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EarthCARE Scientific Validation Implementation Plan (VIP)

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	EOP-PX
Reference	**EC-PL-ESA-SYS-1049**
Issue/Revision	**1.2**
Date of Issue	**26/02/2021**
Status	**Final**

CONFIGURATION APPROVAL

Author Rob Koopman, VIP Configuration Control Manager	**Signature & Date**	Rob Koopman	22/01/2021

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Date: 2021.02.26 01:25:53 +01'00'

ESA-JAXA COLLABORATION VISA

JAXA	**Signature & Date**
ESA	**Signature & Date**

CHANGE LOG

Reason for change / Volumes concerned	**Issue Nr.**	**Revision Number**	**Date**
First issue	1	0	25/09/2019
Volumes 2 and 3 added	1	1	22/01/2021
Minor editorial update to Volume 3	1	2	26/02/2021

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1 INTRODUCTION

The joint EarthCARE Scientific Validation Implementation Plan (VIP) has been structured in three Volumes in order to allow both Agencies to prepare and maintain their respective parts of the plan.
The three Volumes are complemented by the present configuration section for the purpose of configuration management. This overarching configuration section identifies applicable versions of each Volume, that together make up a complete and unique Issue and Release of the entire VIP. Therefore, individual Volumes do not need to carry an issue and release number but only a date, together with the signatures applicable to that Volume. Individual updates of the Volumes always require a full signature loop. In case of major updates of any Volume, ESA and JAXA shall also give their visa in this configuration section, under the heading "ESA-JAXA collaboration visa". In case of minor updates of the underlying (signed) Volumes, it is sufficient that the VIP configuration manager signs the updated configuration document.

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EarthCARE Scientific Validation Implementation Plan (VIP)

Prepared by	**Rob Koopman**
	EOP-PX
Reference	**EC-PL-ESA-SYS-1049 Vol-1**
Date of Issue	**25/09/2019**
Status	**Final**

APPROVAL

Title EarthCARE Scientific Validation Implementation Plan (VIP)	
Author Rob Koopman	**Date** 25/09/2019
Approved By	**Signature & Date of Approval**
ESA / R. Koopman – EarthCARE Validation Engineer	Rob Koopman Digitally signed by Rob Koopman DN: postalCode=75738, o=European Space Agency, street=8-10, Rue Mario Nikis, st=Cedex 15, l=Paris, c=FR, cn=Rob Koopman, email=rob.koopman@esa.int Date: 2019.09.26 10:54:53 +02'00'
ESA / T. Wehr – EarthCARE Mission Scientist	Digitally signed by Tobias Wehr DN: cn=Tobias Wehr, o=European Space Agency, ou=EOP-SMA, email=tobias.wehr@esa.int, c=NL Date: 2019.10.04 17:23:20 +02'00'
ESA/ D. Maeusli – EarthCARE System & Mission Manager	Digitally signed by 45765163-9250-55F1-902B-780D0BAD5377 Date: 2019.10.03 09:32:32 +02'00'
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ESA / A. Lefebvre - EarthCARE Project Manager:	Alain Lefebvre Digitally signed by Alain Lefebvre Date: 2019.11.13 18:14:16 +01'00'

CHANGE LOG

Date	Reason for change
25/09/2019	First version

CHANGE RECORD

Release Date: 25/09/2019		
Reason for change	**Pages**	**Paragraph(s)**
First version	All	All

DISTRIBUTION

Name/Organisational Unit

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1 VOLUME 1

1.1 Introduction

This document describes the plan for implementing the scientific geophysical validation of the EarthCARE mission.

In scope of the EarthCARE inter-Agency cooperation, ESA and JAXA have agreed that:

- Within the commissioning of the EarthCARE spacecraft, JAXA will perform the commissioning of the JAXA Cloud Profiling Radar (CPR) instrument, including a validation plan to be defined by JAXA under the ESA-JAXA collaboration.
- ESA will integrate the JAXA-defined CPR validation plan (Volume 3) into the overall EarthCARE validation plan.

Accordingly, the joint EarthCARE Scientific Validation Implementation Plan (VIP) has been structured in 3 volumes in order to allow both Agencies to prepare and maintain their respective parts of the plan.

The Volume 1 is co-authored by ESA and JAXA, providing:

- an overview of the EarthCARE mission and objectives
- a short description of the EarthCARE instruments and data products
- the context of the validation plan in the overall Commissioning Phase activity
- the validation objectives
- a top-level validation schedule
- the scope, structure and approval process of the EarthCARE VIP document.

Although much of the focus of the EarthCARE VIP document is put today on the validation activities to be performed during the Commissioning Phase (E1), the initial version of the validation plan already provides some overall planning information on the long-term validation activities expected to be implemented along the Exploitation/Routine Phase (E2). Hence, an update of the present validation plan may already be expected to be generated by the start of Phase E2.

1.2 Applicable/Reference Documents

1.2.1 Applicable Documents (volume 1)

AD-1. EarthCARE Mission Requirements Document, EC-RS-ESA-SY-012 v5.
AD-2. EarthCARE System Requirements Document, EC-RS-ESA-SY-001 v1a
AD-3. EarthCARE Production Model, EC-TN-ESA-SYS-0380, v6
AD-4. ESA EarthCARE Product List, EC-ICD-ESA-SYS-0314, v5.0
AD-5. JAXA EarthCARE Product list, NDX-110003 rev E

1.2.2 Reference Documents

RD-1. ESA Announcement of Opportunity for the Validation of EarthCARE, EC-PL-ESA-SYS-884 and http://earth.esa.int/aos/EarthCARECalVal

RD-2. JAXA EarthCARE 1st Research Announcement (Validation), https://www.eorc.jaxa.jp/EARTHCARE/document/RA/1stRA_Val/EC_1stRA_Validation_en.html

RD-3. JAXA 2nd Research Announcement on the Earth Observations, https://www.eorc.jaxa.jp/en/research/ra/2nd_ra_eo/index.html

RD-4. 1st ESA EarthCARE Cal/Val Workshop Report, EC-RP-ESA-SYS-983, http://esamultimedia.esa.int/docs/EarthObservation/EarthCARECalVal_Workshop_Report_2018.pdf

RD-5. The EarthCARE Science Report, ESA-SP-1279

RD-6. EarthCARE Instruments Description, EC-TN-ESA-SYS-891

RD-7. Paper on the EarthCARE Mission published in Bulletin of the American Meteorological Society (August 2015) http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-12-00227.1 A

1.2.3 Acronyms and Abbreviations

ATLID	Atmospheric LIDar
BBR	Broad-Band Radiometer
CEOS	Committee on Earth Observation Satellites
CPR	Cloud Profiling Radar
EarthCARE	Earth Clouds, Aerosols, and Radiation Explorer
EOEP	Earth Observation Envelope Programme
ESA	European Space Agency
IOCR	In-Orbit Commissioning Review
JADE	Joint Algorithm Development Endeavour
JAXA	Japan Space Exploration Agency
LEOP	Launch and Early Operations Phase
MOS	Mission Operations System
MRD	Mission Requirements Document
MSI	Multi-Spectral Imager
MOU	Memorandum of Understanding
NICT	National Institute of Information and Communications Technology
PDGS	Payload-Data Ground Segment
PLSO	Post-Launch Support Office
VIP	(EarthCARE) Validation Implementation Plan

1.3 EarthCARE Mission

1.3.1 EarthCARE Mission Objectives

The Earth Explorer Core Missions are an element of the Earth Observation Envelope Programme (EOEP) established by the European Space Agency (ESA). These missions are led by ESA to cover primary research objectives set out in the Living Planet Program. EarthCARE, standing for Earth Clouds Aerosols and Radiation Explorer, is the third Earth Explorer Core Mission and is being developed in collaboration with the Japan Aerospace Exploration Agency (JAXA); JAXA provides one of the active core instruments, namely the Cloud Profiling Radar (CPR) plus the associated ground segment data processing capabilities in Japan.

The EarthCARE mission has been specifically defined with the basic objective of improving the understanding of cloud-aerosol-radiation interactions and Earth radiative balance, so that they can be modelled with better reliability in climate and in numerical weather prediction models. Specifically, the scientific objectives are:

- Observation of the vertical profiles of natural and anthropogenic aerosols on a global scale, their radiative properties and interaction with clouds;
- Observation of the vertical distributions of atmospheric liquid water and ice on a global scale, their transport by clouds and their radiative impact;
- Observation of cloud distribution ('cloud overlap'), cloud precipitation interactions and the characteristics of vertical motions within clouds;
- Retrieval of profiles of atmospheric radiative heating and cooling through the combination of the retrieved aerosol and cloud properties.

In order to fulfill the above objectives, the EarthCARE mission will collect co-registered observations from a suite of four instruments located on a common platform. The Optical payload encompasses the three European instruments, namely an ATmospheric LIDar (ATLID), a Multi-Spectral Imager (MSI) and a BroadBand Radiometer (BBR). The fourth instrument, provided by JAXA, is the Cloud Profiling Radar (CPR). The two active instruments (ATLID and CPR) will provide vertical profiles of the atmosphere along the satellite nadir path. The two passive instruments (BBR and MSI) will provide scene context information to support the active instruments data interpretation.

The instruments' data will be processed individually and synergistically (see Figure 1) to retrieve the vertical structure and horizontal distribution of cloud and aerosol fields, together with the outgoing radiation, over all climate zones.

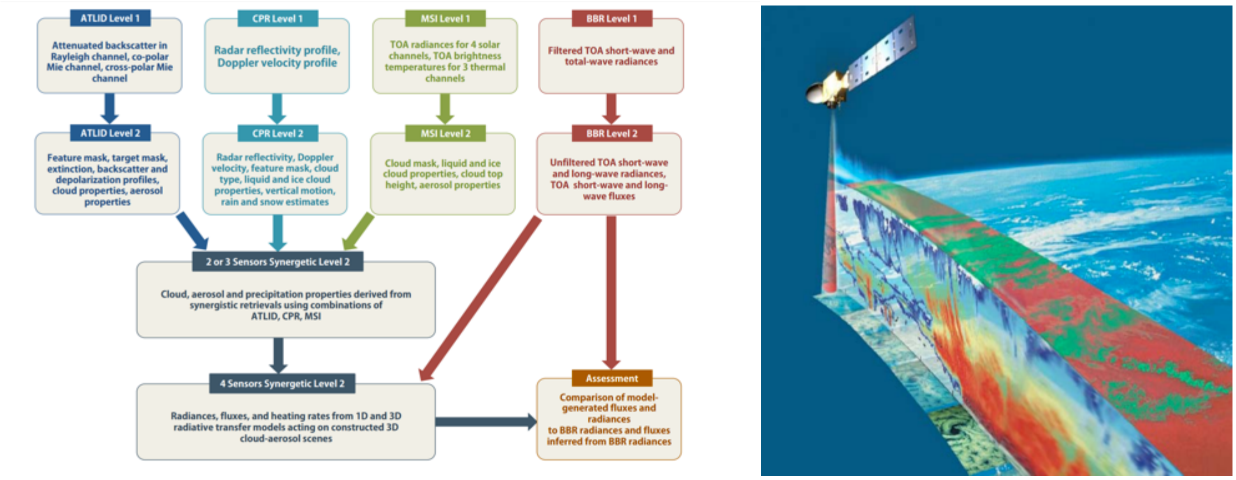

Figure 1 Contributions of multiple remote-sensing techniques towards fulfilling the EarthCARE mission objectives

1.3.2 EarthCARE Satellite and Instruments Characteristics

An artist's view of the EarthCARE satellite in-orbit with both CPR antenna and solar array already deployed is depicted in Figure 2. The spacecraft configuration results from extensive trade-offs performed during the early phases of the Project. Optimization took place according to the major mission requirements, in particular the accommodation of the four instruments payload, their field of view, and the impacts of the relatively low orbit required to enhance the active instruments' performance. The streamlined shape of the spacecraft, with its trailing solar array, minimizes its cross-section and reduces the residual atmospheric drag.

Figure 2: EarthCARE satellite artist's view

The instrument viewing geometry in Figure 3 illustrates the satellite ground track, the CPR beam at normal nadir, the lidar beam de-pointed backward by 3° to reduce specular conditions, the across track swath of the MSI with its offset in the anti-sun direction to mitigate sun-glint and finally the 3 BBR views in nadir, forward and backward directions required to retrieve the emitted flux.

