record
- FR** – Functional Requirement
- GCOS** – Global Climate Observing System
- GEOSS** – Global Earth Observation System of Systems
- GlobCover** – ESA Project to deliver global composites and Land Cover maps using ENVISAT’s MERIS data (<http://due.esrin.int/globcover/>)
- G-POD** – ESA Grid Processing on Demand for Earth Observation Applications.
- GTOS** – Global Terrestrial Observing System
- HLR** – High Level Requirement
- HR** – Human Factor-Related Requirement
- IR** – Interface Requirement
- IGOS**
- IPCC** – Intergovernmental Panel on Climate Change
- LC** – CCI Land Cover project
- Metadata** – Information describing significant aspects of EO space data for the purposes of data search discovery and access management (from data collection to individual variables in each data file) (RD-22 Annex 4).
- MR** – Maintenance Requirement
- NWP** – Numerical Weather Prediction
- OAI/PMH** - Open Archives Initiative Protocol for Metadata Harvesting
- OC** – CCI Ocean Colour project
- Operational Archive** – store of full product data sets immediately accessible to users
- Off-Line Archive** – store of data sets intended to preserve data for the long-term and not necessarily immediately accessible to users.
- OR** – Operational Requirement
- PoR** – Portability and Scalability Requirement
- PSD** – Product Specification Document (AD-2)
- PVP** – Product Validation Plan (AD-2)
- QR** – Quality Requirement
- PR** – Performance Requirement
- ReR** – Reliability Requirement
- RR** – Resource Requirement



Secondary Data – includes associated auxiliary and ancillary data, CAL/VAL databases and electronic versions of mission, products and algorithm documentation containing information used to generate and explain the released data products.

(RD-22 Key Guideline 1.1)

SEWG – CCI System Engineering Working Group

SL – CCI Sea Level project

SM – CCI Soil Moisture project

SR – Security, Privacy and Safety Requirement

SST – Sea Surface Temperature

Version n – current released version number of the ECV data product record

VR – Verification and Validation Requirement

WCRP – World Climate Research Programme

WGMS – World Glacier Monitoring Service

1.3 Executive Summary

This document provides a summary of the ESA Climate Change Initiative programme’s production system requirements for generating all Essential Climate Variables in the programme. These are derived from the System Requirements Documents produced by each CCI ECV team individually. This summary is further informed by consideration of system and software standards, feedback from the CCI representatives of climate modelling users (CMUG), and emerging developments in comparable climate record and dissemination systems.

1.4 Scope

The ESA Climate Change Initiative (CCI) is a programme which will contribute to the generation of Essential Climate Variables (ECVs) by producing a set of validated, error-characterised ECVs from existing satellite observations. This is in order to fulfil GCOS Climate Monitoring Principles (RD-7, especially Principles 3, 10, 16, 17 and 18 directly). The Programme consists of thirteen Projects, each addressing a particular ECV, and CMUG, the Climate Modelling User Group. Phase 1 of the CCI was launched in 2009 and is focussed primarily on requirements analysis and specifications, algorithm development, ECV prototyping and validation. The next Phase will build on this work for systems development and ECV production.

This document is the result of the first system engineering recommendation (SE-1 in AD-1;- SE-2, SE-3 and SE-4 are also relevant) from the Climate Change Initiative Second Collocation report;

“The SEWG should review requirements and analyse requirements across the CCI to derive commonalities from the preliminary system analyses”.

It is also a response to the first system requirement in it (SR-1 in AD-1; SR-2 to SR-6 are also relevant);



“Algorithm developers, scientists and end users should be involved in drafting CCI system requirements”.

The guidelines in this document are intended to advise on the system requirements that the CCI ECV production systems (as well as the product catalogue and data dissemination) will need to fulfil in order to respond to GCOS requirements (RD-1, RD-20). The following High Level CCI System Requirements (HLR) have been derived from all relevant GCOS Climate Monitoring Principles (RD-7) along with existing individual CCI ECV SRDs. GCOS Climate Monitoring Principles outside the scope of the CCI Programme have not been encompassed in the high level CCI System requirements. The traceability of each high level CCI system requirement (CCI-HLR-*nnn*) to a specific GCOS Climate Monitoring Principal is indicated through use of a reference number for each principal (G1-G20).

The list of 18 high level CCI system requirements are applicable to all components of the CCI systems or related activities.

CCI-HLR-001	The CCI Systems teams shall sustain production of climate-relevant, long time series of CCI products for the duration of the CCI programme and anticipate production beyond (G16 ¹).
CCI-HLR-002	The CCI Systems teams shall be aware of the benefits of CCI product generation where feasible for change-sensitive, poorly observed key climate parameters, (G7), with consideration for environmental and climate-monitoring assessments such as IPCC (G5).
CCI-HLR-003	The CCI Systems teams shall establish and collaborate with external partners for input data acquisition, optimisation of product generation, product validation, scientific collaboration and future development of the CCI systems.
CCI-HLR-004	The CCI Systems teams shall plan for and promote the conversion of R&D product generation to sustainable product generation, (G9), by producing new peer-reviewed CCI products. (G16).
CCI-HLR-005	The CCI Systems teams shall quantify, document and improve the accuracy, error and uncertainty of each CCI product version, in a version specific Error Characterisation Report (ECR). (G4).
CCI-HLR-006	The CCI Systems teams shall quantify, document and reconcile inter-satellite biases in the long time series of multiple EO datasets used for CCI product generation and validation (G12).
CCI-HLR-007	The CCI Systems teams shall quantify, document and reduce error, bias and inhomogeneity in the long time series of CCI product (G20).
CCI-HLR-008	The CCI Systems teams shall quantify and document CCI system performance and seek improvements in this during the Programme.

¹ This reference number indicates the applicable GCOS Climate Monitoring Principle from which the CCI requirement was derived,



CCI-HLR-009	The CCI Systems teams shall regularly request and document user feedback on the CCI products and the overall impact of the CCI results.
CCI-HLR-010	The CCI Systems teams shall follow the guidelines provided by the Data Standards Working Group (DSWG).
CCI-HLR-011	The CCI Systems teams shall instigate independent CCI product validation as specified in the corresponding PVP.
CCI-HLR-012	The CCI Systems teams shall provide a data management system that facilitates use and interpretation of CCI data and products (G10).
CCI-HLR-013	The CCI Systems teams shall assess the impact of and communicate all CCI system changes prior to implementation (G1).
CCI-HLR-014	The CCI Systems teams shall routinely reassess, prioritise, document, and implement CCI system and user requirements to ensure operation of a robust potentially long-term system (G8).
CCI-HLR-015	Each CCI ECV production team shall produce full climate data records during the Programme for release, and enable one full re-processing of these for release unless otherwise specified, using internationally recognised software standards
CCI-HLR-016	Each CCI ECV production team shall make its data products available for dissemination to users
CCI-HLR-017	All CCI ECV production teams shall coordinate the activities of ECV production
CCI-HLR-018	Each CCI ECV production team shall anticipate being able to continue producing and disseminating data for climate research beyond the current CCI programme.

1.5 Intended Audience

The audience for this document is intended to be the ESA managers of the CCI programme, the CCI ECV Production Teams and their Technical Officers.

1.6 Layout of this Document

This document contains the following sections:

- (1) introductory information about the document
- (2) introduces the system requirements
- (3) details of system requirements, which are placed into categories according to the ECSS software requirements standards (RD-2 section D.2) and definitions.

1.7 Summary of Assumptions for ECV Production

The following highlights the current expectations for ECV production:

There will initially be a distributed arrangement of ECV production systems, able to generate full data-sets of products for each ECV independently (with a product specification evolved from each ECV's PSD) from input data sets available through ESA, on high performance and/or clustered computers.



ECV production teams are welcome to use agile programming techniques to enable rapid updates to algorithms. For this they will be in close-working teams. As with all teams there will be a strong science lead and input.

There will be a capability of frequent re-processing of the entire climate data set following algorithm updates or other issues such as updated input data sets.

The systems will be modular and designed flexibly to facilitate algorithm updates, other system improvements, and migration to new technologies as these become available in order to improve performance and to avoid obsolescence (AD-2 section 3.3.4).

It is proposed that full sets of output data products and secondary data and information needed to interpret them will be made routinely available to users in high-availability backed-up operational archives accessed using a common catalogue via a common CCI programme web portal(s). The web portal(s) services may support CCI in a similar way to how CMIP5 is supported.

2 SYSTEM OBJECTIVES AND REQUIREMENTS

2.1 Context of the CCI Projects

The context of the CCI projects' system requirements includes elements common to that of other contemporary ESA programmes such as GMES (RD-3, GSC-DEF-01 to 05).

2.1.1 CCI ECVs

The CCI ECV production systems include the following ECVs;

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

Each CCI ECV identifies a specific Essential Climate Variable required to satisfy GCOS requirements (RD-20) and hence those of the IPCC.

The CCI system may incorporate, at a later stage, further ECVs.

2.1.2 Contributing Mission Data

In addition to the data from the following sensors from the ENVISAT and ERS-2 missions; SAR, ASAR, ATSR-series including AATSR, GOME, GOMOS, MERIS-FRS, MIPAS, RA-2 and SCIAMACHY the CCI ECV production systems will use data provided by instruments



on-board other European or non-European missions. These may be complementary to each other in terms of spectral bands, radar frequency, ground resolutions, swath widths, revisit time or lifetimes. In addition, when they become available data received from the Sentinel and other Earth Explorer missions will be incorporated into the CCI ECV production systems to extend the climate record into the future.

2.1.3 CCI Development phase

The development phase of the CCI corresponds to the period referred to in the SOW Phase 1 (AD-2), i.e. the period following the contracts kick-off until the completion of the defined CCI phase I work. This period is from 2010-2013. This build-up phase overlaps with and is followed by the CCI main production programme, as each ECV project has a separate start and end date for each phase.

2.1.4 CCI Main Production Phase

In the Production Phase 2 the full time series of data products will be generated from the satellite data archive. In due course data from the GMES Sentinel missions will be processed to continue the climate record into the future. These data products will be disseminated to users such as the climate modelling community, other climate researchers and a wider user base, for validation of the climate record, and research.

2.2 Presentation of Requirements

2.2.1 Type of Requirements

In section 3 system requirements are placed into groups according to the ECSS standard (RD-2 section D.2) Requirement Labelling Scheme.

2.2.2 Requirement Labelling Scheme

The requirements are indicated and numbered according to the CCI programme, their requirement category *aaa*, and number within that category *nnn* (CCI-*aaa-nnn*).

2.2.3 Relationship to CCI Requirements Specification

Reference to a particular ECV SRD from which a requirement is obtained is noted alongside the requirement. Normally the specific reference is an example only, and a similar requirement can be found in other CCI ECV SRDs.