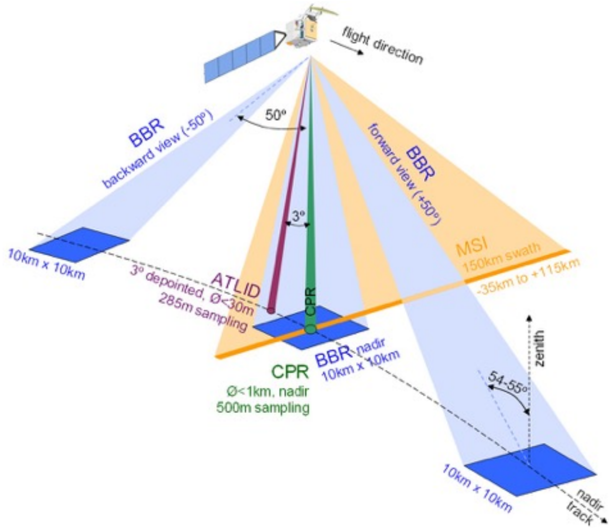

Figure 3: Instruments viewing geometry

Stringent platform and instrument alignment requirements were specified to ensure the co-registration of the two profiling active instruments measurements to better than 350m and accurate knowledge of their position in the swath of the imager. The spacecraft structure design, layout and materials have been selected for their good performance in this respect.

The very compact core spacecraft together with its minimized satellite cross-section in the flight direction as can been seen from the semi-transparent view in Figure 4 resulted from the low orbit altitude (393 km) selected for the EarthCARE mission; that orbit altitude was derived from trade-offs among others: the power demand for active instruments, the optical resolution for passive instruments as well as the amount of propellant required to compensate the residual air drag.

Once deployed in orbit, the EarthCARE spacecraft will have a length of ca. 19 meters.

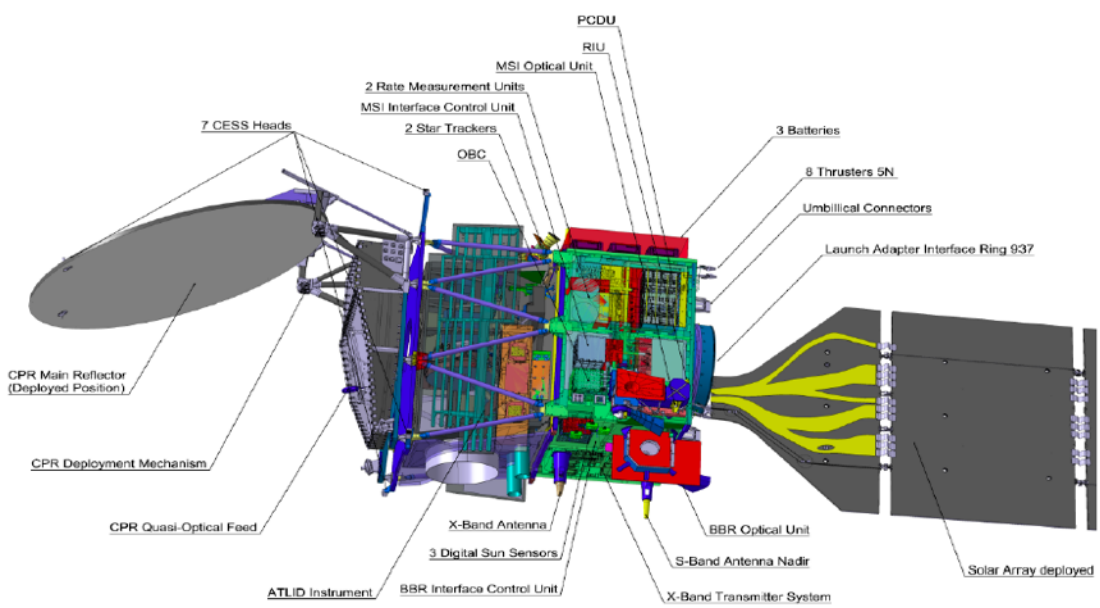

Figure 4: Spacecraft semi-transparent view

The design lifetime of EarthCARE is 36 months, including an initial 6 months period covering spacecraft commissioning and initial calibration and characterization activities (Phase E1). During this period, observational data will be provided to external expert teams who have been assigned by ESA and JAXA respectively in order to perform specific analysis tasks focusing at instrument calibration and geophysical validation of EarthCARE key data products.

Nominally, the Phase E1 will be followed by a 2.5 years exploitation/routine period (Phase E2) during which the spacecraft will be operated according to a stable, repetitive scenario, with systematic processing and archiving of data products within the ESA EarthCARE Payload Data Ground Segment (PDGS) and the CPR Mission Operations System (MOS); both PDGS and MOS will be in charge of disseminating EarthCARE data products to public user community as well as to scientific experts and validation teams to continue supporting data product calibration and validation activities along Phase E2.

1.3.2.1 Atmospheric LIDar (ATLID)

ATLID, the ATmospheric LIDar, measures atmospheric profiles of clouds and aerosols with a vertical resolution of about 100 m from ground up to an altitude of 20 km, and a resolution of 500 m between 20 km and 40 km altitude. Its line-of-sight has an offset of 3° along track (backwards pointing) with respect to nadir. The instrument transmitter emits short laser pulses at a wavelength of 354.8 nm with a repetition rate of 51 Hz corresponding to about 140 m sampling along the horizontal track of the satellite. Several shots can be co-added on board to improve the signal to noise ratio. As a baseline two shots will be co-added resulting in an effective along-track sampling distance of 280 m. The ATLID receiver collects the backscattered photons with a 60 cm diameter telescope. UV pulses transmitted will be subject to narrow-band particle scattering from atmospheric aerosols, which do not affect the spectral shape of the incident light, and Rayleigh scattering due to the Brownian motion of atmospheric molecules, which causes broadening of the incident spectrum. The ATLID receiver separates the contributions from aerosols and molecules with a high spectral resolution filter (narrow bandwidth Fabry-Perot etalon) centered on the central received wavelength.

Most of the ATLID in-flight calibration is carried out during the normal measurement flow. Calibration parameters are extracted by proper echo selection and post processing. The main calibration sequences are as follows:

- The background signal (sunlight in the ATLID receiver wavelength range backscattered from the earth atmosphere) is estimated before and after each echo, which allows an accurate offset subtraction on each echo.
- The spectral cross-talk is continuously monitored by applying a dedicated processing on stratospheric backscatter (assumed to contain pure Rayleigh backscatter) and cloud/ground echoes.
- The lidar constants of each channel are calibrated using the atmosphere backscatter (stratosphere and ground echoes) in conjunction with backscatter prediction model and selected test site with known ground albedo and atmosphere optical depth.
- Provision is made for regular detection dark signal calibration for potential compensation of dark signal non-uniformity.

In addition, further dedicated calibration modes can be activated as needed, in particular in the commissioning phase.

1.3.2.2 BroadBand Radiometer (BBR)

BBR, the Broad-Band Radiometer, will measure top-of-atmosphere (TOA) radiances, at the same location, in two wavebands, using three quasi-simultaneous along-track views pointing nadir, forward and aft of nadir. The latter two oblique views are instrument fixed at approximately 50° to the nadir, which gives an on-ground observation zenith angle of approximately 55°. BBR performs measurements in a Total Wave (TW) and a Short Wave (SW) band. Long Wave (LW) data is estimated by subtraction of SW from TW channel measurements. The default footprint on ground for which instrument requirements have been defined is 10 km by 10 km. This is generated by weighted summation of smaller individual ground pixels (< 1 km by 1 km), so other pixel sizes can and will be generated as well.

Measured radiances need to be filtered by the instrument spectral response. After un-filtering, using correlation with MSI data for improved performance, an estimate of the reflected solar and Earth emitted radiances will be obtained. Conversion to flux is performed analytically using Angular Dependence Models. The BBR radiances and derived fluxes can be compared to radiances and fluxes modelled from cloud and aerosol profiles synergistically retrieved from ATLID, CPR and MSI observations. By this, the BBR observations serve as an assessment of the retrieved cloud and aerosol scenes.

In-flight calibration employs two internal black bodies ("hot" and "cold") and a system by which the sun can be observed via a diffuser. The instrument will view its black bodies and the sun in regular intervals (order of magnitude every 90 seconds for the black body calibration and every two months for the solar calibration). BBR does not have a deep space view.

1.3.2.3 Cloud Profiling Radar (CPR)

CPR, the Cloud Profiling Radar, will be the world's first spaceborne W-band (94.05 GHz) Doppler radar and it will measure vertical profiles of cloud echo intensities and vertical velocities of cloud particles. CPR is under development by cooperation between JAXA and the National Institute of Information and Communications Technology (NICT).

CPR is a highly sensitive Doppler radar because of its 2.5 m-diameter large antenna and 1.5 kW high-power transmitter. The sensitivity of CPR is better than -35 dBZ at top of the atmosphere (20 km) on condition of 10 km horizontal integration. The vertical sampling interval is 100 m and the vertical resolution is 500 m. The foot print size is less than 800 m. The horizontal resolution is 500 m, since data will be averaged with along track for good SNR. The vertical range of the observation altitude can be changed with low (16 km), middle (18 km), and high (20 km) depending on the latitude. To measure the accurate Doppler velocity, high coherency and high SNR are required. Therefore, it is important to get the accurate antenna pointing and the pointing knowledge.

In order to evaluate the performance of CPR, several types of calibration will be performed. CPR is designed to measure the transmittance power, the receiver performance and linearity and bias of the logarithmic amplifier. Overall performance of CPR will be evaluated by using an active radar calibrator (ARC) equipped on the ground in the external calibration.

1.3.2.4 Multi-Spectral Imager (MSI)

MSI, the Multi-Spectral Imager, is a seven-band, push-broom scanner providing images at 500 m ground sampling distance over a 150 km wide swath, which is offset from nadir (covering at least -35 to +115 km across track) in order to minimise sun-glint. The imagery will serve as context information for the quasi-simultaneous along track measurements of the CPR and ATLID, and also provide additional data on cloud types, texture, cloud top temperature and other micro-physical parameters such as cloud phase. Collection of aerosol information is a goal requirement. The MSI channels (from 670 nm to 12 µm) approximate the wavebands of NOAA's AVHRR with an additional TIR channel at 8.8 µm, common with the SEVIRI instrument on Meteosat Second Generation. The level 1 product is radiance in the visible (VIS), near-infrared (NIR) and two short-wave infrared (SWIR) bands, and brightness temperature in the three thermal infrared (TIR) bands.

MSI VIS-NIR-SWIR channels use regular dark and sun calibrations (via a diffuser) for in-flight calibration. There are two identical diffusers available, the first one for frequent use and the second one for occasional use to monitor the degradation of the first diffuser. TIR channels are calibrated using an on-board black body and a deep space view.

1.3.3 EarthCARE Products Levels and Data Products

1.3.3.1 EarthCARE Products Levels

All data products generated in frame of the EarthCARE mission will be categorized per Product Level. The definition of each Product Level has been specifically tuned for the EarthCARE mission and can be found in Table 1:

Level 0 Product	Raw instrument science packets, ordered in time, with duplicates removed, annotated with quality flags and time stamps related to the data acquisition at the ground station. For expert users only.
Level 1b Product	Instrument data processed to physical units, with error bars, quality flags and geolocations
Level 1c Product	EarthCARE MSI only: Level 1b data re-sampled onto the grid of one selected MSI reference channel.
Level 1d Product	Special/auxiliary products created to support higher-level processing of EarthCARE products.
Level 2 Product	Derived geophysical variables, either at the same resolution and location as Level 1b data (“native grid”) or re-sampled to a common grid (“joint standard grid”), with error bars, quality flags and geolocations
Level 2a Product	EarthCARE specific definition: a Level 2 product derived from one single EarthCARE instrument
Level 2b Product	EarthCARE specific definition: a Level 2 product synergistically derived from two or more EarthCARE instruments

Table 1 EarthCARE Product Levels

Higher Level Products (e.g. Level 3) may be developed by third parties at a later stage but are not addressed further in the present VIP document.

Access to some of these Product Levels may be restricted depending on the category of Users and/or during initial in-orbit operations.

1.3.3.2 EarthCARE ESA Data Products (total: 44)

In accordance to AD-4, 44 EarthCARE Data Products will be generated by ESA. The associated production model is described in AD-3.

EarthCARE data products are referenced by their product identifiers which consist of two parts separated by a hyphen. The first part indicates instrument data used for the generation of the product (A=ATLID, B=BBR, C=CPR, M=MSI, X=none).

- Level 1b science products:

  Fully calibrated and geolocated instrument science measurements. These are on the native instrument grid for ATLID, MSI and the BBR single pixel product B-SNG, and integrated 10 km along track for the nominal BBR product B-NOM. In addition (not shown here) there are various calibration products for each instrument. The CPR Level 1b product is generated by JAXA, see section 1.3.3.3 below.

  - **A-NOM**: ATLID attenuated backscatter for the three channels (Rayleigh, Mie co-polar, Mie cross-polar)
  - **B-NOM**: Filtered BBR radiances for 2 spectral bands, integrated 10 km along track (standard product)
  - **B-SNG**: Filtered BBR radiances for 2 spectral bands, at native instrument resolution (expert product)
  - **M-NOM**: MSI radiances and brightness temperatures for 7 spectral bands

- Level 1c product:

    - **M-RGR**: MSI nominal level 1b data interpolated to a spatial grid common to all MSI bands. The grid spacing is similar to the one of MSI nominal level 1b (about 500 m across and along track).

- Level 1d products (auxiliary products):

    - **X-MET**: ECMWF meteorological fields limited to EarthCARE swath
    - **X-JSG**: Spatial grid shared by all instruments ("joint standard grid")

- Level 2a products (single instrument products):

    - **A-FM**: ATLID feature mask
    - **A-AER**: ATLID aerosol profiles
    - **A-EBD**: ATLID extinction, backscatter (corrected for attenuation), and depolarisation
    - **A-TC**: ATLID target classification
    - **A-ICE**: ATLID ice concentrations
    - **A-CTH**: ATLID cloud-top height
    - **A-ALD**: ATLID aerosol layer descriptor

    There is no BBR level 2a product.

    - **M-CM**: MSI cloud mask
    - **M-COP**: MSI cloud optical properties
    - **M-AOT**: MSI aerosol optical thickness

    - **C-FMR**: CPR feature mask and reflectivities
    - **C-CD**: CPR cloud Doppler parameters
    - **C-TC**: CPR target classification
    - **C-CLD**: CPR cloud profiles

- Level 2b products (synergy products, i.e. using data from two or more instruments)

    - **AM-MO**: ATLID-MSI merged observations
    - **AM-CTH**: ATLID-MSI cloud-top height
    - **AM-ACD**: ATLID-MSI aerosol column descriptor

    - **AC-TC**: ATLID-CPR target classification

    - **BM-RAD**: BBR unfiltered radiances (using MSI in retrievals)
    - **BMA-FLX**: BBR fluxes (using MSI and ATLID in retrievals)

    - **ACM-CAP**: ATLID-CPR-MSI cloud and aerosol products (variational synergy product)
    - **ACM-COM**: ATLID-CPR-MSI cloud and aerosol products (ad-hoc composite synergy product)
    - **ACM-3D**: ATLID-CPR-MSI 3D scene construction indices
    - **ACM-RT**: ATLID-CPR-MSI radiative transfer model results

    - **ACMB-DF**: ATLID-CPR-MSI-BBR radiative closure assessment

1.3.3.3 EarthCARE JAXA Data Products (total: 11)

In accordance to AD-5, 11 EarthCARE Data Products will be generated by JAXA.

EarthCARE data products are referenced by their product identifiers which consist of two parts separated by a hyphen (same as ESA data products). The first part indicates instrument data used for the generation of the product (CPR=CPR, ATL=ATLID, MSI=MSI, AC=CPR-ATLID, ACM=CPR-ATLID-MSI, ALL=Four sensors).

- Level 1b science products:
  - **CPR_NOM**: CPR one-sensor received echo power and Doppler product
- Level 2a products (single instrument products):
  - **CPR_ECO**: CPR one-sensor echo product
  - **CPR_CLP**: CPR one-sensor cloud product
  - **ATL_CLA**: ATLID one-sensor cloud and aerosol product
  - **MSI_CLP**: MSI one-sensor cloud product
- Level 2b products (synergy products, i.e. using data from two or more instruments):
  - **AC_CLP:** CPR-ATLID synergy cloud product
  - **ACM_CLP:** CPR-ATLID-MSI synergy cloud product
  - **ALL_RAD:** Four sensors synergy radiation budget product
- Auxiliary products (ECMWF):
  - **AUX_2D:** ECMWF-AUX-2D product
  - **AUX_3D:** ECMWF-AUX-3D product

1.4 Scope And Relation To Other Documents

1.4.1 Scope and Purpose

This document sets out the Implementation Plan for all the EarthCARE scientific validation activities. The audience for this document includes both ESA and JAXA Mission Management & Performance/science experts, national and international validation stakeholders and the Validation Teams themselves.

The EarthCARE scientific Validation Implementation Plan (VIP) provides an executive overview of all activities that were submitted to the ESA EarthCARE Validation - Announcement of Opportunity (AO, see RD-1) plus the JAXA ones in a common format. JAXA activities consist of Research Announcements (RA, see RD-2 and RD-3), direct contracts to universities and research institutes by the agency, and the cooperation with the NICT defined in the MOU between the JAXA and the NICT. Full details of individual projects are provided in the relevant AO/RA proposal and are not duplicated here. An executive summary of each AO / RA proposal is given in Volumes 2 / 3 respectively.

The purpose of the VIP is to provide a reference for the diverse and widespread activities that are expected to occur as part of the validation of the EarthCARE mission after launch. The VIP can be considered in this respect as the “handbook” of all validation activities by the scientific community plus ESA / JAXA internal and funded product quality related activities. It should be noted that calibration and validation of EarthCARE by the scientific community is a pre-requisite to the acceptance of the Mission as “fit for purpose”: the validation performed is independent and will be performed by experienced scientists and engineers in specialized disciplines. Independent validation is a critical aspect that provides credibility to a mission. Furthermore, such calibration validation will take place, and will be reported in the scientific literature. As such, the EarthCARE

VIP is a means to help both ESA and JAXA to work in a coordinated and effective manner with the scientific validation of the mission in the interest of an operational mission success.

A schedule of all planned and potential validation activities is provided in section 1.6 to facilitate effective communication, planning, coordination and exchange of results amongst EarthCARE validation teams and activities and other relevant activities at ESA / JAXA or under contract by the EarthCARE / CPR Projects (Phase E1) and EarthCARE Mission Manager (Phase E2). As such, it provides a means to coordinate external activities in a manner that empowers both validation scientists performing the work and the mission management.

Whereas the validation requirements will only be recapitulated in the present plan, the validation activities are presented in full detail, including a coverage analysis allowing to highlight potential gaps and issues that must be resolved to ensure a successful scientific validation of all EarthCARE products. Each Agency also addresses its coordination mechanisms. Therefore the EarthCARE VIP will be a living document that will be jointly maintained by ESA and JAXA for the duration of the EarthCARE mission as some activities may need to be adjusted and/or initiated.

1.4.2 Definitions

In order to understand the scope of the EarthCARE VIP document and its relation to other documents and plans, it is important to clarify, define the following key terms, in particular after noting that these terms are quite often mis-used:

- **Characterization** is the process of probing the properties of a system as a function of expected operating conditions. For example, characterization of degradation and non-linearity are common activities that need to be addressed by most missions.
  The characterization outputs are applied among others to the subsequent step of calibration.

- **Calibration** is the process of quantitatively defining the system response to known controlled signal inputs (CEOS definition). This involves establishing, under specified conditions, the relationship between values indicated by a measuring instrument (engineering units) and the corresponding known values of a standard (physical units).
  This relation is applied in the data processing chain ("product calibration") and/or to an on-board instrument or platform configuration ("instrument/platform calibration"). An example is radiometric calibration, which assigns, for various levels of incident radiation, the relation between charge read-out from a detector and radiance in SI units. Two special cases of calibration are:
  - **External Calibration** is a special case where measurements from other (often sub-orbital) independent instruments are used to corroborate this relation. It can be considered a form of verification.
  - **Vicarious Calibration** is a special case of **product calibration**, where measurements from other independent instruments are needed to establish this relation. This typically involves the satellite sensor observing the target area that has been characterized by the independent sensor (e.g. a desert).

  Initial calibrations are performed to establish a baseline for the mission. A subset of calibrations needs to be repeated at regular intervals in case the relation between engineering and physical units is time dependent, e.g. in case of degradation.

Once the initial mission characterization and calibration baseline has been established, the product verification can begin.

- **Verification** is the process of assessing whether a system or product meets its specification. In line with the IEEE, (Algorithm) Verification will exclude any assessment that involves independent data (i.e. from instruments external to the mission). Mission verification is a broad activity which addresses the platform and payload, including thermal, mechanical and electronic aspects although this document will focus on verification of the geophysical performance.

- **Validation** is the process of assessing by independent means the quality of the data provided (CEOS). This document will focus on geophysical validation. These independent means are datasets from instruments external to the mission, e.g. surface-based instrumentation measuring the same geophysical quantity as the satellite sensor that is being validated.
  - **Correlative measurements** and **correlative datasets** refer to the "independent means" in the definition of validation. These are the data from instruments that are independent from those on-board the EarthCARE satellite, typically from other satellites or sub-orbital data (i.e. from airborne, shipborne, or ground-based (fixed or mobile instruments).

- **Commissioning** is the process of assessing that all systems have first survived the launch then can be operated according to the mission requirements including the fulfilment of the scientific performance of the mission. Commissioning will encompass in-orbit check-out (switch-on of various equipment/sub-system and instrument followed by some operational health checks), characterization, calibration, verification and validation. Results of the commissioning will be presented and evaluated during the In-Orbit Commissioning Review (IOCR).

1.4.3 Relation to Other Documents

The EarthCARE VIP document is closely linked to the EarthCARE Mission Requirements Document [AD-1] and as such is an essential planning tool towards confirming the fulfillment of the EarthCARE mission and performance objectives.

However, a number of other plans will be also used to support both on-ground and in-orbit characterisation, calibration, verification, calibration and commissioning activities. A mapping of all the key plans contributing to the demonstration of EarthCARE mission and system requirements is shown in Figure 5, allowing as well to put the present VIP document into its overall EarthCARE context, including its boundaries.

Although encompassing the validation activities taking place during Phase E1, the Commissioning Plan will provide the overall framework for the organization of the commissioning and then refers to the lower-level plans for details.

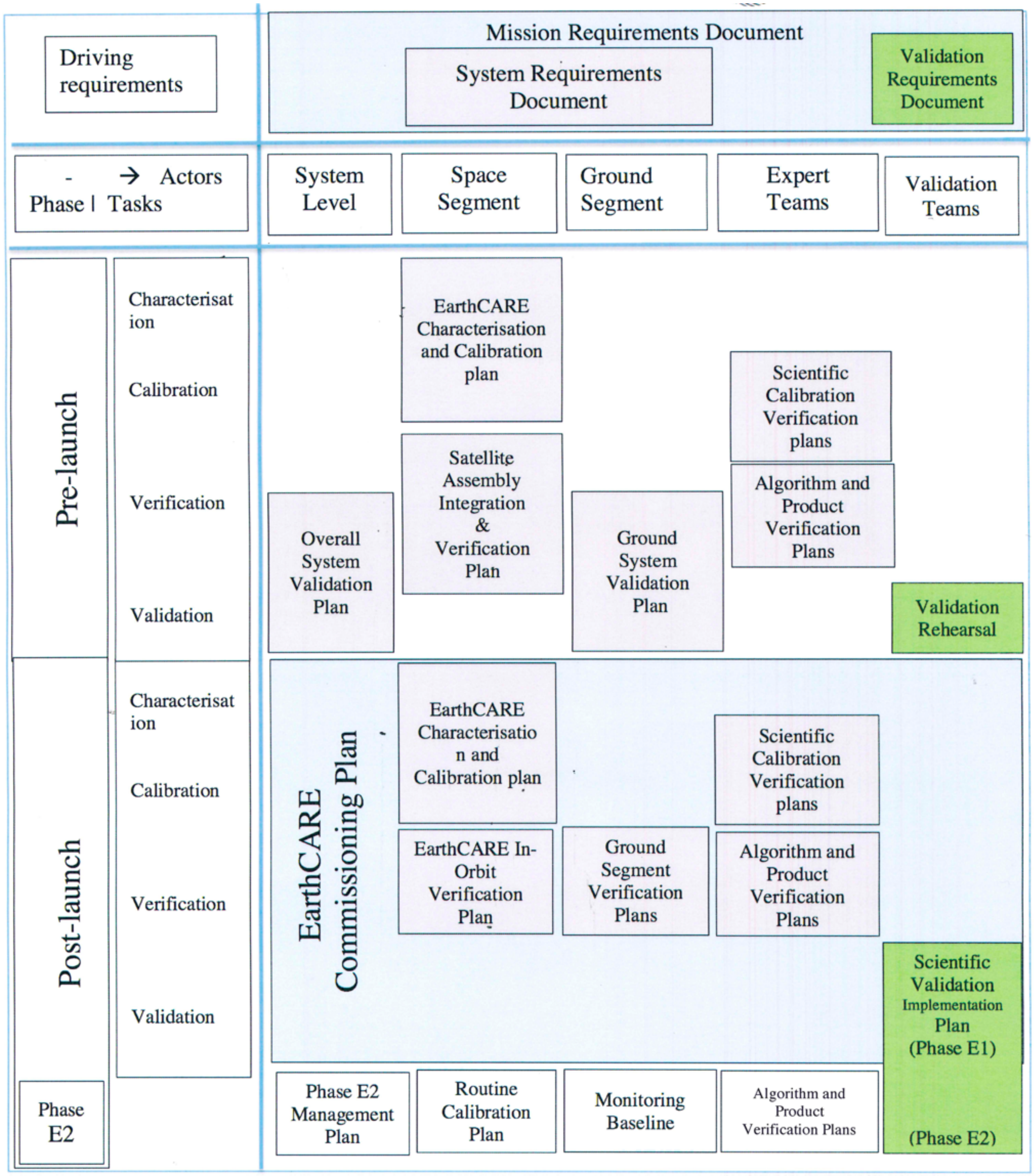

Figure 5 Mapping of the different EarthCARE plans

1.4.3.1 Inter-actions With Other EarthCARE Teams

Figure 5 is as well briefly highlighting the entities in charge of the implementation of the different EarthCARE plans and therefore provides a snapshot of inter-actions that can be expected in-between the Validation Teams during their implementation of the EarthCARE VIP.