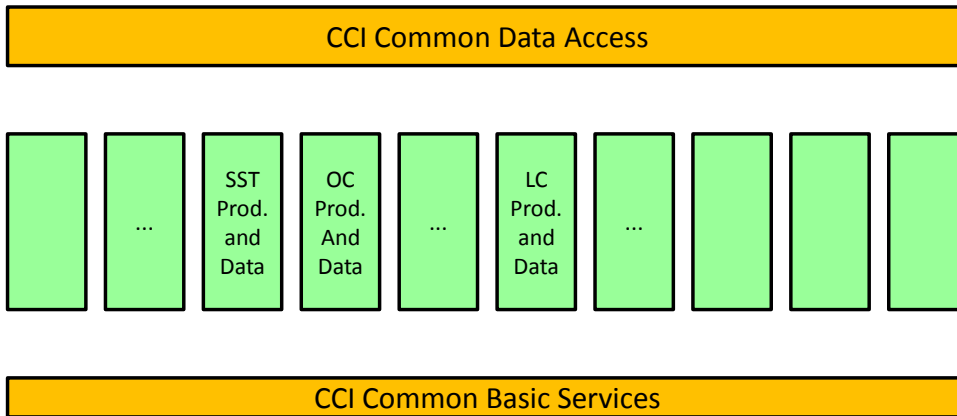
2.3 System Design Concepts

2.3.1 Science Leadership

Development of algorithms to generate climate products, and maintenance of product quality, will benefit from science leadership integrated with system development and operations (RD-6). This pre-requisite is encompassed within the CCI programme system requirements, for example in the system requirements for Ocean Colour (RD-13 SR-4110-4150), “The individual production and data environments per ECV are close to the

scientific groups to support an agile, continuous development and nimble reaction to issues with short cycles. The production environments are optimised for re-processing and validation. Strict versioning ensures production of stable product releases”

2.3.2 Possible Common “CCI” Services



(Fig. 2-4, RD-13)

In the example above of one scenario for running the operational systems, a common user service is suggested for data product dissemination, potentially enabling users to access a range of ECV products while support for this access may be shared between the CCI ECV production teams. Common services within CCI are conjectured such as a back-up archive, or a cloud service for processing, accessible by ECV teams (RD-13 sect.2.4). If available, these shared facilities within CCI might require fewer overall resources than if provided individually by each ECV team. However each ECV production stream is operated independently to ensure the integrity of each.



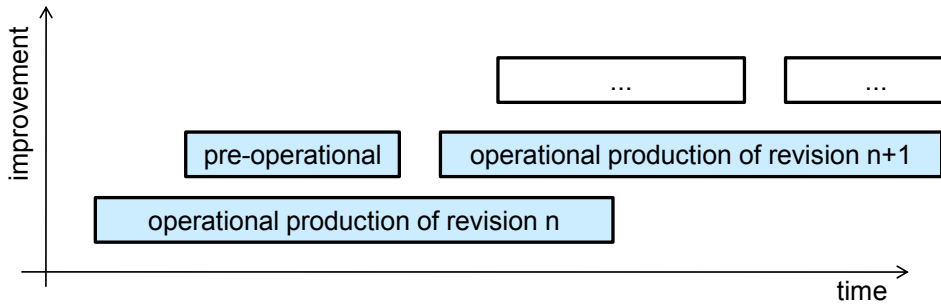
2.3.3 Continuous Provision of Full Climate Data Records to Users

This section includes proposals for the continuous provision of a full ECV climate record while enabling science algorithm development.

The diagram below, from the CCI Second Collocation meeting (RD-24), is a model proposed by SST and OC which demonstrates how a full Climate Data Record (AD-1, i.e. the full product data set for one ECV) can be continuously available for the user. At any instant the existing full data set version n is available for user access while a new generation of products version $n+1$ is being produced. Before the new dataset becomes operational, a pre-operational preview of it will be available to users to gain familiarity and for validation. This overlap of availability between data versions n and $n+1$ will help users to adapt to the new version.

In this model frequent re-processing is envisaged after algorithm or other significant updates, with production of the new generation of data products overlapping production of the previous generation. Though other valid ECV production models may not envisage *simultaneous* processing and re-processing, they should nevertheless ensure that at all times at least one validated version of the full output data set will be operationally available to users (see sections 3.1.3, 3.2.1 and 3.11.7 for treatment of older product versions), while a new version of the full output data set may be being produced. ECV teams might not necessarily release products at each re-processing, since at times the processing may assist algorithm and software development though a new product release is not believed justified.

esa **Improvement Model** 



- **Continuous availability of a full, consistently reprocessed CDR**
 - Focussing on stability for climate-quality
 - Overlapping pre-operational provision to give users time to move
- **Repeated reprocessing**
 - Operational processing and simultaneous rapid reprocessing as part of improvement cycle
 - Full effect of scientific innovations apparent only on reprocessing the complete archive

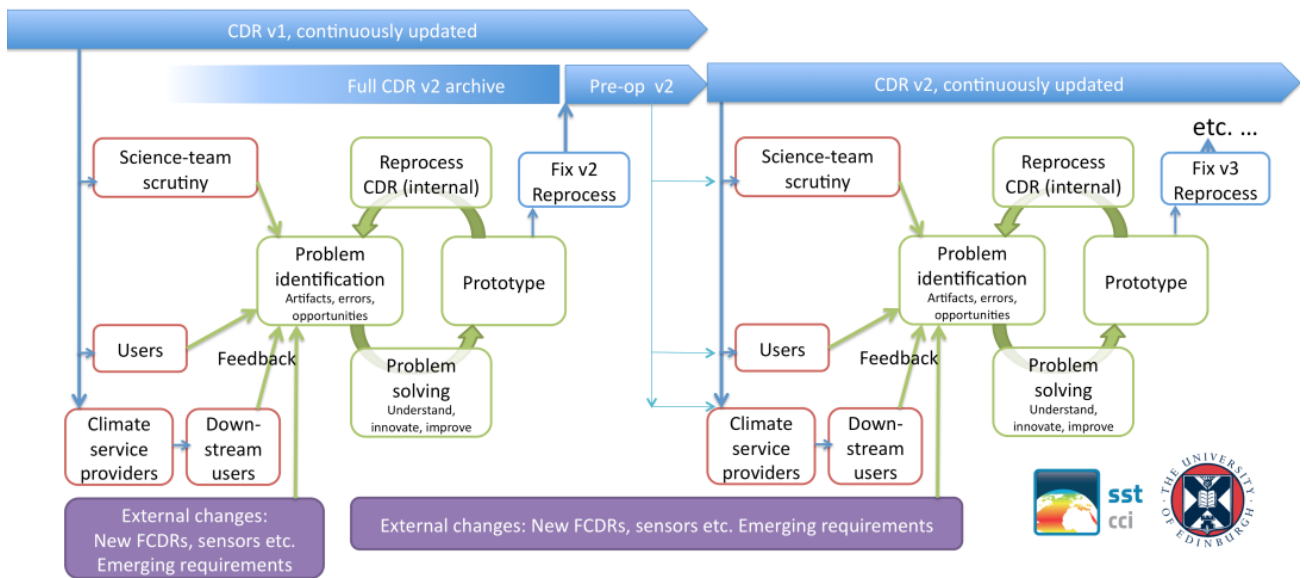
(based on a paper by C. Merchant)

CCI Co-location, ESRIN, 12-14 October 2011



The diagram below from the CCI Second Colocation Report (RD-24) indicates this with a fuller impression of the whole cycle of development of product generation. Additionally each full Climate Data Record (CDR). i.e. one ECV's product data set is continuously extended into the future as further contemporary input data is processed.

Model for Continuous Improvement with Product Versioning





3 CCI ECV PRODUCTION SYSTEMS REQUIREMENTS

3.1 Functional Requirements

3.1.1 Primary Objectives

The CCI ECV production teams will ensure delivery of quality assured (see section 3.9) Essential Climate Variable data products evolving from those identified and specified for the prototype system in the Product Specification Documents (PSDs) (e.g RD-12 SRB-REQ_0-500k), with volume, timeliness and geographic coverage necessary for supporting the GCOS requirements (RD-20). These systematic and sustained observations are needed by the World Climate Research Programme (WCRP), the Intergovernmental Panel on Climate Change (IPCC), and the emerging Global Framework for Climate Services (GFCS).

CCI-FR-001	In the full production phase each CCI ECV production team shall ensure delivery of all the quality-assured Essential Climate Variable data products evolving from those specified in the PSD.
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3.1.2 Systematic Processing of Data

In the operational phase the CCI ECV projects will be able to obtain, ingest and systematically process all relevant and necessary input and secondary data available through ESA (building on those defined for the prototype in the relevant DARD), and store and distribute all released products with their metadata evolving from those defined in the relevant ECV PSD (eg. RD-8 SR/FR/SYS-0201/2, RD-16 SR-100-110, RD-13 SR-1210 and RD-12 SRB-REQ_0-013 and _5-040).

CCI-FR-002	Each CCI ECV production team shall be able to obtain, import, archive and process all relevant and necessary input EO and secondary data required for product generation and validation.
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CCI-FR-003	Each CCI ECV production system shall produce ECV products using algorithms specified in a corresponding version of the ATBD.
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CCI-FR-004	Each CCI ECV production system shall be able to store all ECV products with their metadata in an operational archive for distribution to users.
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The released products will be generated to the required ECV product levels and appropriate for each sensor type, evolving from those defined in the PSDs and as needed to meet GCOS requirements and including climate modelling and research requirements. They will be



archived and the most recent made available for on-line access to users (eg. RD-8 SR/FR/SYS-0203/6, RD-12 SRB-REQ_9-010 and _10-040). They will have a validation chain available for quality checking of the retrieved products (RD-8 SR/FR/SYS-0209, RD-12 SRB-REQ_6-000) and with full traceability of products to all inputs involved in their generation (RD-8 SR/FR/SYS-0212, RD-12 SRB-REQ_9-010).

CCI-FR-005	Each CCI ECV production team shall make all validated released products stored in the operational archive available for online access to users, with full traceability.
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3.1.3 Availability of Full Climate Data Set

The first full processing will generate the complete ECV climate data set with a specification evolved from each ECV's PSD, using the complete input data archive available through ESA and specified building on that defined for the prototype in the DARD. Following this at any one time there must always be a complete ECV climate data set available (derived from this full input data archive and extending to the most recent input data available for climate product production) which is *immediately accessible* to users (see section 3.2.1 for archiving and access of older products, 3.11.7 for back-ups and 3.3.4.7 for reduced availability).

CCI-FR-006	Each ECV production team shall ensure that there shall always be at least one complete ECV climate data set (extending this into the future if more recent FCDR input data is received) available in the operational archive which is immediately accessible to users.
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It is expected that ECV products will be made available to users collectively through a common web portal (RD-12 SRB-REQ_8-010); this will add to the usefulness of the operational systems as a basis to enable construction of virtual multiple-ECV sets of products for future users.

3.1.4 Data Re-processing

The CCI ECV production systems need to have the capacity and functionality to perform re-processing of the whole or part of the archive of systematically generated ECV products with a product specification evolved from each ECV's PSD (extending into the future if new FCDR input data is received). This may be needed when new approved and validated algorithms are implemented and/or new input data and auxiliary data are released (eg. RD-13 SR-0400, RD-12 SRB-REQ_15-080 & _15-230), there are other relevant updates, or as requested by the CEOS Climate Working Group. Re-processing must be performed with at least comparable performance usually (see section 3.2.2), quality, validation and traceability as for previous processing (section 3.2.2, e.g. RD-13 section 3.4 and SR-1520). This will be assisted by harnessing the latest computing architecture developments (RD-12 SRB-REQ_15-180). Released new products must be archived while preserving previous



product versions (eg RD-16 section 5.2, RD-12 SRB-REQ_8-010 and _9-010; see sections 3.2.1 and 3.11.7).

CCI-FR-007	Each CCI ECV production team shall be able to perform re-processing of the whole or part of the archive of systematically generated ECV products (and extending processing into the future for more recent FCDR input data) with at least comparable performance, quality, validation and traceability as for the original processing.
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CCI-FR-008	The released new products from re-processing shall be placed in the operational archive while preserving previous product versions.
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3.1.5 *New Input Data*

The ECV production systems will need to be flexible so as to incorporate new or changed input data and associated secondary data and information when they become available, so as to build on the climate record and extend it into the future; e.g. from existing sensors, existing sensors but changed coverage, calibration or other features, new sensors, new satellite missions such as the Sentinels and Earth Explorers as appropriate, or from another source such as matched-up in-situ observations (e.g. RD-16 v1.4 section 8.2 SR-540). These may require new or updated algorithms (e.g. RD-13 section 2.5 SR-0400), and in some cases to address a much higher temporal frequency and volume of input data.

CCI-FR-009	Each ECV production system shall be able to incorporate appropriate new or changed input data and its secondary data when they become available, so as to build on the climate record and extend it into the future.
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3.1.6 *Preservation of Climate Record*

The full sets of released data products and all necessary secondary data and metadata, and all other data needed for validation of the products by climate research users, need to continue to be archived, backed-up, secure and obtainable into the future (AD-2 sect. 3.5.4, AD-3, AD-4, RD-13 SR-0010). This should follow European Long-Term Data Preservation guidelines (RD-22) including provisions to avoid data loss (see also sections 3.2.1 for archiving and 3.11.7 for backing up data).

CCI-FR-010	The full sets of released data products and all necessary secondary data, metadata, and data for their validation shall continue to be archived, backed-up, secure, and accessible into the future, and extended for new missions with an horizon of 15 years.
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3.2 Performance Requirements

3.2.1 CCI ECV Data; Long Term Archiving

It is an objective of phase II of the CCI programme that the CCI ECV data record will be extended into the future encompassing new missions over the next 15 years (AD-2 sect. 3.5.4). This implies that the following will need to remain archived and accessible to (or obtainable for) users:

- Input data obtained to generate released ECV products, archived as long as needed for configuration control and for the validation of products by users (e.g. climate researchers), with access by permission of the data provider (AD-4)
- Intermediate data products (RD-22 Annex 4) generated but not released operationally, as long as needed for the validation of released products by users (e.g. climate researchers)
- Higher level output data products that are systematically generated from the above and released to users
- Associated metadata, auxiliary and ancillary data, and other secondary data and information (AD-4 item 9)
- Processing algorithms' documentation, system design documentation and source codes (all archived, with documentation to be made available on request, and source code made available to authorised users on request where open source)

CCI-PR-001	The full output data record released by each ECV production system, with all its associated secondary information, shall continue to be extended and archived into the future, encompassing new missions through the next 15 years. The latest released ECV product version at least will be operationally accessible to the user, with the earlier released versions available upon request.
CCI-PR-002	The input data and intermediate data products used to produce each ECV production system's released output data record shall remain archived and obtainable by users on request, for traceability and the validation of released products.
CCI-PR-003	The processing algorithms' documentation, system design documentation, and source codes used to produce all releases of the ECV production system's output data record, shall remain archived into the future on the same timescale as the output data record.

3.2.2 CCI ECV Data; Processing Performance

The ECV production systems must be able to generate the complete product suite (section 3.1.3 req. CCI-FR-005), specified initially in and evolved from the PSDs, within CCI I Phase 2 for validation and release to users (e.g. RD-8 SR/PR/SYS-0301). This is commensurate with the primary objectives (section 3.1.1 CCI-FR-001) and shall achieve the throughput



needed to enable at least one subsequent full re-processing (section 3.1.4) also within CCI I Phase 2.

CCI-PR-004	Each ECV production system must be able to generate the complete product suite with optimised performance, to allow sufficient time for a full re-processing within Phase 2.
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The ECV production systems must be able to re-process the entire current input data set (building on those defined for the prototype in the relevant DARD), to regenerate the complete product suite for release within a timescale that enables the scientific and technical needs for re-processing to be met in a timely fashion (section 3.1.4) (e.g. RD-13 sect. 3.4). Products should be regenerated with at least similar throughput as during the first processing of the full product suite, unless it is agreed that scientific or technical updates justify a reduction in performance. Annual or more frequent reviews by each ECV team's science leader with that ECV project's Climate Research Group, advised by the software development team and in the light of feedback from external users, will decide on the benefit of re-processing to generate a fresh output data set for distribution. This will be coordinated with existing data quality working groups for each sensor where appropriate. Reasons for re-processing for product release to users could include; to process new versions of input data, to improve the accuracy, or to reduce the error in or the uncertainty of the products.

CCI-PR-005	Each ECV production system shall be able to re-process the complete product suite at least once within Phase 2 (unless otherwise stated), and extend the climate record into the future with similar throughput.
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CCI-PR-006	Reviews shall take place at least annually (unless otherwise stated) with the ECV's Climate Research Group who with the ECV Project Science Leader shall decide on the benefit of re-processing for a new product release.
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CCI-PR-007	Each ECV production system shall re-process the complete product suite when requested by the ECV's Climate Research Group and the Project Science Leader.
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The ECV production systems will be flexible and have the capability to process or re-process parts only of the existing input data set if needed to generate output products (unless documented scientific constraints prevent this). They will be able to process new input data from existing sensors incrementally if they become available in the future (section 3.1.5 CCI-FR-009). Processing may start from a higher data level (RD-22 Annex 4) if identifiable intermediate data products are preserved and updates affect only the higher level products.

Batches of input and associated data should be stored efficiently so as to enable processing to continue with a minimal delay, in the event of loss of a batch of data in the input data



stream. This will optimise the performance of data transfer, and minimise breaks in processing if a batch of input data is lost or corrupted.

CCI-PR-008	Each ECV production system shall usually be sufficiently flexible in the handling of input data to be able to process or re-process efficiently parts only of the input data.
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The ECV production systems should be organised so as to optimise the transfer of data via (internal or external) networks (e.g. RD-8 SR/GR/SYS-0110) to maximise performance.

The ECV production systems must develop an initial capability to be able to ingest and process Sentinel and other Earth Explorer data when it becomes available to produce climate products, so as to be able to achieve science goals (section 3.1.1) and extend the climate record into the future.

CCI-PR-009	The ECV production team's science leader and board shall evaluate the need for new algorithms to ingest and process Sentinel and other Earth-observing mission data, and the capacity to incorporate this into the existing system.
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CCI-PR-010	The ECV production systems shall develop an initial capability to be able to ingest and process Sentinel and other Earth Explorer data when it becomes available, to produce climate products and extend the climate record into the future.
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3.3 Interface Requirements

3.3.1 Major Users of CCI ECV Data

The CCI project objectives include the provision of long-term records of climate data for users such as:

- climate modellers such as CMUG and the wider community that they represent (including data assimilation, NWP), climate research groups (AD-2 CR 2),
- strategists and those they represent (e.g. IPCC, WCRP, Earth-observing communities like GTOS, IGOS, CORDEX,),
- research or collaborative groups specific to particular ECVs (e.g. WGMS for Glaciers) (RD-19).
- potentially there may be other users outside these fields including commercial users and non-scientists.



3.3.2 Input Interfaces

Each ECV's processing system will need when relevant to be able to use the interfaces of data providers if 'pulling' data, or enable the data provider to 'push' the data to the ECV system.

Each ECV will be processed using the input data obtained from ESA sources specified initially in the DARD for the prototype and as updated in the light of full requirements for the operational phase and future developments.

CCI-IR-001	Each ECV production system shall be able to use the interfaces of the data providers to obtain the input and secondary data needed, and as these are updated in the light of future developments, in order to generate the ECV products.
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Each ECV will be processed using the appropriate auxiliary and ancillary (secondary) data obtained from relevant sources as specified initially for the prototype in the DARD and updated in the light of future developments. This will be coordinated with other ECV teams using the same type of secondary data, to provide consistency across CCI.

CCI-IR-002	Each ECV shall be processed using the appropriate auxiliary and ancillary (secondary) data, informed by the means with which any other ECV systems use the same data.
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The proposed internal CCI web-site to promote the common handling of input data could help by using a script to pass the files, and log file fetch transactions using the http protocol.

The ECV teams shall maintain contact with the teams responsible for the calibration and validation of the L1 data sets to ensure the most up-to-date calibration is being used (RD-8 section 4.1.2 SR/IR/SYS-0408). They shall arrange to receive automated alerts from data providers concerning data issues and updates, if available.

CCI-IR-003	Each ECV production team shall maintain contact with the teams responsible for the calibration and validation of the L1 data sets for news about updates.
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3.3.3 Internal Interfaces

3.3.3.1 Operational Compatibility Among CCI ECVs

The ECV production systems need to be configured so that each ECV can be generated independently of the status of another ECV's production. This is to avoid dependencies between ECV production streams in which one delays, stops or is otherwise detrimental to the production of another ECV. Hence the operations of any one CCI ECV production stream must not compromise those of another CCI ECV, wait on processing by components from another ECV, or wait for products from another ECV



CCI-IR-004	<p>The progress of any one CCI ECV production stream shall be independent of that of another and shall not:</p> <ul style="list-style-type: none"> • compromise that of another CCI ECV • wait on processing by components from another ECV • wait for intermediate products from another ECV • wait for output products from another ECV for use as ancillary data
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3.3.3.2 Inter-Team Communications

During operational running of the CCI ECV systems, ECV teams must keep all other teams informed of new developments such as a new algorithm becoming operational, new input data being processed, re-processing of data leading to a new generation of products coming on stream, system updates affecting external interfaces, and significant steps towards such developments. This will be done by posting news on a common wiki or web-site newsgroup, from which email or other messages will be automatically generated and sent to all team representatives. This will help to coordinate the development of products for users and keep each ECV team aware of the current work of other teams (RD-6).

CCI-IR-005	<p>Each ECV production team shall keep all other ECV production teams informed of significant operational developments as they occur by means of a common cascading news facility.</p>
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The CCI common portals for the handling of input data or for data product dissemination may be suitable for providing this facility.

3.3.3.3 Inter-System Interfaces

Certain interfaces between ECV production systems will be defined by ESA and the ECV projects to promote scientific cooperation and consistency, and operational compatibility. A uniform, robust and flexible means of communication needs to be defined between external ECV production system interfaces, to allow scientific ECV collaboration (such as the use of the output of one ECV as input to another ECV) without compromising individual ECV production (see section 3.3.3.1). The proposed CCI web portals, an internal one for the common handling of input data and an external for the dissemination of products to users, will log transactions. This and other logged or automated information will help to promote cooperation and compatibility.

Collaboration, such as the distribution of programme code where permitted, should be enabled (RD-12 SRB-REQ_15-210, and _15-400) as desired.

Such Inter-System Interfaces will allow flexibility and independence of ECV production in a distributed manner, in which each ECV system can generate products at local facility/ies yet help to enable the distribution of data and software between ECV production teams.