The satellite-platform and instrument-level characterization, calibration and verification will rely on intense involvement of the EarthCARE prime contractor, instrument suppliers. Some independent (with respect to the instrument developers) scientific experts will also support the in-orbit verification of the payload calibration and the level 1 algorithms; these scientific experts will also perform Level 2 algorithm verification.

Similarly, for the ground segment, individual verification plans are applicable to the Flight Operations Segment and the Payload Data Ground Segments (at ESA and JAXA). Here the verification will include involvement of the relevant subsystem developers.

The Validation Teams will take care of the implementation of the EarthCARE scientific validation plan; they will exchange information, through their validation contact points at each Agency, with other validation teams and project engineers/scientists. For that validation purpose, they will be provided with overpass data generated by the mission analysis teams. The scientific algorithm experts will provide them with an overview of the algorithms and interact on findings during inter-comparisons. The performance engineers will provide simulated data, and the payload engineers will inform the validation teams when the instrument configuration is sufficiently stable to begin collocated measurements and campaigns.

The Validation Teams will perform correlative analysis; intercomparing independent data with EarthCARE products, taking into account as far as possible any transformation that would make the comparison more accurate. Especially during the commissioning phase, rapid feedback loops are needed, and therefore preliminary data from EarthCARE are to be compared to preliminary correlative data if no consolidated data are available. Also the collocated correlative data are uploaded to the validation data centers for rapid exchange with other Principal Investigators and Scientific Expert teams. Validation analysis will cover quantification of differences but also their characterization as a function of dependencies (e.g. dependence on day or night or solar zenith angle).

After commissioning, during the exploitation phase, the organization of activities will be less resource intensive than during commissioning. Based on the findings of the commissioning phase, a baseline for routine characterization and calibration planning will be established. Also, the systematic product monitoring baseline will be consolidated in the PDGS and the instruments and platform health monitoring will be routinely performed at the FOS and the PLSO. In addition, the long-term validation phase will commence, see 1.5.1 below.

Therefore, the EarthCARE VIP Plan will not only support ESA and JAXA towards coordinating their respective validation activities but will also foster exchange of information in-between the involved partners:

- the Principal Investigators that make up the Validation Teams of each other's activities in order to foster collaboration.
- ESA /JAXA staff, which will interact with the Principal Investigators or provide inputs or outputs via the validation coordination contact points. In this context the document also helps to size the efforts needed to support the Validation Team, e.g. by the ground segment and the centres hosting the correlative (= independent) data, or the mission analysis teams.
- EarthCARE Science Experts, and the broader scientific community and to create confidence that EarthCARE products are properly validated.

1.4.4 Document Structure

Since this plan intends to coordinate the validation activities in-between ESA and JAXA, the EarthCARE VIP is structured into 3 Volumes to simplify the maintenance of that document by the respective Agencies:

- Volume 1 is an introductory volume that presents the mission and describes the context of the validation in the overall EarthCARE system commissioning. Volume 1 is co-authored by ESA and JAXA and provides an overview of:
    - the EarthCARE mission and its objectives
    - the EarthCARE instruments
    - the EarthCARE products levels and data products
    - the context of the validation plan in the overall Commissioning Phase activity
    - the validation objectives applicable to the Commissioning Phase (E1) and the Exploitation/Routine Phase (E2) respectively
    - a top-level validation schedule

- Volumes 2 (author: ESA) and 3 (author: JAXA) address per respective Agency:
    - the EarthCARE production model specified by that Agency
    - for each of the instruments that Agency is responsible:
        - an overview of the associated characterisation, calibration and verification activities
        - a short description of the corresponding Level 1 data product
    - a short description of the level 2 data products to be generated by that Agency
    - a recapitulation of the validation requirements
    - a description of the coordination mechanisms
    - validation approaches and common practices
    - a detailed overview of the validation activities
    - potential areas of improvement

1.5 Top-level Validation Objectives

1.5.1 Phase E1 Validation Objectives

The objective of EarthCARE Validation during the Commissioning Phase (E1) is to perform a preliminary assessment of the quality of EarthCARE Level 1 and selected[1] Level 2a and 2b products by comparing them to correlative data. In view of the urgency of Commissioning, these correlative data will themselves often be fast-delivery preliminary data as well.

A second objective is to characterize deviations between EarthCARE products and correlative data in terms of dependencies (for example on Latitude, Solar Zenith Angle, etc.).

For EarthCARE, this phase covers the first 6 months after launch. Within this period, the instruments will be switched on and the functional checking and performance verification of the instruments, platform and ground segment will be performed. Also, the initial validation of the L1 and selected L2 data products will be performed. Due to EarthCARE production model complexity (AD-3), the verification and validation of some level 2 products cannot be completed before handover to the operating entity. In such cases, the formal handover marks the end of phase E1 even though technically not all Level 2 requirements have been validated.

[1] please refer to Volumes 2 and 3 for details on which L2a and L2b products are in scope of the Commissioning phase validation.

During the formal In-Orbit Commissioning Review marking the end of commissioning, the in-orbit verification of the System Requirements (AD-2) and the preliminary validation of the Mission Requirements (AD-1) are reviewed and the mission is declared operational (which implies a handover of responsibility from mission development to mission operations).

1.5.2 Long-term Validation Objectives

For Phase E2, the first objective is to complete the preliminary validation (including characterization of discrepancies) of all EarthCARE data products, including all Level 2b synergistic products.

As statistics build up, the second objective will be achieved, namely to obtain consolidated long-term validation results.

A third objective applies after any improvement of algorithms followed by (priority) reprocessing of the collocated EarthCARE data, namely to perform a 'delta validation' by repeating the inter-comparison with collocated correlative observations but now with the improved subset of collocated EarthCARE products (reprocessed with the new algorithms) and the (consolidated) correlative data.

1.6 Overall Joint Schedule

1.6.1 Indicative Timeline for Phases E1/E2

For complex missions like EarthCARE, to have a very strong coupling between all the requirements verification and validation and the preparation for the Exploitation/Routine Phase is unpractical and would introduce a schedule uncertainty on the latter phase. Therefore, it is common practice to have an absolute target duration for the Commissioning Phase. For EarthCARE, the In-Orbit Commissioning Review (IOCR) is tentatively set 6 months after launch, even if not all data products will have been validated by then and hence no full compliance with the Mission Requirements AD-1 can be demonstrated yet. In this period, the highest priority regarding data products is the verification and validation of the Level 1b products. As soon as the Level 1b products of an instrument appear to have achieved a reasonable stability and performance, the validation of the respective down-stream Level 2a products, and eventually Level 2b products, can start. The initial validation of Level 2 data products during the Commissioning Phase will be important to further consolidate the confidence in the Level 1b data, as well as for an initial assessment of the validity of the retrieval algorithms.
The IOCR will allow to assess EarthCARE readiness to enter in the operational phase (E2).
This review will (among others) take the assessments of the Level 1b (and Level 2, if available) data product quality available by the time of the IORC into consideration in order to assess if the mission is ready to enter the mission exploitation phase (E2). The data product verification and validation will continue during Phase E2.

An indicative timeline for EarthCARE commissioning and validation activities is presented in Figure 6

At the beginning of Commissioning Phase E1, the initial activities to prepare instruments for scientific data acquisition will vary greatly between instruments. After checkout, decontamination, and characterization and calibration, the acquisition of scientific data products can begin. Initial data products will be used for product and algorithm verification and once the data processors have been tuned they will also be made available to support validation.
It should be noted that independent collocated measurements can however begin as soon as instrument settings have been stabilized. It will not be necessary to delay collocated measurements until the processor settings have stabilized, since it will be possible to re-process products with the latest settings at a later point in time.

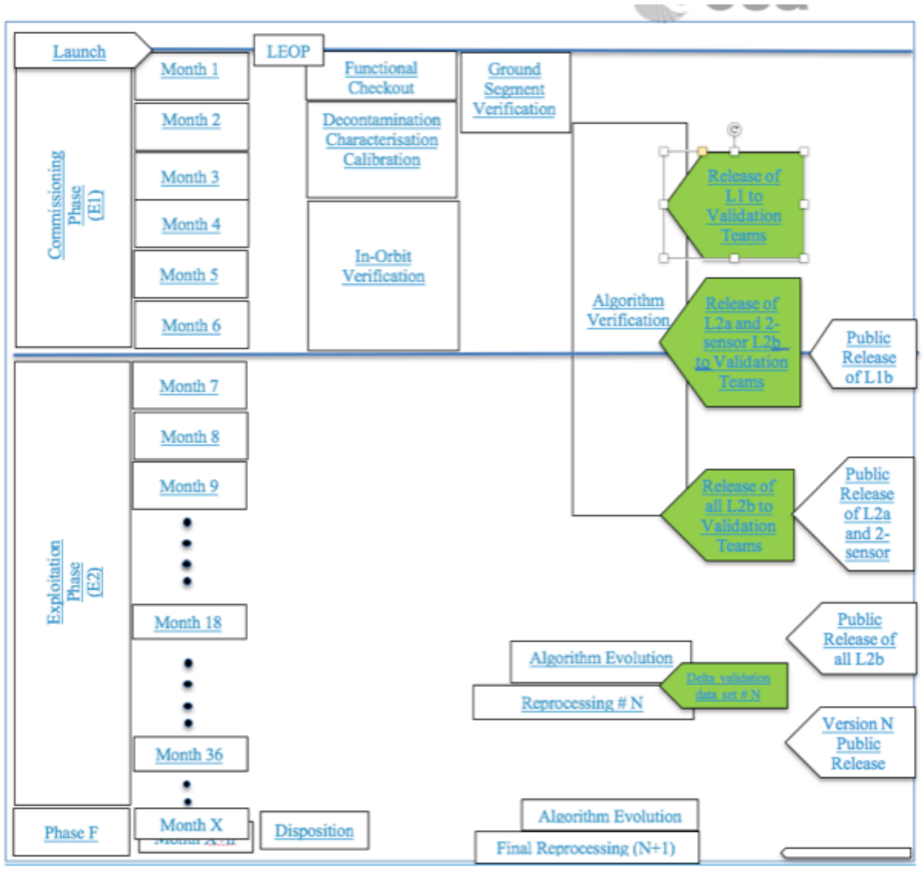

Figure 6 Indicative Timeline for EarthCARE Commissioning, Validation and Data Releases

After the completion of the commissioning, i.e. in Exploitation/Routine Phase (E2), EarthCARE platform and instrument settings are expected to have stabilized, and mainly routine characterization, calibration, and monitoring is expected to be required nominally.
The Phase E2 validation program will focus on the completion of the initial validation of products that could not be validated during phase E1 (typically the L2b synergetic products), and on the long-term validation where more statistical relevance is obtained. Also delta-validation will be performed in case of data processing algorithm updates and product reprocessing. The organization of the Phase E2 validation activities (AO/RA or additional operational or semi-operational activities) will be subject of issue 3.0 of this plan.