CCI-IR-006	Each ECV production system shall contribute to CCI inter-team interfaces to help identify and make available software if open source, and data, for the information and use as appropriate of another CCI ECV production team.
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3.3.4 Output Interfaces

3.3.4.1 Standards for Data and Metadata

To ensure compatibility with large existing climate data initiatives such as the Fifth Coupled Model Intercomparison Project (CMIP5), each ECV should have output data products in NetCDF format, with metadata conforming to CF conventions. All data must conform to the CCI Data Requirements (AD-3), which covers data formats, file naming, and common vocabulary, and additional conventions agreed by the DSWG

CCI-IR-007	Each ECV production system shall generate the full climate record of output data products in NetCDF format, with metadata conforming to CF conventions, conforming to AD-3.
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CCI-IR-008	Each ECV production system shall as a baseline produce ECV products in the output format(s) specified in the corresponding PSD.
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3.3.4.2 Dissemination of CCI ECV Data - Introduction

For the primary method of data dissemination, the CCI ECV teams will enable the handling of ad-hoc requests for products from users in a common web-based system (RD-7 P.N. 17, e.g. RD-8 SR/IR/SYS-0404). A Web portal specifically for CCI is proposed, as is use of the Earth System Grid Federation.

Alternatively in certain cases they may accommodate agreed regular requests for ECV data distribution from specific users individually, e.g. via ftp (e.g. RD-13 SR-3120, RD-16 SR-530-532).

CCI-IR-009	Each ECV production team shall provide or participate in providing interfaces for free and open data access and distribution of the complete CCI ECV product record, product subsets and related metadata and secondary information to multiple users.
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3.3.4.3 On-Line Access to CCI ECV Data Products via ESGF

The CCI will provide users with straightforward access to all data products via a dedicated web-based system as the default method. However another route for web access is the ESG Federation (RD-4). This has been designed to handle large volumes of climate model experiment data for a consortium of data providers and archives. Its Obs4MIPS facility provides a mechanism to handle observational data similarly



The [ESGF](#) is a collaboration that provides software infrastructure for the management, dissemination and analysis of model output and observational climate data. It supports current CMIP5 activities, and prepares for future assessments. The ESGF has enabled CMIP5 data to be used for the IPCC AR5 report. It fosters collaboration and has a component architecture designed to handle large-scale data management for worldwide distribution. It serves climate data from multiple locations and sources, including model simulations, satellite observations and reanalysis products.

[Obs4MIPS](#) is an activity to make observational products accessible for climate model intercomparisons through the ESGF. It includes a collection of well-established and documented datasets that have been organized according to the CMIP5 model output requirements. This data is in netCDF format; complying with the CF convention and consistent with CMIP5 model output, under configuration management, validated and peer-reviewed, residing in a long-term archive, covering a period generally of years, convertible to the Obs4MIPS format with only limited additional processing, and including uncertainty estimates for the dataset values.

There are several ESGF gateways (including at BADC and DKRZ) in a federated system, which provide data discovery services. Data services are provided by data nodes of which several are existent in Europe, which publish data to index nodes providing search services and a web interface to find and download data. Each node provides a catalogue interface (using THREDDS middleware), and security middleware which incorporates user management (for registration and authorization credentials). Other data services currently include a faceted search interface to the data, an OpeNDAP interface to provide sub-setting facilities and direct access to the data archive, GridFTP to provide high bandwidth data download, and a Publisher component to ingest data and metadata into the data node. ESGF has version control and can manage more than one version at once for publication and discovery. It performs user registration in a distributed manner and has a white-list.

Hence those CCI ECV teams using ESGF for their ECV operational archives will use or deploy data nodes to provide data services, and so expose their data to the ESG Federation gateway(s) to harvest the data.

Those CCI ECV projects that consider that involvement in ESGF could be of benefit to themselves and to CCI, will investigate the use of an existing ESGF data node for the exposure of their data or setting up a new data node, taking advantage of available infrastructure and support. They will also consider whether to supply their data through ESGF via Obs4MIPS or otherwise. Use of ESGF should greatly assist the ability of their CCI ECV products to be used in the IPCC’s AR6 report.

CCI-IR-010	All appropriate CCI ECV projects will investigate the use of an ESGF data node for the exposure of their data, and of Obs4MIPS as the mechanism by which to supply the data.
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3.3.4.4 Mechanisms of Web-Based Data Dissemination to Users

All CCI ECV production teams will provide their individual ECV product data sets in NetCDF format [AD-3], which they will make available via the common CCI web portal(s) or gateway(s) (as well as ESGF if appropriate). They will maintain this operational output product archive so that it is routinely accessible to users.

CCI-IR-011	Each CCI ECV production team shall make its ECV NetCDF data products and metadata available via the common CCI web portal(s) and keep these routinely accessible to users
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In common with the approach of the ESGF, the CCI common portal will enable CCI ECV data to be obtained by users as downloads from the portal using a catalogue to access the ECV product archives, and including access to catalogue metadata.

A CCI portal user will be able to perform a search query on the product metadata (RD-12 SRB-REQ_22-090), comprised of search terms such as Product type, Product name, Mission name, Date of acquisition, Time of acquisition, and Area of interest.

The CCI web-site will provide automated request and order confirmation and data tracking information.

CCI-IR-012	The CCI ECV production teams shall provide users with straightforward access to all data products via a common web-based system; users shall be able to perform search queries on the metadata, and the web-site shall handle data requests automatically.
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To achieve this, output data product catalogues from each ECV should be published to a common CCI catalogue(s). When an ECV project changes available data products and hence the local catalogue, they must ensure that the system notifies this to the common CCI catalogue so that this is up to date.

CCI-IR-013	Each CCI ECV production team shall publish its data product catalogue to a common CCI catalogue(s) and keep this updated, and shall consider similar for the ESGF.
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The CCI web portal will also contain links to individual ECV web-sites.

The portal will provide the basic functions, upon which it would be possible at a later date to develop further features such as the Open Geospatial Consortium Web Map Service protocol (OGC WMS) and the Open-source Project for a Network Data Access Protocol (OpenDAP) access for CCI output products (ECV SRDs, e.g. RD-12 requirement SR SLTAC-3.1.1). Features such as sub-setting, re-gridding, cropping (RD-13 SR-3170) and



aggregating ECVs could later also be introduced, as well as visualisation and data analysis tools, and functions to help the users read ECV output data.

In the event of further development of the CCI common data portal, it shall be ensured that metadata and services are compliant with the relevant requirements of the INSPIRE Directive (<http://inspire.jrc.ec.europa.eu/index.cfm>). This will include Metadata describing the CCI datasets, as well as Web Services such as Discovery, Download, and View.

3.3.4.5 Mechanisms for CCI Products Download

The CCI web portal will be able to register a user, provide an interface and functionality for authentication (RD-12 SRB-REQ_10-210), an interface for catalogue search, enable a product to be downloaded to an authenticated user, and perform transaction accounting. To ensure consistency of user interface look-and-feel, an uncomplicated format, or style guide in the case of multiple CCI web portals, should be agreed and defined between ECV production teams for such graphical user interfaces. This should be informed by user feedback and all interfaces must adhere to it (RD-12 SRB-REQ_22-200 & SRB-REQ_22-210).

CCI-IR-014	The CCI web portal(s) shall be able to register a user, provide interfaces and functionality for authentication and catalogue search, enable a product to be downloaded to an authenticated user, and perform transaction accounting without manual intervention.
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CCI-IR-015	A common uncomplicated format or style guide shall be defined for web portal(s) for the download of CCI climate data products.
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3.3.4.6 Coordination of CCI User Services

It is an objective that CCI on-line user services will be designed to enable coordination between the ECV products in order to fully exploit these data for climate change and other studies.

To this end a capability to enable the download of scientifically related multiple-ECV data download requests should be included in the web-page design by ECV production team members, aimed to minimise degradation from the nominal download performance.

CCI-IR-016	The CCI climate product web portal(s) shall be able to address multiple-ECV data downloads without a disproportionate impact on download performance.
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3.3.4.7 Information for Users

The CCI common web portal(s) will provide information about the ECV products (as groups of products or separately). It/they will inform users about the data available, how to request data products, how to use and understand the output products, their specification, configuration history (including how to trace the inputs) and quality information (much available in file attributes). It will facilitate feedback on products and issues (see below). Each ECV team will contribute to the CCI user documentation by providing this information (e.g. RD-8 SR/IR/SYS-0405 to 0408).

The CCI web-site will also have information on inter-dependencies between ECV products, and news about output products. It will also have a simple user guide of a few pages only for modellers/users who have no knowledge of satellites.

CCI-IR-017	<p>The CCI climate product web portal(s) shall provide information about ECV products supplied by their production teams (either separately or in groups) including;</p> <ul style="list-style-type: none"> Identifying the data available How to request, use and interpret the products The products' specification, configuration history and quality Inter-dependencies between products (if any) News, including on new products following re-processing
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The ESGF facility, Obs4MIPS, also provides product information. A comparison may be informative especially for ECV production teams who make their data available through this for climate models and ultimately the IPCC AR6.

Data product users will also be kept informed on the CCI portal by online news bulletins of significant issues reducing access to the output data set (see section 3.1.3 CCI-FR-006, section 3.4.1 CCI-OR-44).

CCI-IR-018	<p>If part or all of the complete ECV data set will be unavailable for more than one working day through the CCI common portal, the ECV production team shall ensure that an online news bulletin is posted on the CCI portal.</p>
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3.3.4.8 Interactions with Users

This web-site should be designed to be a top link when climate data is sought with Google or other search engines.

The CCI web-site(s) from which ECV products can be disseminated should have a mechanism to enable users to provide feedback or queries about ECV products, or to report operational problems with the portal.

The CCI online portal will require a ticketing or other monitoring system for user queries which can assign queries about products to appropriate data experts or operators. There should be a means of checking that queries are assigned and receive a timely response and



correspondence should be retained. Some support will also be needed to maintain the website and provide basic user help services.

To achieve these objectives, each ECV production team should appoint a science product representative to monitor, communicate and interact with the users (see section 3.3.1) of its ECV products. They will respond as needed to relevant incoming user queries about data issues. They and an operational representative from each ECV production team should form an email group to which the appropriate portal email queries are automatically directed, once the user has selected the ECV concerned from an on-line drop-down list. The operator will ensure that any science product query has been taken on by the science representative, or will resolve the queries themselves. A moderator appointed by ESA or rotating between the ECV production teams will be included in each ECV-specific or other user-query email group and will maintain overall oversight of the response to queries, and identify queries not specific to a particular ECV. The queries should be ticketed if this can be automated.

CCI-IR-019	The CCI climate product web portal(s) shall have a user forum/blog to enable feedback on ECV products from users, monitored by ECV team science product representatives.
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CCI-IR-020	The CCI climate product web portal will require a moderated system for user queries with a science product representative and operator from each ECV team to resolve these for their ECV, and an automated mechanism for monitoring progress and retaining correspondence.
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CCI-IR-021	The maintenance of the CCI climate product web portal shall be managed <i>collectively</i> by operational representatives from the ECV production teams who shall provide user help services for general operational issues raised in user queries which are not restricted to a specific ECV.
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See also section 3.3.4.5 CCI –IR-014 and CCI-IR-015 concerning web-page design.

CCI-IR-022	The design, development and style of the CCI climate product web portal(s) shall be coordinated with support from the ECV production teams, with the portal(s) designed to be a top link when climate data is searched for with Google or other search engines.
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3.3.4.9 CCI ECV Product Transfers to Registered Users

The design of CCI ECV production systems can permit the secure transfer of requested data to the servers of registered users, by (s)ftp (e.g. RD-16 SR-532, RD-9 SR-UIF-0010-IN) or other secure non-COTS mechanisms.

Such users, identified by an ECV's Climate Research Group, may include specific groups in the climate research community (see section 3.3.1, RD-19). They may also be provided with tailored information on products, and direct dialogue.



3.3.4.10 Access to Algorithms

ECV production teams may consider making algorithms available to users who can then try them, modify them and upload the new algorithm version to the ECV project website/server of origin for testing (section 1.3.4, RD-13 SR-3270 to 3310, RD-16 SR-620). This will promote the improvement of science algorithms and interaction with science researchers in that field (section 3.3.1, RD-19). A proposal is to use a software repository under configuration control, which can be accessed by registered users. They would submit updated code to the repository for review and improvement (RD-13 SR-3260).

3.4 Operational Requirements

3.4.1 System Monitoring

The ECV production systems will inform their respective system operators by logs, messages and displays, of the status of all components and any significant events (e.g. RD-16 section 7 SR-320) and at any time will provide the system operator with the current status. The ECV production teams will monitor the system status routinely to be ready to intervene as needed. The system operator will be able to stop the system and then restart it knowing the current status and using if appropriate intermediate products retained at the system stop (RD-16 SR-460 to 480, RD-13 SR-1500). The ECV production team will be able to access and analyse the data as necessary in the event of a problem.

The ECV production systems will automatically inform their own operator(s) and the operator(s) of the common user web portal(s) of problems affecting the transfer of output products to the operational archive, or in updating the operational archive catalogue and/or common catalogue (see section 3.3.4.7 CCI-IR-018, section 3.3.4.8 CCI-IR-020, 021).

CCI-OR-001	Each ECV production system shall inform its respective system operator(s) by logs, messages and displays, of the status of all its components and any significant events and at any time shall provide the system operator with the current status.
CCI-OR-002	Each ECV production team shall monitor its system status routinely during processing. The system operator shall be able to stop the system and then restart it knowing the current status, and using if appropriate intermediate products retained at the system stop.
CCI-OR-003	The ECV production team shall be able to access and analyse data if necessary to understand or resolve system problems or data product problems.
CCI-OR-004	The ECV production systems shall automatically notify their operator for the common user web portal(s) of problems affecting the transfer of output products to the operational archive, or in updating the operational archive catalogue and/or common catalogue.



3.4.2 CCI Data Long Term Archiving: Re-Processed Data

A released new version, n+1, of ECV output product data resulting from re-processing must be archived operationally (for immediate access) *together* with the current version, n, until validation quality checks demonstrate to that ECV team's Climate Research Group that version n+1 can supersede version n. Only after an overlap of at least six months can version n be moved to a non-operational remote archive (see sections 3.1.3, 3.2.1 and 3.11.7 for long-term archiving) once users have adapted (and to be consistent with AD-4 and requirements CCI-FR-005 and 008).

CCI-OR-005	Each ECV production team shall initially retain the current version n of the ECV output data products alongside a new re-processed version n+1 in the operational archive. There shall be an overlap of at least half a year to enable successful validation quality checks to complete and users to adapt, before moving the old version to a remote archive.
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3.4.3 Network Connections

In an ECV production system, adequate network bandwidths between processing nodes, the input data repository, and local and remote output product archives must be established (RD-16 sect.10) to enable input data ingestion, processing and output product archiving to achieve the throughput needed to meet CCI reliability and performance requirements (sections 3.11, and 3.2 especially CCI-PR-004, 005, 009 and 10).

CCI-OR-006	In each ECV production system, sufficient network bandwidths between system components shall be established to enable data transfer and processing rates to achieve the throughput needed to meet CCI reliability and performance requirements.
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3.4.4 System Configuration

The ECV production system modules must be configurable (e.g. RD-16 SR-250) so as to be able to work successfully whether on one or many processing nodes (even if current system is not multi-node).

CCI-OR-007	In each ECV production system all system modules shall be configurable so as to be able to work successfully whether on one or many processing nodes.
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3.4.5 Operational Staff

Each ECV production system must be supported by at least one trained operator when processing is required (as in section 3.11.6); with at least one adequately trained reserve operator available as back-up (e.g. RD-8 SR/OR/SYS-0504-0506).

CCI-OR-008	Each ECV production system shall be supported by at least one trained operator when processing is required, with at least one adequately trained reserve operator available.
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3.4.6 System Back-Ups

During operations when the product data set is being generated, there should be regular system back-ups to avoid data loss and to preserve the operational system software (for the long-term archive, see section 3.11.7 CCI-ReR-008 for back-ups and section 3.13.3 CCI-PoR-005 for porting apply).

CCI-OR-009	<p>Each ECV production system, including all software and data in the operational archive, shall be regularly backed up during operations as follows;</p> <ul style="list-style-type: none"> • Week-day daily incremental back-up when no full back-up is done • Weekly full back-up; • Full back-up moved monthly to storage at a separate site
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3.5 Resource Requirements

3.5.1 CCI Affordability

The CCI ECV production system teams should consider taking advantage of access to existing and planned national and European space infrastructure. This could reduce immediate costs and provide a future long-term resourced platform for continuing ECV production. This implies the following approach where possible:

- Use of existing national and international space-related infrastructure to fulfil CCI project requirements
- Re-use of available data transfer, processing and archiving facilities that have on-going maintenance and industry support
- Use of existing supported network infrastructures and commercial communication services
- Re-use of commonly available existing software tools which have continuing support, such as integration frameworks, middleware and test tools

Re-use of commonly available general hardware and applications services (e.g. for data obtainment, archiving, retrieval, configuration management) which have on-going maintenance and support.

The ECV production system development teams can also help to achieve affordability by;



- Achieving a flexible system design which minimises needs for redesign to include new capabilities
- Facilitating the system's ability to adapt to more advanced yet cost efficient technologies

CCI-RR-001	Each ECV production system team shall consider where possible the use of existing and planned national and European maintained space infrastructure to achieve affordability without compromising CCI product quality, while remaining flexible to accommodate future capabilities and technologies.
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3.5.2 Data Storage

The CCI ECV production systems need sufficient storage;

- for all the input, output and secondary data, software and information listed in section 3.2.1 which are required for archive (see section 3.13.2 for scalability for the future),
- as required temporarily during processing itself (eg. RD-8 SR/RR/SYS-0601-605), and
- to permit regular local and remote back-up as described in section 3.11.7.

CCI-RR-002	Each ECV production system shall have sufficient storage; <ul style="list-style-type: none"> • for all the data and information required for archive , • as required during processing, and • to permit back-up.
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3.5.3 Processing Capability

The CCI ECV production systems will need sufficient memory and CPU power to meet the processing and re-processing performance requirements defined in section 3.2.2 (requirements CCI-PR-004 and 005, RD-8 SR/RR/SYS-0606) for current requirements, and be extendable for future needs (see section 3.13.2 for scalability).

CCI-RR-003	Each CCI ECV production system shall have sufficient memory and CPU power to meet current and future processing and re-processing performance requirements.
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3.5.4 Maintenance

The ECV production teams will provide sufficient human, software and hardware resources to be able to maintain (see maintenance requirements in section 3.12) the systems (e.g. RD-12 SRB-REQ_14-450) so that they meet the operational requirements (section 3.4), performance requirements (section 3.2) including the timescales envisaged (section 3.2.1), and reliability requirements (section 3.11).



CCI-RR-004	Each ECV production team shall provide sufficient resources to maintain the system so as to meet the operational, performance, and reliability requirements and timescales.
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3.5.5 Interfaces

The ECV production systems will need to have suitable resources to support the interfaces for obtaining and disseminating data and communicating within the CCI programme and beyond, as in section 3.3.

CCI-RR-005	Each ECV production team shall provide sufficient resources to support internal and external interfaces and communications.
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3.5.6 Scalability and Portability

Resources for the ECV production systems need to be planned so that they are scalable and portable (see section 3.13) for later use on an upgraded platform (RD-16 SR-240). This is so that production can continue into the future taking advantage of new technologies, and data will remain preserved and accessible (sections 3.1.5 and 3.1.6).

CCI-RR-006	Each ECV production team shall provide suitable resources to enable future system scalability and portability.
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3.5.7 Staffing

For each ECV production system the science leader (section 2) will steer and maintain oversight of algorithm development, and advise on the priorities of the science community. The leader will be supported by a science software development and system maintenance team (e.g. RD-8 SR/OR/SYS-0507-0508, RD-6), while the operational system will be adequately supported by system operators (see section 3.4.5). The development team will between them develop and take responsibility for algorithm and other code improvement, test and integrate these into the ECV production system, and manage the system's configuration control. They will ensure that sufficient documentation and communication with other team members is provided to enable ECV production and availability of the operational product archive to achieve the reliability required in section 3.11, even in the absence of the team member nominally responsible for the activity concerned.

CCI-RR-007	<p>Each ECV production system shall be adequately led, developed and supported in operations and development to achieve the reliability requirements by;</p> <ul style="list-style-type: none"> • The science leader (section 2), • The science software and system maintenance team • System operators (section 3.4.5)
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3.6 Verification and Validation Requirements

3.6.1 Introduction

New versions of the ECV output data products will be brought into production following developments such as new or improved algorithms or new input data versions or types becoming available (e.g. RD-13 section 2.5 SR-0400). Where system software is first used or later updated, it must be verified and validated before being made operational.

CCI-VR-001	For each ECV production system when system software is first used or later updated, it shall be verified and validated before becoming operational.
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The software verification process is defined as being “intended to confirm that adequate specifications and inputs exist for any activity, and that the outputs of the activities are correct and consistent with the specifications and input.” (RD-2 section 4.2.8)

3.6.2 Verification Testing Requirement

Unit tests for all new or changed system functions and subroutines, integration tests for each affected system module, and system tests for the entire system must be planned, executed and documented (e.g. RD-16 section 9.2 SR-680), and designed to be repeatable with rigorous version configuration control (e.g. RD-12 SRB-REQ_15-200 and _18-180). Ultimately the system will be tested using real data, to verify that outputs are consistent with input and specified requirements, and to validate that the science requirements for each ECV production system have been fulfilled (RD-2 Part1B).

CCI-VR-002	<p>At each update of ECV production system software, the following shall be planned, executed and documented and designed to be repeatable, with rigorous version configuration control;</p> <ul style="list-style-type: none"> • Unit tests for all new or changed system functions and subroutines, • Integration tests for each affected system module, and • System tests for the entire system <p>Ultimately the system shall be tested using real data;</p> <ul style="list-style-type: none"> • to verify that outputs are consistent with input and specified requirements, and • to validate that the science requirements for each ECV production system have been fulfilled
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3.6.3 Testing Procedures

ECV teams will need to provide a testing environment to test software updates prior to release, with suitable test and comparison data, and enable these tests to be repeated.



Configuration control must be maintained, but agile methods may be used in developing new algorithms or code prior to code release and becoming operational (e.g. RD-13 section 5.4 SR-4160-4210).