1.6.2 Data Release During Phases E1 / E2

ESA and JAXA EarthCARE data products will be released in stages corresponding to the product complexity.

Members of the ESA and JAXA Validation Teams and the Joint Algorithm Development Endeavour (JADE) teams will have exclusive access to preliminary data products after successful initial quality check, under non-disclosure agreements. Preliminary data products are generated with initial processing settings and calibration parameter estimates. They are accompanied by data quality disclaimers that identify known artefacts and incomplete calibrations. There will be no public release of preliminary data products.

ESA and JAXA have defined **target dates** for the release of preliminary data, as given below, indicating by when the data is to be available. However, the agencies are aiming at the earliest possible release of (subsets of) the product suite, before the target dates, in order to facilitate the earliest possible start of validation activities and to maximise the feedback to the product improvement process.

These **target dates for the release of preliminary data** to the Validation and JADE/algorithm development teams are as follows:

- Level-1 products: 3 Months after launch
- Level-2a and two-sensor Level-2b products: 6 Months after launch
- Three and Four-sensor Level-2b products: 9 Months after launch

The release of preliminary data to the Validation Teams will be accompanied by data quality disclaimers identifying parameters affected by incomplete calibrations and other known sources of degraded quality. It is understood that ESA and JAXA will not guarantee the quality of preliminary data products, and in particular the parameters mentioned in the quality disclaimers. The validation team must use it with full understanding of this situation, and use such products only for feedback to the Agencies. The Validation Teams will subsequently analyse the well-calibrated and consolidated data products as soon as these become available. Consolidated data products are generated with the results of complete calibration and improved processing settings after feedback from the Validation Teams, the Engineering Teams and the Algorithm Teams on the preliminary products. Consolidated products can also be accompanied by data quality disclaimers. There will be an ongoing iterative process to improve data products before and after public release

In case the algorithms and processors need to be updated before the public release, the products generated with these updated processors will again be made available first to the members of the ESA and JAXA Validation and JADE teams. The results of verification and validation will be assessed at staggered product reviews prior to their public release. An indicative timeline for these **public release target dates** is as follows:

- Level-1 products: 6 Months after launch
- Level-2a and two-sensor Level-2b products: 9 Months after launch
- Three and Four-sensor Level-2b products: 18 Months after launch

1.7 Validation Plan Updates

The Volume 1 of the Scientific Validation Implementation Plan represents the common definitions and context of both ESA and JAXA. Therefore any changes must be endorsed by both Agencies. It is however expected that Volume 1 will rarely require updates.

The Volume 2, describes the ESA activities of the overall EarthCARE Validation Plan.
The Volume 3, describes the JAXA contribution to the overall EarthCARE Validation Plan, defined by JAXA under ESA-JAXA collaboration.

The major releases of Volumes 2 and 3 are expected to be as follows:

- Issue 1.0 representing the initial responses of the ESA Announcement of Opportunity and the JAXA Research Announcement and additional activities. Its target release date is Q4 2019

- Issue 2.0, representing the validation activities from Volume 1.0 that obtained funding, and where applicable additional gap-filling activities that have been brought forward since Version 1.0. Its target release date is after the ESA-JAXA prelaunch workshop
- Issue 3.0 capturing in greater detail the long-term validation activities (also any systematic activities in addition to the AO/RA, like ESA's DISC, FRM, and SPPA activities). Its target release date is at the start of the Exploitation Phase

For these three major issues (and additional major versions if needed) ESA and JAXA will synchronize their releases.

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EarthCARE Scientific Validation Implementation Plan (VIP)

VOL. 2

Prepared by	**Rob Koopman**
	EOP-PX
Reference	**EC-PL-ESA-SYS-1049 Vol-2**
Date of Issue	**22/01/2021**
Status	**Final**

APPROVAL

Title EarthCARE Scientific Validation Implementation Plan (VIP)	
Author Rob Koopman – EarthCARE Validation Coordinator	**Date** 22/01/2021
Approved By	**Signature & Date of Approval**
ESA / T. Wehr – EarthCARE Mission Scientist	Digitally signed by Tobias Wehr DN: cn=Tobias Wehr, o=ESA ESTEC, ou=Mission and Science Division, email=tobias.wehr@esa.int, c=NL Date: 2021.01.26 16:23:06 +01'00'
ESA/ D. Maeusli – EarthCARE System & Mission Manager	Digitally signed by 45765163-9250-55F1-902B-780D0BAD5377 Date: 2021.01.26 16:42:12 +01'00'
ESA / D. Bernaerts - EarthCARE Project Manager:	Dirk Bernaerts 2021.02.05 08:59:44 +01'00'

Rob Koopman

Digitally signed by Rob Koopman DN: postalCode=75738, o=European Space Agency, street=8-10, Rue Mario Nikis, st=Île-de-France, l=Paris, c=FR, cn=Rob Koopman, email=rob.koopman@esa.int Date: 2021.01.22 16:30:52 +01'00'

CHANGE LOG

Date	Reason for change
22-01-2021	First version

CHANGE RECORD

Release date **22-01-2021**		
Reason for change	**Pages**	**Paragraph(s)**
First version	All	All

DISTRIBUTION

Name/Organisational Unit

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2 VOLUME 2

2.1 Introduction

2.2 ESA Applicable / Reference Documents (volume 2) (all to add as needed)

2.2.1 Applicable Documents

[AD 1] EarthCARE Validation Requirements Document, EOP-SM/3125/TW-tw, v1.1
[AD 2] Protocol for exchange of data for EVDC ESA Validation Data Centre, ESA-EOPGM-PR-0002 v1.1
[AD 3] Terms and Conditions for the Utilisation of Data under the ESA Category-1 scheme (https://earth.esa.int/files/terms)
[AD 4] Earth Explorers Data Policy (https://earth.esa.int/web/guest/-/revised-esa-earth-observation-data-policy-7098)

2.2.2 Reference Documents

[RD-1.] The EarthCARE Science Report ESA-SP-1279
[RD-2.] EarthCARE Mission Requirements Document, EC-RS-ESA-SY-012 v5.0
[RD-3.] EarthCARE System Requirements Document, EC-RS-ESA-SY-001 v1a
[RD-4.] EarthCARE Production Model, EC-TN-ESA-SYS-0380, v6
[RD-5.] ESA EarthCARE Product List, EC-ICD-ESA-SYS-0314, v5.0
[RD-6.] Feasibility Study for In-Orbit Verification of EarthCARE geolocation and co-registration performances, EC.TN.ASD.SY.00235, issue 1 (19 Dec 2016)
[RD-7.] EarthCARE Instruments Description EC-TN-ESA-SYS-0891, v1.0

2.3 ESA In-Orbit Characterisation, Calibration and Verification

2.3.1 Scope of the In-Orbit Verification (IOV)

In-orbit verification (IOV) covers initial switch-on and functional and performance verification of instruments and data products up to Level 1b (see also vol. 1 section 1.4.2). Instrument settings (on-board parameters) are being optimised in this phase, and initial sets of calibration parameters are derived and verified for each instrument. In-flight performances are compared to the ones on-ground (prior to launch). Performances established during IOV are the initial values for long-term performance monitoring. Synergy aspects such as an initial check of instrument co-registration using land marks or terrain elevations are covered as well. The IOV phase for EarthCARE is expected to have a duration of 2-3 months. By the latest towards the end of IOV, instruments will be operated as in routine operations, so scientific data will be available and useful as inputs to the validation teams even before formal completion of this phase.

2.3.2 ATLID Instrument and L1 Products

The IOV for ATLID is split into three phases:

Phase 1: Decontamination
To reduce contamination on the critical optical surfaces of the emission path exposed to vacuum, i.e., the external window of the beam expander (EBEX), ATLID is put into decontamination mode for the first month of IOV. This involves local heating (to 40°C) of the emission baffle close to the window and the EBEX front tube. In parallel, the Detector and Fibre Assembly (DFA) will be heated to the same temperature in order to remove any excess moisture. The laser will be off in this phase.

Phase 2: Laser switch-on and functional verification
The laser is put into its warm-up sequence, with heaters and laser diodes being switched on and thermal stabilisation reached. Dark current calibrations are performed on the primary detectors as well as the co-alignment sensor (CAS).
The laser is then switched on for the first time in orbit and its energy is verified. This is followed by Initial Adjustment Operations: A coarse alignment of emitter and receiver is achieved using the beam-steering mechanism (BSM) together with the CAS. At this point ATLID will enter its nominal measurement mode and acquire the first atmospheric measurements. A number of specific calibrations are then executed: coarse and fine spectral calibration mode to allow setting of the optimum laser frequency, imaging mode to verify proper alignment of fibres with respect to the detectors, and emission defocus calibration to optimise EBEX temperature settings and thereby the beam defocus.
Functional verification of ATLID is performed in this phase, verifying the correct operations and commandability of all its subsystems.

Phase 3: Performance verification
Essential ATLID performance parameters are verified in this phase where ATLID is in its nominal mode:

- Total noise in darkness (from Dark Current Calibration mode)
- Laser pulse energy
- Spectral cross-talk
- Fibre/detector relative alignment
- Background subtraction accuracy
- Accuracy of the attenuated backscatter for the three ATLID channels

2.3.3 BBR Instrument and L1 Products

The IOV for BBR is split into four phases:

Phase 1: Instrument switch-on activities
This phase includes an incremental switch-on of the BBR, covers BBR functional testing (e.g., various chopper drum speeds are tested) and includes a decontamination phase of several hours duration. At the end of this phase, the BBR will be in operational nominal mode with default settings, producing nominal science telemetry.

Phase 2 : Instrument in-orbit health status and characterisation
Instrument housekeeping and science telemetry is checked to characterise the health status of the BBR in various areas: thermal control, mechanisms, power consumption, datation, and detector health and performance. The correct operation of all instrument subsystems is checked. A short shortwave (solar) calibration and a swap of the hot/cold blackbody settings are performed.

Phase 3 : Instrument in-orbit calibration
This phase covers a full solar calibration, optimisation of the blackbody heater powers, and verification of the monitoring photodiode measurements.

Phase 4 : Instrument and Level 1 in-orbit performances.
Data from the previous phases (1-3) are used to derive the longwave and shortwave performance in detail. Specifically for the longwave, gain and noise values and their stability are analysed. For the shortwave channel, filter transmissivity and monitoring photodiode noise levels are assessed. In addition, the stability of the chopper drum speed is checked.

2.3.4 MSI Instrument and L1 Products

(**TBW** – summary of MSI IOV Plan from Industry)

2.3.5 Level 2 products

The internal consistency of level 2 products can be verified without using external validation data for comparison, as demonstrated for previous Earth Observation missions. A detailed plan for this verification activity is not yet available, and ideas are currently being collected from the Level 2 development teams. As an example, the global statistics of a parameter could be derived as a function of another parameter from which it should be independent (e.g., aerosol optical thickness as a function of across-track distance). If a dependence is found, this would point to a measurement or processing artifact which needs to be corrected.

2.3.6 Synergy between instruments

Measurements from EarthCARE instruments will be combined to derive geophysical parameters in a synergistic way. It is therefore essential to verify not only each instrument individually, but also those parameters which affect the synergistic use of their data products, in particular their geolocation and co-registration for which there are requirements on system level. During IOV a verification based on landmarks is foreseen.

2.4 ESA EarthCARE Data Processing and Product Description

2.4.1 Production Model

The Production Model for EarthCARE science data products generated by ESA [RD-4.] shows all data products and the dependencies between them, i.e., it specifies for each data product which other data products are required on input. Furthermore, it shows which data products are being produced by a single data processor. A preview is available in Figure 1 for orientation. A full scale version of Figure 1 can be found in [RD-4.] . It is used to define processing chains in the development system (the EarthCARE end-to-end simulator E3SIM) and the operational system (the EarthCARE Payload Data Ground Segment PDGS).

Each of the small boxes represents a single EarthCARE data product described in [RD-5.] . For each product, the product identifier (such as “AM-CTH”) and a brief description of the main parameter (such as “cloud top height”) are specified.
Dependencies between data products are shown as well as dependencies on dynamic auxiliary input data (for example orbit and attitude data and meteorological fields). Static input data such as land/water masks and digital elevation models are not shown. Large boxes containing small boxes indicate that several products are generated by a single data processor (such as all level 1 products per instrument, or level 2a A-AER + A-EBD + A-TC + A-ICE). Otherwise, it is assumed that a given data processor creates a single product. Arrows indicates products required on input by another product. Processing is strictly from “top” to “bottom”. The vertical position of a product indicates its dependency on products “higher up” the chain.