CCI-VR-003	Each ECV production team shall provide a testing environment to test software updates prior to release, with suitable test and comparison data, and enable these tests to be repeated, maintaining configuration control.
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Regression testing for new versions of operational software (ie. for incremental code updates whose results are compared to those of the previous version for verification) can be enabled by retaining test harnesses, previous test data and results.

CCI-VR-004	“Regression” testing for new versions of operational software involving only an incremental code update shall be enabled by retaining test harnesses, previous test data and results for comparison.
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When performing a software update, or repeated testing of for example a new algorithm, compromise of the stability of the operational chain should be avoided (RD-13 SR-4170). This could be achieved by for example, maintaining consistent configuration, the use of separate accounts and care with access rights.

CCI-VR-005	When performing software updates or tests, compromise of the stability of the operational processing chain shall be avoided.
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A system anomaly report management log or system must be employed to track all anomalies or observation reports made during verification (RD-12 SRB-REQ_15-210), which must include tracking of all existing anomalies or observations derived from any reused system (RD-12 SRB-REQ_18-150).

CCI-VR-006	Each ECV production team shall employ a system anomaly report management log or system to track all anomalies or observation reports made during verification, or persisting from any reused system.
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3.6.4 Existing Software

Where existing software is being re-used in an ECV production system, an assessment should be made of the software with regard to an international software engineering standard (such as ECSS standard ECSS-Q-ST-80C section 6.2.7.8, RD-12 SRB-REQ_18-100-140) which concerns verification. The findings should be documented in a software re-use file if sufficient documentation is not already available. A baseline for the system needs to be established to enable testing, verification and configuration control to be performed from this point, if not already in existence.



CCI-VR-007	Where an ECV production system re-uses existing software, an assessment shall be made of it with regard to an international software engineering standard concerning verification. A baseline for the system shall be established for testing, verification and configuration control.
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3.6.5 Validation

Validation “is intended to confirm that the technical specification and the requirements baseline functions and performances are correctly and completely implemented in the final product” (RD-2 section 4.2.6).

Strict criteria must be established for the replacement of any module within an ECV operational production system or sub-system which relates to product contents. Ie. before replacement of such a module or retrieval algorithm the ECV’s Climate Research Group must confirm that the new code is fully validated (see section 3.9.2.3), the replacement code has been reviewed, and installation of it operationally must be done under configuration control (RD-2 section 6.2.6, RD-8 SR/QR/SYS/1001). This may result in the need for “backwards” re-processing of data to maintain the consistency of the climate data record.

The validation must therefore establish that the system produces the expected scientifically valid results so that its intended use is fulfilled.

For software updates which are for adaptive, perfective or corrective maintenance to the system’s software infrastructure and which do not change product contents, verification and validation may be handled internally within the ECV’s science software and system maintenance team, with code review performed by a team member not involved in the specific update. Configuration control should be maintained.

CCI-VR-008	Before replacement of a module or retrieval algorithm in the ECV operational production system which effects product contents, it shall be demonstrated to the Science Leader and confirmed by that ECV’s Climate Research Group that the new software is fully validated, the replacement code has been reviewed and installation shall be done under configuration control.
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CCI-VR-009	For software updates to the system’s software infrastructure not effecting product contents, verification, validation and code review shall be performed but can be handled internally within the ECV’s science software and system maintenance team. Configuration control shall be maintained.
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A system anomaly and observation report management system or log should be employed to track all system anomaly and observation reports made during validation and on-going usage (RD-12 SRB-REQ_15-210).



CCI-VR-010	For each ECV production system a system anomaly and observation report management system or log shall be employed to identify, track and record resolution of all such reports made during validation and on-going system usage.
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3.7 Design Requirements

3.7.1 Software Modularity

The ECV production systems should be designed with modular functionality and well-defined inter-module interfaces (AD-2 section 3.3.4) such that software updates can be made to individual system modules or the entire system, and modules can be readily replaced e.g. so as to facilitate replacement of an algorithm (e.g. RD-16 section 9.2 SR-400, RD-8 SR/MR/SYS/1201, RD-12 SRB-REQ_15-230).

CCI-DeR-001	Each ECV production system shall be designed with modular functionality such that software updates can be made to individual system modules or the entire system, and modules can be readily replaced.
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3.7.2 Intra-System Interfaces

The interfaces between the modular components within an ECV production system should be fully defined at the design level (e.g. RD-16 section 9.2 SR-670).

CCI-DeR-002	In each ECV production system the interfaces between the different modular components shall be fully defined in the design documentation.
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3.7.3 Processing Stages

The different processing stages within each ECV production system, e.g. pre-processing, retrieval, post-processing must be separately executable independent modules that may be scheduled independently (e.g. RD-8 SR/OR/SYS-0501).

CCI-DeR-003	In each ECV production system the different processing stages shall be distinct modules so that they can be scheduled independently.
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3.8 Documentation Requirements

The documents needed to support operations for each ECV production system (see CCI Statement of Work 2) will include the following from Phase I;

- System Specification Document v1 or higher
- Input Output Data Definition (IODD) v1 or higher



- Product User Guide

The following documents will need to be updated for the full production phase of the CCI programme;

- Product Specification Document
- Data Access Requirements Document
- Acceptance Test Procedures

The Acceptance Test Procedures or the operational release of the ECV production software will include the Integration and Test Plan describing procedures for unit, integration and system testing

The following subject matter will also need to be documented to support operations if not already;

- System Design
- Operations and Maintenance Plan
- Operations Procedures
- Software Quality Assurance Plan
- Future System Support Plan
- Product Release Notes.

The Operations and Maintenance Plan and Software Quality Assurance Plan will together define; resources needed, management of testing and new software and product releases, non-conformance reports and change requests, team organisation, system and product monitoring mechanisms, configuration management, maintenance management, description of validation and release cycle, development and operations schedule, risk management and register.

The Operations Procedures will contain detailed descriptions of individual procedures sufficient to enable other team members to understand and perform them.

The Future System Support Plan (see section 3.12.2, req. CCI-MR-004) will describe the support that each ECV production system will need to continue operations into the future beyond the CCI programme.

A simple user guide shall be available through the common web portal (about 5 pages in length) for modellers/users who have no knowledge of satellites.

CCI-DR-001	Each ECV production team shall provide system documentation in compliance with appropriate provisions of an internationally recognised software engineering standard.
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3.9 Quality Requirements

3.9.1 Quality Control of Data

3.9.1.1 Input Data

There should be integrity checks on input data on ingestion into the ECV production system (e.g. RD-16 section 8.2 SR-550 on, RD-12 SRB-REQ_3-030 and _3-040).

All data levels should automatically be checked for quality and assigned flags, for example pass, warning or fail flags (e.g. RD-16 section 6 SR-270 on), plus other indicators and statistics (RD-12 SRB-REQ_3-030 SRB-REQ_4-010).

Checks of the metadata will be made compared to the data, with a checksum on the latter. It should also be possible to set manual quality flags (e.g. RD-16 section 9.2 SR-314).

CCI-QR-001	<p>There shall be integrity checks on input data on ingestion into each ECV production system or the ECV production suite;</p> <ul style="list-style-type: none"> • they shall automatically be checked for quality and assigned status flags, • the metadata shall automatically be compared to the data, • It shall be possible to set manual flags when appropriate
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The system should be able to continue processing further independent input files after finding one with an error (RD-8 SR/RR/SYS-1102). Other files such as auxiliary files associated with the file causing an error should be moved with it to a waiting queue (RD-12 SRB-REQ_1-020).

Useful diagnostic information should be provided on a file causing an error identifying the latter's nature and location, via messages to the operator and/or log messages.

CCI-QR-002	<p>The system shall be able to continue processing further independent input files after finding one with an error, and moving it out of the operational stream. Diagnostic information shall be provided on the file to the operator.</p>
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3.9.1.2 Data Products

The Quality Assurance Control for the CCI data products should follow international standards such as the Quality Assurance for Earth Observation QA4EO (RD-23, QA4EO-QAEO-GEN-DQK-001 for product quality indicator framework, and RD-7), in order to assure validity and usefulness to users (see section 3.1.1).



The ECV production team need to be able to make quantitative quality control checks on products to ensure that standards are being maintained. Visual quality checks may also be needed according to the ECV, so the system should be able to display the input data or output product in these cases (e.g. RD-16 section 6 SR-312).

CCI-QR-003	The Quality Assurance Control for the CCI data products shall follow the GCOS Climate Monitoring Principles (RD-7) and international standards. The system shall enable quantitative checking of products, and be able to display the data as appropriate, for quality checks.
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3.9.2 Quality Control of Software

3.9.2.1 Programming Language and Standards

The programming languages used must meet standards such as ANSI and/or other community best practice and be platform-independent and hence portable to new platforms (e.g. RD-16 section 9.2 SR-640).

CCI-QR-004	The programming languages used shall meet standards such as ANSI and/or other community best practice and be platform-independent.
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Software development must meet the relevant items of an international software engineering standard (such as RD-2 ECSS standard ECSS-E-ST-40c, the appropriate criticality level for CCI being Level D (RD-2 Annex D), the lowest, as the production systems are not mission-critical). This will enable the system to be maintainable into the future with new generations of hardware and staff.

N.B. The approach for the CCI is to achieve good practice in software development, management and maintenance, with configuration control, verification and validation of software development.

CCI-QR-005	Software development shall comply with an international software engineering standard, to facilitate its long-term maintenance.
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A software configuration system must be used to manage all source code artefacts during software implementation, so maintaining integrity and traceability during development and subsequent updates (section 3.14, RD-12 SRB-REQ_15-200).

CCI-QR-006	Each ECV production team shall use a software configuration system to manage all source code artefacts during software implementation.
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3.9.2.2 Open Source Software and Agile Code Development

The use of agile code development techniques is welcomed as an approach for software development, based on good communication within a close-working team, with strong science leadership in this case, to enable rapid development of algorithms.

The use wherever feasible of open source software within the CCI projects (AD-2 sections 3.3.4 and 4.7.4, e.g. RD-13 SR-3300-10, RD-16 section 9.2 SR-620) may assist agile code development by enabling algorithms to be accessible to authorised users outside the CCI such as authorised climate researchers. Within the CCI programme open source software will promote further coordination between teams and enable feedback. It will also make easier the long-term maintenance of the code by successive team members.

Where existing code is being re-used that is not open source, a plan should be made to migrate it to open source wherever feasible. If this is not practical then sufficient visibility and documentation of the algorithms or functionality should be provided to assure product validation and system maintenance. The implications of the use of this code for the long-term viability and maintenance of the ECV production system must be explained in the Future System Support Plan.

CCI-QR-007	New software developed within the CCI programme and other software wherever possible, shall be available as open source at least within CCI.
CCI-QR-008	Where existing code that is not open source is being re-used in an ECV production system, plans shall be made either to migrate it to open source, or to ensure its functionality is documented and visible and impacts on future system support are identified.

For verification and configuration control issues see sections 3.6 and 3.14 respectively.

3.9.2.3 Validation in Algorithm Improvement Cycles

To confirm that ECV products are scientifically valid (see section 3.6.5), improvements to algorithms or other processing can be demonstrated more quickly, when appropriate, by comparing the products generated from a sub-set of input and auxiliary data with in-situ data matching it in space and time, instead of using the entire satellite data set (e.g. RD-13 issue 1.0 section 4.5). Care needs to be taken that the selected sub-set is representative and that the typical variation within the full range of data products will not cause a problem for the envisaged improvement in the algorithm. All data used for validation should be preserved and maintained as an on-going activity (see section 3.2.1).

3.10 Security, Privacy and Safety Requirements

3.10.1 Security and Confidentiality for Registered Users

The CCI systems will protect the identity and confidentiality of logged requests of registered users.



CCI-SR-001	The CCI systems shall protect the identity and confidentiality of logged requests of registered users.
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3.10.2 System Security and Safety

The operational system, including its internally stored and preserved products, needs to be built with protection against malicious computer use. The operational system should be protected against the exploitation of security holes (RD-12 SRB-REQ_16-080), by worms (RD-12 SRB-REQ_16-090) and viruses (RD-12 SRB-REQ_16-100). Furthermore, validation of system operability will include security penetration tests (RD-12 SRB-REQ_16-440) if the system has unprotected external access. Security patches provided for the operating system should be promptly applied (no later than one month after reception).

CCI-SR-002	Each operational ECV production system, including its internally stored and preserved products, shall be protected against malicious computer use, and shall be routinely maintained.
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For security of archive see section 3.11.7.

3.11 Reliability Requirements

3.11.1 CCI Technical Risk

Each ECV production team should be able to justify their selection of system hardware and software components as achieving minimum technical risk, maximum reliability and maximum cost efficiency by the use of state-of-the art yet robust technologies. An example of a hardware system designed to achieve this is the RAID system which can divide and replicate data among multiple physical drives.

CCI-ReR-001	Each ECV production team shall be able to justify their selection of system hardware and software components as achieving minimum technical risk, and maximum reliability, cost-effectively.
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3.11.2 CCI Failure Monitoring Detection and Isolation

The CCI ECV production systems must contain built-in monitoring facilities within each production system and at their external interfaces to detect and isolate all types of failures and to expedite recovery actions– see sections 3.4, 3.9.

CCI-ReR-002	Each CCI ECV production system shall contain monitoring facilities internally and at the external interfaces to detect and isolate failures
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3.11.3 Availability of ECV Output Climate Product Archives and Catalogues

Each complete operational archive of ECV output products, its catalogue and the CCI common catalogue should be maintained and protected (e.g. by supporting the hardware with cooling systems and UPS). Hence they should all remain available to external users at least 95% of the time during two months, including both planned and unplanned outages

CCI-ReR-003	Each ECV production team shall maintain and protect its operational product archive, its catalogue and its contribution to the CCI common catalogue so that they remain available to external users for at least 95% of the time over two months.
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Representatives from each ECV production team should ensure that the web-site functions which support access by external users to the ECV data products must be available at least 95% of the time over two months (See section 3.3.4.8 CCI-IR-020,-021).

CCI-ReR-004	The functions of the web-site which support access by external users to the ECV data products shall be available at least 95% of the time over two months.
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3.11.4 End-to-End Availability for each CCI ECV

For each CCI ECV production system, the probability of system availability *when needed* for generating products and timeliness requirements must be at least 95% of the time over two months. This is to achieve the required product processing and re-processing performance (see section 3.2.2). Outages caused by planned maintenance and unplanned events should be minimised to maintain the required data production rate and enable a rapid response to data issues.

CCI-ReR-005	For each CCI ECV production system, the probability of system availability <i>when needed</i> for generating products and timeliness requirements shall be at least 95% of the time over two months, including both planned and unplanned outages.
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3.11.5 CCI Degraded Hardware Scenarios

The CCI ECV production systems should be designed to avoid the impact of unavailability of any system hardware component involved in data production or data product flow to the operational archives. In particular, the CCI ECV systems should take advantage of their modular design (see section 3.4.4) to allow flexible reallocation of processing units to manage degradation of performances.



CCI-ReR-006	Each CCI ECV production system shall be able to take advantage of its modular design to allow flexible reallocation of processing units and hence maintain system and archive availability.
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3.11.6 Availability of CCI ECV Production System Operations

Nominal ECV operations will be based on the following availability to achieve the required operational product availability and processing performance:

- Generation of products *when required* (and eventual on-going acquisition of new input data streams when available to produce climate products): as implied above, systems operating 24h/7 days per week, hence with support by operators for 8hr/5 days per week.
- CCI Common User Web Portal(s) to have the support of an operator and science products representative provided by each ECV production team (CCI-IR-020) able to respond to operational queries within 2 working hours, and science queries to receive a response within 2 working days.

CCI-ReR-006	Each CCI ECV production system shall generate products <i>when required</i> with systems operating 24h/7 days per week, and operational support for 8hr/5 days per week to maintain reliability.
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CCI-ReR-007	The CCI Common User Web Portal(s) shall have the support of an operator and science products representative from each ECV production team, able to respond to operational queries within 2 working hours, and science queries within 2 working days.
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3.11.7 CCI Long Term Archiving: Data Duplication and Storage

Archives of CCI ECV data and software must be fully duplicated and held in (at least) two different physical locations to avoid data loss due to media degradation, obsolescence or accident (RD-22 Guideline 5.4). This will include the input data sets needed for traceability and validation by users, all auxiliary, ancillary and other secondary data and information, validation data, intermediate data products (if needed for traceability and validation by users), and all released output data products and associated metadata and information (as in section 3.2.1 requirements CCI-PR-001-3). Each ECV production team will be responsible for identifying, populating and maintaining the duplicate repositories subject to LTDP Guidelines (RD-22), anticipating their indefinite continuance.

CCI-ReR-008	Each ECV production team shall ensure that complete archives of its CCI ECV data and software shall be duplicated and held in (at least) two different physical locations to avoid data loss. This shall include all data listed in requirements CCI-PR-001-3. Each ECV production team shall be responsible for identifying, populating and maintaining the duplicate repositories, with a view to their persistence beyond the current CCI programme.
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3.11.8 Error Handling during Processing

Each ECV system must detect problems while processing, especially system and processing problems. It must inform the operator by messages and logs, but should not crash and should continue processing from the next valid input data, if processing cannot continue from the current input data (RD-8 SR/RR/SYS-1102). If the number of errors detected exceeds a certain configurable number then the system will stop processing and alert the operator (e.g. RD-13 section 2.5 SR-1490).

The software for each ECV production system should be designed to avoid or trap arithmetic/numerical errors such as dividing by zero, or memory allocation errors. If these occur they should not result in a system crash but should be adequately reported on by the system and if possible processing will continue (RD-16 SR-400).

CCI-ReR-009	Each ECV production system shall detect and report system and processing problems while processing. If found it shall not crash and shall continue processing from the next valid input data. If the number of errors detected exceeds a certain configurable number then the system shall stop processing and alert the operator.
CCI-ReR-010	The software for each ECV production system shall be designed to avoid or trap arithmetic/numerical or memory allocation errors. These shall not result in a system crash but if found shall be adequately reported on by the system and if possible processing shall continue.

3.12 Maintenance Requirements

3.12.1 CCI ECV Production System Evolution without Impact on Operations

The CCI ECV production systems' designs must ensure that any upgrade of hardware or software will not cause a system outage that degrades the availability for ECV production and the on-going operational archive availability beyond the reliability criteria (in section 3.11 requirements CCI-ReR-003-5), or results in a reduction in product generation performance in (see section 3.2.2 requirements CCI-PR-004-5).

CCI-MR-001	Any upgrade of hardware or software to an ECV production system shall not cause a system outage that degrades the availability for ECV production or the on-going operational archive availability in breach of the reliability or performance requirements.
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To achieve the required operational systems' availability, appropriate and commonly recognised Design Patterns can be used. These are general reusable solutions to commonly



occurring problems within given contexts in software design. They can be used as templates when software solutions are sought, and can promote robustness. The adoption of widely recognised Design Pattern nomenclature will also enhance understanding by other ECV production teams of the techniques used (RD-25).

3.12.2 Continuing Capacity of Software and Hardware for CCI ECV Data Generation

The software modules and hardware of the CCI ECV production systems must be maintained during the current CCI programme, so that they can continue throughout to provide the capacity and availability necessary to support the processing of the input data sets with secondary data, so as to generate the ECV data products. They should continue to meet the reliability criteria (in section 3.11 requirements CCI-ReR-003-5), for this and in anticipation of continuing production past completion of the current CCI programme. To assist this, all new or updated software in each CCI ECV production system must be sufficiently well commented and documented that succeeding staff will be able to understand and maintain it.

CCI-MR-002	The software modules and hardware of the CCI ECV production systems shall be maintained so that they can generate the ECV data products throughout CCI Phase II, according to the reliability requirements, and would be able to continue past completion of the current CCI programme.
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CCI-MR-003	All new or updated software in each CCI ECV production system shall be sufficiently well commented and documented that succeeding staff would be able to understand and maintain it, according to the reliability requirements, past completion of the current CCI programme.
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A support plan must be constructed (see end of section 3.8), indicating how all ECV production system assets are to be maintained into the future. This plan will cover all assets on which the ECV production system is dependent, including in-house and proprietary software, OTS software, physical resources, middleware and Open Source software (RD-12 SRB-REQ_14-460).

The support plan must define how updates and service packs will need to be addressed for all ECV production system assets into the future (RD-12 SRB-REQ_14-510 and _14-520). Moreover, the support plan must define how obsolescence will be addressed for all such assets, so defining how the ECV production system will be successfully maintained into the future.



CCI-MR-004	A support plan shall be constructed for each ECV production system indicating how all production system assets on which the system is dependent are to be maintained into the future, and operations supported. It shall define how updates and service packs shall be accommodated and how obsolescence shall be addressed.
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3.12.3 Unplanned ECV Production System Outages

The ECV production systems should be free of any single point of failure (RD-12 SRB-REQ_19-500). There must be a maintenance plan that defines for all system functions alternative system components to use in the event of an outage.

Unplanned outages of ECV production system components must not result in a reduction in reliability below the criteria in section 3.11.

CCI-MR-005	The ECV production systems shall be free of any single point of failure; each team shall have a maintenance plan which defines alternative system configurations to avoid the outage of any system function. Unplanned outages shall not result in a reduction in reliability below the requirements CCI-ReR-003-5.
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3.12.4 Sharing of Software Modules

If a software component or function from one ECV production system is distributed to another, the original ‘owner’ must continue to be in control of its maintenance and configuration control (RD-6 section 4.6 “Community Models”). Hence the owner will continue to be able to distribute updates, and diverging and incompatible software versions will not be in use amongst the ECV production teams impeding validation of products across the CCI programme.

CCI-MR-006	If a software component or function from one ECV production system is distributed to another, the original ‘owner’ shall continue to be in control of its maintenance and configuration control.
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3.12.5 Maintenance of Pre-Existing Software and All Software in Long-Term Future Use

Use of pre-existing software in CCI Phase II, and of all software in the future, will include assessment of possible constraints such as;

- Acceptance and warranty conditions,
- Support documentation,
- Conditions under which installation, preparation, training and use take place,
- Identification & registration via configuration management,
- Maintenance,
- Durability and validity of earlier tools which may be re-used,



- Constraints relating to copyright and intellectual property rights,
- Conditions of licensing, and
- Constraints associated with exportability

(RD-28 section 6.2.7.6, RD-12 SRB-REQ_18-140a-i).