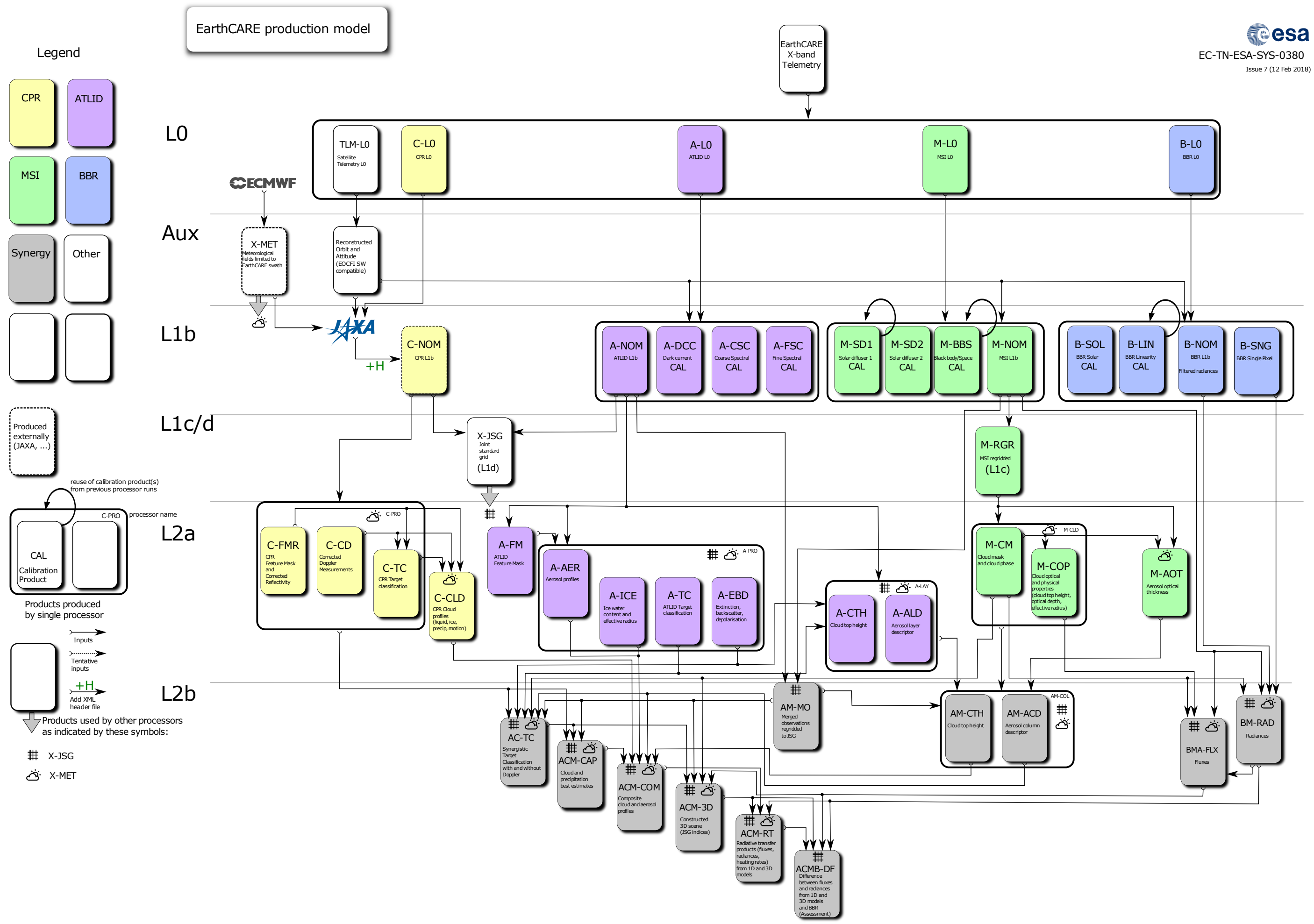

Figure 1: Production Model

2.4.2 *Data Processing to Level 1b and Level 1c*

Raw instrument data (instrument science packets) as downlinked by the satellite are separated per instrument, divided into frames of length 1/8 orbit, sorted in time, and stored together with a descriptive product header into level 0 data products. These are then processed by Level 1 processors (ECGP = EarthCARE Ground Processor), one per instrument, which turn the raw data in engineering units into calibrated parameters such as radiances (for the BBR and MSI) and attenuated backscatter (for the ATLID), stored in Level 1b data products. Geolocations, quality information, and error descriptors are added to the Level 1b products as well. For the MSI instrument, each of the seven spectral bands has its own geolocation in the level 1b product. There is also an MSI level 1c product where measurements are regridded to a common grid for all bands (see [RD-5.] for details).

Operationally, the ECGP processors for the ATLID, BBR, and MSI run in the Core Processing Facility (CPF) of the ESA Payload Data Ground Segment (PDGS), while the CPR ECGP runs in the JAXA Ground Segment in Japan.

The ECGP not only generates the scientific (earth-viewing) data, but also derives information about instrument calibration, either from specific calibration modes (e.g., sun and internal black-body views for the MSI and BBR) or from nominal measurements (e.g., data above 30 km altitude for the ATLID). This is called "online" calibration. "Online" calibration results may be directly fed back automatically into the ECGP, or be stored for later ("offline") manual use. The principle is to perform "online calibration" as far as possible within the constraints of automatic processing and data granularity of 1/8 orbit. For an overview of calibrations for each EarthCARE instrument, see [RD-7.] .

2.4.3 *Offline Calibration*

Where these constraints preclude calibration, e.g., because a longer time series of measurements or operator intervention is required, the calibration is not performed by the ECGP, but by a dedicated "offline" processor instead. This processor typically runs less frequently than the "online" processor. For example, it would be activated on specific calibration measurements, or periodically on longer sequences of data. Offline processing is performed in the Instrument Calibration and Monitoring Facility (ICMF) of the ESA PDGS.

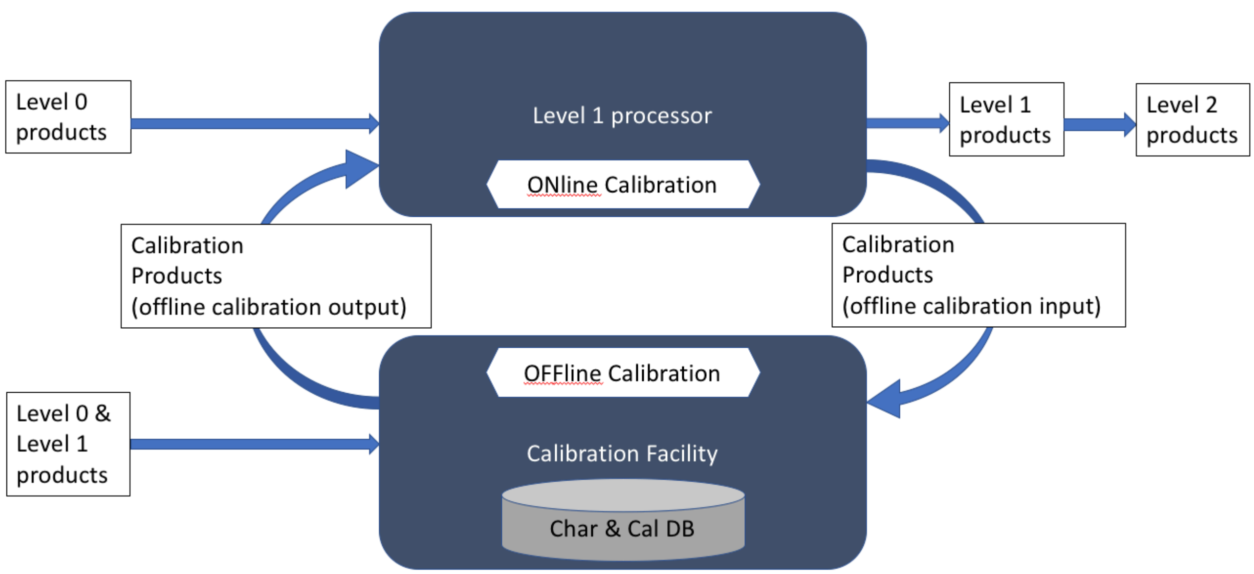

Figure 2: online and offline calibration

Both "online" and "offline" calibrations may lead to updates of the Calibration and Characterisation Database (CCDB) which is then used for future ECGP runs. They may also inform updates of onboard instrument parameters by the ESA Flight Operations Segment (FOS). Finally, they provide inputs for long-term monitoring of instrument performance in the ICMF.

Routine operations offline calibrations use dedicated regular calibrations as well as calibration data derived from nominal earth-viewing measurements. There are initial recommendations for the frequency of calibrations (e.g., weekly or monthly), but these will have to be revisited in the light of actual in-orbit stability of the instrument and so are not reported here in detail.

2.4.3.1 ATLID offline calibration

For ATLID a complex set of offline calibrations has been defined. These calibrations can be divided into four groups: initial adjustments, routine operations, drift monitoring and laser recovery. The calibrations within these groups roughly (but not completely) correspond to the operational modes of ATLID, and for several of them necessary input data are already prepared by the ATLID ECGP.

Initial adjustments offline calibrations support the ATLID IOV operations as described above in section 2.3.2, phase 2. They may have to be repeated later in the ATLID life as contingency operations. In the coarse co-alignment calibration, the line-of-sight (LOS) direction of the emitted laser beam is varied in a spiral pattern. Co-alignment sensor (CAS) signals are analysed to find the optimal beam position which will then be chosen as operational setting. In the coarse spectral calibration the spectral detuning between the emitter and receiver is varied to find the optimal setting (minimal cross-talk). This computation is done automatically in the ECGP, however the offline calibration operator performs an additional cross-check on the results and may accept, correct or discard them. In the emission defocus calibration the beam expander temperature is varied which modifies the divergence of the emitted laser beam. CAS signals are analysed to determine the "best focus" setting for the beam expander temperature. Finally measurements in imaging sub-mode (IMG) are used to characterise the fibre spot position on the CCD image zone and adapt detection chain acquisition delays as needed.

In the fine spectral calibration the spectral detuning between the emitter and receiver is varied to find the optimal setting (minimal cross-talk), as in the coarse spectral calibration, but now in a narrower spectral range with smaller spectral steps. Again, this computation is done automatically in the ECGP, and the offline calibration operator performs an additional cross-check on the results, accepting, correcting or discarding them. Dark current, Mie/Rayleigh spectral crosstalk, and Rayleigh and Mie co-polar channel absolute calibrations provided by the ECGP are cross-checked and the corresponding calibration database (CCDB) entries are updated as needed. Additional (and at this stage not yet consolidated) offline calibration algorithms cover an alternative method for the Mie co-polar channel absolute calibration and a method for the Mie cross-polar channel absolute calibration, using specific targets. Finally, an offline calibration method for the dark signal non-uniformity (DSNU) of the CAS is available to be used in case of CAS anomalies.

Drift monitoring will be performed over the instrument lifetime for the calibration parameters described so far, to evaluate instrument health and performance, and to intervene with updates of the CCDB or instrument operational settings as required. A number of additional parameters will be monitored as well: The Pixel Response Non Uniformity (PRNU) of the CAS as derived from routinely acquired CAS background images is monitored so that detector defects can be properly compensated by the centroiding algorithm use in the laser beam steering closed loop. The emitter-receiver co-alignment itself which is controlled in this closed loop iwill be monitored as well in order to detect any drifts. Finally the drift of the ATLID master clock frequency is monitored and compensated as needed in order to reduce biases on the geolocation altitude.

In the last group, laser recovery, there is currently only a single offline calibration operation defined. This is the laser cavity offset check, a contingency operation where the offset commanded on the master oscillator piezo-mirror, used for cavity length adjustment, will be verified.

2.4.3.2 BBR offline calibration

BBR offline calibrations are performed in order to determine and monitor drifts in instrument spectral response and in detector linearity. It is currently foreseen to run them every 6 months.