CCI-MR-007	Use of pre-existing software in any ECV production system shall include assessment of possible constraints on its re-use.
CCI-MR-008	Use into the future of all software in an ECV production system shall include assessment of possible constraints on its continuing use.
CCI-MR-009	Each CCI production system shall have all licences needed to use all software required for CCI product generation for the duration of the CCI programme and beyond.

3.13 Portability and Scalability Requirements

3.13.1 Portability of CCI ECV Production System Functions

The design of the CCI ECV production systems will facilitate the porting of functions (processing modules, operational and back-up archiving, data distribution etc.) to new platforms (AD-2 section 3.3.4,) as operations continue into the future, to take advantage of new technologies, improved processing power and to avoid obsolescence. The software should therefore be designed flexibly to be configurable for different processing architectures such as parallel processing and variable numbers of processing nodes (e.g. RD-16 SR-240, 250, 260). The operating system (e.g. RD-12 SRB-REQ_17-010), programming languages, software libraries and tools selected must be widely available and conform to platform-independent standards, and hence be portable to different platforms (e.g. RD-8 SR/PR/SYS/0901).

CCI-PoR-001	The design of the CCI ECV production systems shall facilitate the porting of all functions to new platforms. The software shall be configurable for different processing architectures while it and the operating system, programming languages, software libraries and tools shall conform to platform-independent standards and be portable to different platforms.
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Information was gathered about the hardware and operating systems being used by CCI ECV production teams to generate one year's product sets. This indicated that teams are generally using or planning to use the UNIX or Linux or compatible operating systems. For configuration management (see section 3.14.1, CCI-CR-001, section 3.13.1, CCI-PoR-003) CCI production teams are generally using or planning to use cvs, svn (subversion), Git and Trac or compatible systems. It is recommended that teams continue to use these operating systems or configuration management tools, or systems and tools compatible with them. This will help with the coordination of activities between ECV production teams.



CCI-PoR-002	Each ECV production team using or planning to use a UNIX or Linux or compatible operating system in CCI Phase I or II shall continue to use this or an operating system compatible with this, or if not shall be able to justify this technically or scientifically.
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CCI-PoR-003	Each ECV production team using or planning to use a configuration management system in CCI Phase I or II such as cvs, svn, Git or Trac or other compatible system, shall continue to use this or a system compatible with it, or if not shall be able to justify this technically or scientifically.
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3.13.2 Scalability

The CCI ECV production systems will be scalable so as to be able incrementally to accommodate new algorithms, input data sources and other developments in the future (AD-2 sections 3.3.4 and 3.5.4). This will be facilitated by the modular design of the system architecture, extending the system hardware when needed, and technological advances. The CCI ECV production teams will plan to:

- Continue to process input data and generate products for each ECV from all relevant ESA EO and other data archives as these extend into the future
- Repeatedly reprocess partial or complete data sets as new algorithms or input data become available or other relevant issues arise
- Introduce data from new Contributing Missions as they become available (such as the Sentinel missions, and other European Earth Explorer missions) to extend the climate record into the future (e.g. RD-13 section 5.1 SR-1150-1160).
- Increase storage for data and processing capacity incrementally as needed for the above (see sections 3.1.3, 3.2.1, 3.11.7)

CCI-PoR-004	<p>The CCI ECV production systems shall be scalable so as to be able incrementally to accommodate future developments. Each CCI ECV production team shall:</p> <p>Extend the CCI product time series into the future by processing new input data when available.</p> <p>Repeatedly reprocess partial or complete data sets as new algorithms become available or other relevant issues arise</p> <p>Introduce data from new Contributing Missions as they become available to extend the climate record into the future</p> <p>Increase data storage capacity and processing capacity commensurately with the above</p>
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3.13.3 CCI Long Term Archiving: Data Migration

Long term operational and *back-up* archives of all CCI climate data (see section 3.11.7) and software will be periodically and gradually transferred to state-of-the-art storage technologies to ensure adequate preservation and to prevent obsolescence. The data loss at



the end of the archiving time should not exceed 1% (RD-5). Each ECV production team will be responsible for ensuring this takes place.

Data loss in the long-term caused by the removal of data from an archive (perhaps on its closure), will be avoided by following the LTDP Theme 8 Key Guidelines which includes guidelines on purge prevention (RD-22).

CCI-PoR-005	Each ECV production team shall periodically and gradually transfer the long-term operational and <i>back-up</i> archives of all CCI climate data and software to state-of-the-art storage technologies to avoid data loss.
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3.14 Configuration Control Requirements

3.14.1 Software

All software included in or needed for the support of the ECV production systems will be maintained under configuration control (see section 3.9.2.1, CCI-QR-006), with the file history maintained (e.g. RD-13 SR-1400) This will ensure consistency and repeatability of the output products for an entire processing sequence (e.g. RD-8 SR/CR/SYS-1401), and for new versions of products.

The ECV production systems' software will be configurable where possible (e.g. RD-12 SRB-REQ_20-010) with flexibility to enable building and execution using different module versions, combinations of (eg. per module) and updates of languages and platforms (e.g. RD-13 SR-1400-1430). This will promote its evolution and sustainability into the future (also see section 3.13.1 CCI-PoR-003).

CCI-CR-001	All software included in or needed for the support of an ECV production system shall be maintained under configuration control, with the file history maintained. It shall be configurable with flexibility where possible to enable build and execution using different module versions, languages and platforms.
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3.14.2 Data File Configuration Control

Each individual released data product, associated data at an intermediate data level if existing, and associated secondary data and information (as listed in section 3.2.1 CCI-PR-001-2) will have a unique combination of version number and/or identifying attributes. (RD-16 SR-25). These will be preserved to maintain configuration control and integrity and to enable validation by users. The output product file attributes (AD-3) such as “history” and “source” will include the algorithm, system software, input and secondary data versions used (eg. RD-16), with other information for users such as the source sensor (RD-7 G3). This will help to enable repeated runs for testing, verification, validation and for other purposes.



Each released *set* of data products with the metadata, secondary data and information needed for ECV production and interpretation, will have a unique release version number *n* (see AD-4, for Digital Object Identifier). This will be preserved to maintain configuration control and integrity and to enable identification and validation by users.

CCI-CR-002	Each CCI ECV production system shall uniquely identify each released CCI output product file, associated intermediate level data files, associated secondary data and information, and specified appropriate explanatory metadata.
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CCI-CR-003	Each released <i>set</i> of output products, associated intermediate data and secondary data and information needed for ECV production, shall have a unique release version number which shall be preserved.
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3.14.3 System Configuration Variables

Parameters whose values may change to fine-tune the processing or for other reasons should be configurable and maintained in separate files rather than hard-coded into the processing system (RD-16).

CCI-CR-004	In each ECV production system parameters whose values may change shall be configurable and maintained in separate files.
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3.14.4 Inter-ECV Dependencies

If products from one ECV are to be used for consistency checks for another or as inputs to the generation of products of other ECVs (e.g. RD-13 section 2.2 4th bullet, scenarios section 3.3), these dependencies must be stated in the configuration information of the resultant products, and these inter-dependencies need to be publicised in inter-team communications. Products dependent on more than one ECV must be clearly flagged as such to users and their production must not delay the generation of an individual ECV's data products.

CCI-CR-005	If products from one ECV are to be used for consistency checks for another or as inputs to the generation of products of other ECVs, these dependencies shall be stated in the configuration information of the resultant products, and announced to CCI ECV teams. Such products shall be clearly flagged as such to users and their production shall not delay the generation of an individual ECV's data products.
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3.15 Data Definition and Database Requirements

The definition of the ECV input data will be developed from that for the prototype in each ECV's DARD for full production, while the output product definitions will be similarly evolved from the PSDs. The overall guidelines for ECV output products can be found in the "CCI Data Requirements" (AD-3, see section 3.3.4.1 and e.g. RD-13 section 2.3 3rd penultimate paragraph). The input and output data definitions for each ECV production system will be defined in the IODD for each project. Further information on the interfaces for products and their catalogues is given in section 3.3.

3.16 Human Factor-Related Requirements

The operational system will provide all product availability information in a human-readable format, including information pertaining to the algorithms and input data used across the production chain (RD-12 SRB-REQ_22-040), and on-going system activity (RD-12 SRB-REQ_22-050) such as processing status. Furthermore, the system will provide event status information on the production chain in human-readable format, soon after any significant event occurring (section 3.4.1, RD-12 SRB-REQ_22-060).

CCI-HR-001	Each ECV operational system shall provide information about the following in a human-readable format; product availability, algorithms and input data used across the production chain, and on-going system activity such as event and processing status.
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Manual handling of data is to be avoided except as defined in documented procedures; hence data will be processed automatically with no need for manual intervention in the active processing chain.

CCI-HR-002	In each ECV production system data shall routinely be fully ingested and processed without the need for manual intervention to progress the active processing chain, unless as defined in a documented procedure.
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The ECV production system must not be reliant for maintaining reliability on the expertise of one individual; knowledge should be shared and procedures documented

CCI-HR-003	No ECV operational system shall be reliant for maintaining reliability on the expertise of one individual.
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Where human intervention is required double-checking procedures must be inherent to avoid the introduction of human error to the production system or data products.

CCI-HR-004	In each ECV operational system, where human intervention is required, double-checking procedures shall be inherent to avoid the introduction of human error to the production system or data products.
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3.17 Adaptation and Installation Requirements

The ability to adapt must be considered for future and unforeseen user needs, and to the needs of previously unknown user groups. The URDs gathered the needs of known users, but more needs may be discovered once the data is in use operationally or as technology develops. For instance there could be changes in connectivity to external interfaces. ECV production teams must remain alert for such changes and adapt accordingly. Each ECV production system should be designed in anticipation of evolving user needs.

CCI-AR-001	Each ECV production team shall remain alert for new user, system and procedural needs in operations and be ready to adapt accordingly.
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The needs of a variety of users should be met in different contexts, such as for input to models, for visualisation, and using different media. Other system requirements support this ability to adapt. This could involve different means of data delivery.

CCI-AR-002	Each ECV production team shall be ready to adapt products or the delivery of products to meet the needs of a variety of users with different requirements.
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Reliance should be avoided on particular versions of software tools, operating systems, languages and environments which can be anticipated to become obsolete, impossible to maintain, or incompatible with newer versions of other dependent software etc. For example, the processing system should not be reliant on a feature available in a particular software version, possibly deprecated, which is planned to be dropped in later versions. It also should not rely on combinations of versions of different software packages or operating systems which will not work together unless those particular versions are used.

CCI-AR-003	Each ECV production system shall avoid reliance on particular versions, features of particular versions, or combinations of versions of software tools, operating systems, languages and environments, so as to be able to adapt to the use of newer versions.
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As ECV production continues into the future, awareness should be maintained of the installation requirements for each ECV production system. This is so that system installation starts as and remains performable. The relevant documentation will be provided and kept up-to-date. The system will then be able to accommodate on-going operational developments, be recoverable from system failures, and can migrate to future new platforms.

CCI-AR-004	Each ECV production team shall identify and document the installation requirements for their production system and keep these under review in readiness for developments.
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