The spectral response algorithm uses as input linearity and shortwave ageing calibration products (B-LIN and B-SOL) generated by the ECGP. After correcting monitoring photodiode signals for the solar geometry and averaging them over a calibration period (about 2 days), a fit of a spectral darkening model is performed to derive coefficients describing the spectral response degradation. A similar approach has been used in the past for other radiation monitoring instruments, e.g., CERES. The fit results are then used to update the short-wave gain ratio (per telescope) and the short-wave filter transmission. From this, updated values of the error coefficients for the long-wave radiances and a new short-wave spectral response function are derived. This information is then used to update the spectral correction factor used in the BBR level 2 processors (unfiltering step).

The detector linearity checks start from the linearity calibration products (B-LIN) acquired in a period where the hot and cold blackbodies are swapped over. It is verified whether the time in between two black-body calibrations is short enough so that the linear and quadratic terms of the gain coefficients for the detector response are not changing significantly between two such calibrations. The result is used to update this time in the onboard settings as required.

In addition there are offline algorithms to optimise (in the commissioning phase) the time between total-wave calibrations, and to determine the time slots for solar calibration. Although these are being documented together with the offline calibration algorithms, they are not calibrations in the strict sense.

2.4.3.3 MSI offline calibration

MSI offline calibrations are performed with the primary goal of maintaining the radiometric accuracy of the measured radiances and brightness temperatures over the mission lifetime. Offset and gain for each spectral band are monitored and adjusted in the calibration database as needed.

For the VNS part of the instrument measurements from the daily VNS calibration sequence are used: dark signal measurements and solar measurements via one of two available diffusers. Dark signal measurements provide the “offset” of the measurements. One of the two diffusers is used most of the time (every day), while the other one, the “reference diffuser”, is used much less frequently (once per month) to minimise its own degradation. The differential degradation between the two diffusers is used to determine the degradation of the diffuser used daily so the degradation of the remaining optical path (without the diffuser) can be established. This is then used to correct the radiometric sensitivity of the earth viewing measurements (the “gain”).

Similarly, for the TIR part of the instrument measurements from the daily TIR calibration sequence are used: deep space measurements and measurements of an internal black body which is at a temperature near the upper end of the MSI measurement range. Deep space measurements provide the “offset” of the measurements. The “gain” can then be derived from a combination of the deep space and internal black body measurements.

A more detailed inspection of VNS and TIR calibration measurements by an operator is performed to look for any additional problems, such as unresponsive (“dead”) detector elements, (new) particulate contamination in the optical path, detector bias and temperature issues etc.

Finally, housekeeping parameters are monitored for any drifts (and anomalies) which might affect performance.

2.4.4 Level 2a and 2b Data processing

EarthCARE Level 2 processors derive cloud, aerosol and radiation geophysical parameters from their inputs (see Figure 1). Level 2a processors use data from a single instrument while Level 2b processors combine measurements from two or more instrument in a synergistic way. These processors are being developed by science institutes and run in the PDGS CPF, together with the Level 1 processors. See Vol. 1 of this plan for a list of data products.

2.4.5 Auxiliary data products: X-MET and X-JSG

Two auxiliary data products (Level 1d products) are used by a large number of EarthCARE processors. The first one, X-MET, provides meteorological fields from the ECMWF forecast model on the EarthCARE swath. The most widely used parameters are temperature and pressure, but many other model parameters are also provided. The parameter selection for X-MET is configurable and driven by the needs of the EarthCARE data processors. Data are provided on the original ECMWF model grid, so if ECMWF changes its grid to a higher resolution in the future, the X-MET grid (and data volume) will change accordingly.
The other auxiliary product, X-JSG, provides the Joint Standard Grid, a spatial grid for the synergistic processing of EarthCARE data. This grid is based on the ATLID vertical grid with a sampling of roughly 100 m, and the CPR horizontal grid along track, combining 2 CPR profiles, so that the sampling is roughly 1 km. Across track, the grid is extended at a sampling of 1 km to the full MSI coverage. In case of ATLID or CPR outages the grid will be populated with a synthetic sampling of 100 m vertically or 1 km horizontally, respectively.

2.4.6 Other auxiliary files

In addition, the data processors use other auxiliary files. Specifically, all processors will use processor configuration files containing specific processor settings. Level 1 processors use instrument characterisation and calibration databases as well as orbit files with position and velocity vectors based on the satellite's GPS measurements and attitude files with attitude quaternions based on its startracker measurements. Level 2 processors use climatologies for some parameters (e.g., surface reflectances), look-up tables (LUTs) where time-intensive calculations have been performed in advance, and databases for certain parameters.

2.5 ESA Product Validation Requirements and Priorities

The EarthCARE mission requirements are described in Mission Requirements Document (MRD) [RD-2.] The overarching mission goal is to link cloud and aerosol three-dimensional scenes to outgoing, emitted or reflected, respectively, thermal and solar broad-band radiation to an accuracy of 10 Wm^{-2}. This number provides the overaching guideline for the accuracy requirements of EarthCARE observations. The measurements of ATLID, CPR and MSI are used to retrieve a number of geophysical parameters in the observed scenes, in particular, cloud and aerosol profiles. These retrievals are delivered in the various data products related to aerosol, cloud and precipitation. Radiation relevant products are collected in the ACM-COM product, which will be subjected to radiative transfer calculations resulting in the ACM-RT product. The calculated (broad-band) thermal and solar radiances and fluxes in ACM-RT are then compared to the BBR radiance and flux observations. The degree to which the retrieval-based calculated (ACM-RT) and measured (BM-RAD, BMA-FLX) are statistically consistent is given in the ACMB-DF product. If excellent consistency is achieved, the quantitative understanding of aerosols and cloud profiles and their link to radiation will have been established.

However, this is not expected to be achieved immediately, but eventually, when the quality of the aerosol, cloud/precipitation retrievals and the BBR-derived radiances and fluxes are matured and validated. Due to the multidimensionality of the cloud-precipitation-aerosol-radiation synergistic retrieval problem, a top-down derivation of quantitative observational accuracy requirements for individual (cloud, aerosol, precipitation, radiation) parameters based on the overarching mission requirement to understand cloud-aerosol-radiation interaction to 10 Wm^{-2} accuracy has not been established. Instead, the MRD [RD-2.] and the EarthCARE Validation Requirements Document [AD 1] are suggesting performance and retrieval requirements that deem feasible and reasonable for individual instruments and geophysical parameters. It is assumed that the mission goal of 10 Wm^{-2} can be achieved if statistically sufficient numbers of validated EarthCARE observations have become available.

hard success or fail criteria for observed atmospheric parameters are therefore not defined, but the numbers found in [AD 1] may be considered as guidelines for validation quantitative targets.

For instrument related Level 1 requirements, the guideline numbers per instrument can be found in [AD 1] chapter 3.

The logic of the Production Model (2.4) must be understood when considering the validation priorities. All Level 1 and Level 2a products should undergo (geophysical) validation. Furthermore, the synergistically retrieved (Level 2b) products AM-CTH, AM-ACD, ACM-TC and ACM-CAP, as well as the BBR-derived products BM-RAD and BMA-FLX (see [RD-5.] .

Particular attention may be given to the validation of the ACM-CAP product, as this includes all relevant measurements in a grand synergistic optimization scheme. This product is expected to provide the optimal estimate of the atmospheric parameters retrieved synergistically from all EarthCARE observations sensitive to aerosol, cloud, precipitation and vertical motion in the atmosphere.

It has to be understood that the ACM-COM product is composed of (radiative relevant parameters from) retrievals of ACM-CAP, as one possible rendition of the atmosphere, and other L2a products, in an alternative rendition of the atmosphere. Therefore, only one aspect of ACM-COM might require validation, which is the way the alternative “composite” product has been derived from various L2a products. However, this is of secondary importance compared to the validation of the validation of the products mentioned in the previous two paragraphs.

ACM-3D provides the instruction how to build up three-dimensional scenes for radiative transfer calculations (performed in ACM-RT) and it therefore not suitable for validation with collocated validation data.

ACMB-DF does not need to be validated with collocated observations, because the product itself provides statistics data to assess the consistency of the retrieved cloud-aerosol profiles against BBR-derived top-of-atmosphere radiance and fluxes. Hence the ACMB-DF products themselves consist of data to support the verification of other EarthCARE L2 products but do not introduce new geophysical information.

2.6 ESA Validation Approaches and Common Practice Development

A suite of common practices and validation approaches will be developed in the context of the ESA EarthCARE Validation Team (ECVT, see Volume 1). Common practices need to be developed among others for:

- Common calibration methods for similar instrument types of correlative instruments
- Common reporting of atmospheric conditions/context with each intercomparison
- Handling of wavelength differences between correlative and EarthCARE instruments,
- Common methods for dealing with narrow-Field-of-View (FoV) instrument intercomparisons that are not perfectly collocated (in time and space) with the EarthCARE observation. This involves common collocation distance and time

difference criteria per parameter (e.g. aerosol parameters vs cloud parameters). In addition this may involve additional information to be collected during the observations, to assess whether conditions are representative for those outside the FoV, and apply a weighting factor proportional to the degree of representativity. Depending on the instrument group, this may result in a recommendation to collocate additional instruments, e.g. whole-sky cloud cameras etc. In the case of network stations that surround the EarthCARE observation, common methodology could be needed for averaging these observations to derive the most representative values for intercomparison with EarthCARE (e.g. weighting each station's observations with the distance to EarthCARE sampling, but also taking into account transport by wind (in the case of aerosol) in the determination of the weighting factors)

- Common methods for statistics based validation (involving many collocations)
- Analysis of databases used in processing of instrument data to eliminate possible sources of bias.
- Common approaches per target category (e.g. thin cirrus, snowfall, etc.)
- Common approaches to handle multiple scattering in retrievals (or identification of differences)
- Common approaches to construct synergistic products from several instruments, for intercomparison with their EarthCARE equivalents.
- Common reporting format (e.g. always specify identification of EarthCARE datasets, processor/product version number, timeline plot showing sampling times with respect to mission events (calibrations), geolocation plots to show degree of collocation in time and space (agree on common units e.g. Decimal degrees for Latitude / Longitude, common format per subgroup for reporting of differences, e.g colour scales, and in scatter plots a convention on axis is for EarthCARE and which for the correlative instrument(s)

2.7 EarthCARE Validation Coordination

This section describes the interfaces between the ESA EarthCARE Validation Team (see Vol 1), ESA, JAXA teams and instrument and algorithm experts. The validation portal will be structured accordingly

2.7.1 ESA/JAXA Validation Teams Coordination

As described in Volume 1, whilst each Agency has distinct and complementary responsibilities, ESA and JAXA collaborate intensely on EarthCARE Validation. This involves:

- Regular Coordination meetings and teleconferences
- Agreement on procedures for ESA and JAXA staff to inform each other on instrument and data product characteristics changes, operations anomalies, calibration planning and any other information that is relevant for the work of the scientists in the Validation Teams.
- Coordination on validation campaigns
- scientific exchanges between the ESA and JAXA Validation Team members themselves.

At least one joint pre-launch workshop will be organised to foster scientific interaction

2.7.2 ESA Validation Teams Coordination

The interaction between the teams making up the ECVT and the Instrument experts, algorithm developers, the operations teams at the ground segment (both Flight Operations and Payload Data) needs to be structured in order to reduce interaction overhead, and ensure adequacy of feedback, and to optimise knowledge transfer.

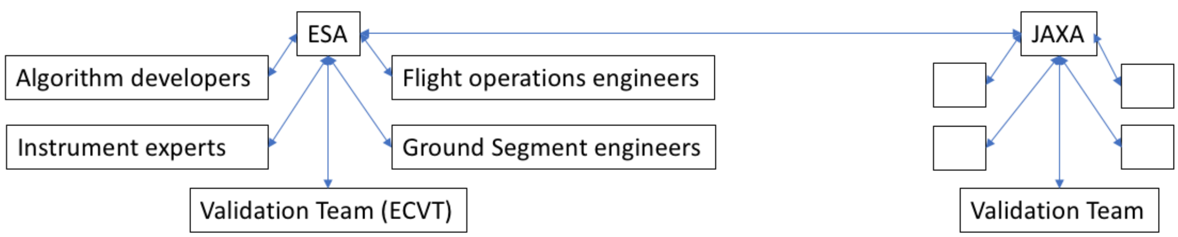

Figure 3: Interactions

In order to foster collaboration and efficient exchanges between scientists working on similar domains, the EarthCARE Validation team is organised according to the following subgroups:

Table 1: EarthCARE validation team structure

Theme	Subgroup	Comment
Data Acquisition	**Campaigns**	
	Networks	
	Models	
Data Analysis	**ATLID L1**	
	MSI L1	
	Clouds	Includes CPRL2A
	Aerosol	
	Radiation	Includes BBRL1

Each subgroup has an ESA coordinator. For the Data Analysis subgroups it is intended to have also a scientific coordinator. The PIs can have representation (Co-Investigators) in multiple subgroups.
PIs will be invited to interact primarily via the discussion boards and information pages on the EarthCARE validation portal (see 2.11.1) and by participating to workshops.

2.8 ESA Schedule

Table 2: Timeline of ESA validation activities

Validation Plan 1.0	Jan 2021

2[nd] ESA Validation Workshop (2.7.1.1)	Q2 2021
Funding convergence	2021-2022
Development of Methods and tools (2.7.1.2)	2021-2022
ESA-JAXA validation workshop (2.7.1.1)	2022
Validation Plan 2.0	2022 after validation workshop
Validation Rehearsal (2.7.1.3)	Q4 2022
Rehearsal/Validation Readiness Review (2.7.1.4)	Q4 2022
Launch	Q1 2023
Preliminary Validation Results Review (2.7.2.2)	Q3 2023
Long-term Validation Phase (2.7.2.3)	Q4 2023->

2.8.1 Pre-launch Activities

2.8.1.1 Workshop(s)

The validation of EarthCARE has been and will be addressed in several workshops.
The first ESA EarthCARE Validation workshop has been held in June 2018 in Bonn, Germany. The report is available online at https://earthcare-val.esa.int/display/EEVP/The+1st+ESA+EarthCARE+Validation+Workshop

The objective of a second validation workshop will be to address validation methods, common instrument calibration standards (e.g. per subgroup), to transfer algorithm knowledge from the L2 algorithm team to the validation team

Furthermore, a joint ESA-JAXA Pre-launch validation workshop is foreseen for 2022. The objective of this joint workshop is to foster scientific exchange between members of the ESA and JAXA validation teams and also the ESA and JAXA algorithm teams.

2.8.1.2 Developments of methods and tools

Prior to the validation rehearsal the validation teams are to finalise the development of intercomparison tools and agree on common methodologies (presumably specific for each group of data products and each family of instruments), for issues as instrument calibration, data sampling/binning/gridding, collocation criteria, etc.

2.8.1.3 Validation Rehearsal

At about 4 months prior to launch, a validation rehearsal will be held. Prior to the rehearsal, each Principal Investigator should have all tools and resources in place and prepare an observation schedule based on a simulated scenario provided by ESA. During the rehearsal he/she will perform (or simulate, in the case of expensive airborne instrumentation) correlative observations corresponding to this scenario and upload the resulting data products in agreed format to the EVDC. ESA will make simulated EarthCARE data available which the Principal Investigator will download and ingest into his/her intercomparison tools and perform simulated intercomparisons.

2.8.1.4 Validation Rehearsal and Readiness review

The simulated analysis results are to be exchanged within the EarthCARE Calibration and Validation Team in the context of the Validation Rehearsal and Readiness Review, and any difficulties encountered are to be reported to ESA. This review will be scheduled approximately one month after the end of the rehearsal. During this review also instrument and algorithm experts will be involved. It is not intended as a formal review (document deliverables and RIDs) but rather as a working session to exchange experiences from the rehearsal and benefit from each other's expertise, and see whether any further action is needed to be ready for commissioning phase validation.

2.8.2 Post Launch Activities

2.8.2.1 Execution of correlative observations

As soon as an EarthCARE instrument will have completed its initial characterisation measurements, and has been switched to Nominal mode, dedicated correlative measurement campaigns can begin (it is assumed that routine network observations are ongoing already). Coincident preliminary correlative data will be uploaded to the EVDC. The beginning of nominal measurements will be different for each EarthCARE instrument. The exact schedule will depend on difficulties encountered during initial instrument characterisation.

2.8.2.2 Intercomparison

Once an EarthCARE data processor will have completed its initial adjustments (again this differs per processor), provision of preliminary data products to the ECVT will begin. ECVT PIs will compare coincident correlative and EarthCARE data products and analyse discrepancies. Using the interactive validation portal, findings will be exchanged and discussed within the ECVT and with algorithm and instrument experts.

2.8.2.3 Phase E1 reporting

Principal investigators will nominally report on a quarterly basis, but during Commissioning more frequent reporting may be needed once preliminary products have become available. These reports should cover measurements made, intercomparisons performed, initial analysis results, status of instruments, calibration, and funding, planned campaigns, and experiences with ESA libraries, facilities, and finally a list of open issues/problems. These reports will be submitted via the EarthCARE validation portal (see 2.11.1). In addition, each Principal Investigator will present his/her Commissioning-Phase findings at the Preliminary Validation Results Workshop, and on a best-effort basis at *ad hoc* meetings.

2.8.2.4 ESA-JAXA Validation Review

The result of this joint review is an input to the subsequent system Commissioning Review. The validation teams report on their findings on preliminary data. The findings should both cover a quantitative assessment of accuracy, and a characterisation of the error dependencies as a function of geophysical parameters. For those level 1 datasets where (minor) changes could already be implemented beforehand, resulting in data products that are expected to be ready for public release, they are also expected to report on delta validation and provide the corresponding data quality assessment that will accompany those products upon public release. This review also marks the formal closure of the Phase E1 validation activity, and the start of the Phase E2 validation.

2.8.2.5 Phase E2 reporting

During Phase E2, the frequency of reporting will be reduced. Common practice for ESA Earth Explorer missions is to organise a yearly EarthCARE Science and Validation Workshop

2.9 ESA Validation Campaigns

Several campaigns have been and will be (partially) dedicated to EarthCARE Validation objectives. Generally, the approach is to identify science campaigns of opportunity, and obtain synergy between the science and EarthCARE validation objectives.
Campaigns are planned typically up to two years in advance, and hence the exact post launch campaigns are not known yet, although initial plans can be found in the section 2.9.1.

Major pre-launch campaigns are listed below:

- EPATAN, Iceland region, September-October 2016
- A-CARE, Mediterranean, April 2017
- TROCACERO (TBD), Cape Verde, June-July 2021

2.10 ESA Detailed Validation Plans

The activities of the ESA validation have been solicited by an Announcement of Opportunity issued in 2017 (see http://earth.esa.int/aos/EarthCARECalVal)and reviewed during the 2018 ESA Validation Workshop in Bonn (https://earthcare-val.esa.int/display/EEVP/The+1st+ESA+EarthCARE+Validation+Workshop) .
The following sections provide an overview of these activities, and a mapping of their coverage.
The section 2.10.1 provides top-level meta-data and a brief textual summary of the projects proposed and accepted. Section 2.10.2 provides an analysis of the coverage of the validation activities, in terms of instrument types and geography. Section 2.10.3 provides details for each of the AO projects. In the issue 1.0 of the validation plan, it is limited to a template, as the actual tables are in the process of being completed on the interactive validation portal and will be made available on the public portal once the information has been consolidated. Section 2.10.4 addresses the detailed coverage per EarthCARE geophysical product parameter. The issue 1.0 only includes a template for the coverage table for the same reason as for 2.10.3 above.

2.10.1 Top level summary of validation activities

Table 3: Proposal descriptions

Proposal ID	Title	Principal Investigator	Scope of the Activity
37730	EarthCARE BBR L1 and L2 Products Assessment	Nicolas Clerbaux	This proposal contributes to the characterisation of BBR L1 products in terms of geolocation, PSF, pixel cross

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			talk, and view collocation. Radiometric quality assessment (gain linearity, noise, stability) is also performed. The activity also includes characterisation of Short Wave signal subtraction accuracy and effect of CDM speed. The team will perform an evaluation of BM-RAD by comparison with GERB, CERES, ScaRaB, and CLARREO. It will formulate a protocol for BMA-LX validation and closure analysis.
38018	Validation of EarthCARE products by comparison with airborne measurements and global NWP predictions	Franco Marenco	This contribution consists of direct intercomparison of FAAM aircraft cloud and aerosol observations (product comparison and scene classification validation) and from satellite retrievals (including investigation of representativity and scale), and data assimilation in NWP models. Also CPR data will be compared to model output.
38188	German Initiative for the Validation of EarthCARE (GIVE)	Ulla Wandinger	This proposal combines satellite, aircraft, in-situ and model contributions to direct intercomparison and assessment of spatial and temporal representativeness. It includes the HALO aircraft with EarthCARE -like payload, ground stations with Lidar and radar and various auxiliary data. It will also contribute to the validation of radiation closure. It is foreseen to integrate groundbased stations with auxiliary data networks like ARM or SURFRAD. The LACROS mobile station will be operated, with its Raman Lidar, radars and sun photometers. Also the activity includes intercomparison with PollyNET which is a network of >10 multi-wavelength Lidars plus several mobile stations. The proposal also contributes several mobile radars operating at 94ghz The proposing team foresees 2 to 3 airborne campaigns with 3 to 4 weeks duration with HALO, additional validation with the DLR-FALCON, and with the French FALCON The team intends to validate BMA-FLX with ground stations and SEVERI,
38623	SPACECARE (Study of Precipitation in the AntarctiC with EarthCARE)	Christophe Genthon	This team will perform validation of C-TC, C-CLR, ACM-CAP with a precipitation Radar in the Antarctic. Considering the precipitation collocation criterion (not as extreme as

			for clouds) and the denser spacing of orbits near the poles, this contribution has more significance than, for example, a single cloud validation station near the equator. This proposal contributes data points in a region that is extremely different from other areas of the globe.
38644	ACTRIS for EarthCARE L2 product evaluation (AECARE)	Arnoud Apituley	This proposal contributes correlative observations for L2A ATLID aerosol and cloud extinction backscatter and depolarisation. It will also contribute correlative observations for CPR (FMR, CD, TC, CLD) and AC-TC and ACM (CAP, COM, 3D), and ABCM-DF, namely calibrated radar reflectivity factor, Doppler velocity, Lidar-attenuated backscatter coefficient, microwave radiometer liquid water path, and (combining information from multiple instruments) target categorisation, liquid water content, ice water content, drizzle flux, drizzle drop size, ice effective radios and TKE dissipation rate. Also the team will use its expertise with the EarthCARE simulator and algorithms to explore any deviations found
38709	Evaluation of EarthCARE Radiances and Fluxes with CERES Data Products	Norman Loeb	This proposal contributes to BBR validation by using CERES (and other instruments) It includes the following main activities 1) radiance intercomparison 2)TOA Fluxes intercomparison 3) surface fluxes evaluation (also groundbased) 4) Cloud properties BBR vs MODIS using GEO satellites and CERES algorithms
38757	LALINET EARTHCARE CAL/VAL	Eduardo Landulfo	This proposal contributes intercomparison of ATLID with Lidars in South America, in particular: 1) Vertical profile of attenuated backscatter range at 355, 532, and 1064 2) vertical profiles of aerosol optical properties (routine and coincident) from the LALINET network.
38768	Validation of EarthCARE level2 radar products in high-latitude and Arctic climates	Dmitri Moisseev	The project contributes intercomparison activities involving 2 Finnish ACTRIS cloud profilers, and additionally precipitation measurements from 1 site, and scanning weather radars from the FMI

			contributing also to precipitation intercomparison.
38809	Balloon Aerosols Instruments for the Validation of EarthCARE (BAIVEC)	Jean-Baptiste Renard	This proposal is entirely dedicated to balloon-borne validation of EarthCARE. It has two main components: 1) LOAC optical particle sizer/counter measurements under weather balloons. 10 Flights per year dedicated to EarthCARE overpasses from France, perhaps additional flights from France, Kiruna, and Canada (Timmins) 2) Strateole2 stratospheric balloons with a mixed payload of in-situ samplers (reeled down to 2km below the balloon) and backscatter Lidar. 2 campaigns of 20 flights each are already planned (each of these flights circling the globe many times), preceded by a campaign of 5 flights. Both contributions are aimed at ATLID calibration (Mie channels, and potentially also the Raman channel depending on the aerosol density) and validation
38810	MORECALVAL : MObile Radar-Lidar-Radiometer EarthCARE CAL/VAL project	Julien Delanoe	This proposal combines airborne and (mobile) ground-based intercomparison instruments, namely: 1) The French Falcon 20 or ATR42 with RALI platform with a payload consisting of a 95GHz Doppler radar and 355 HSRL (and also 532 and 1064) 2) The HALO Platform (DLR) with as payload an HSRL operating at 532 & DIAL@935nm, Cloud radar, MWRs, Hyperspectral Imager, and radiometers 3) The Mobile Atmospheric Station: a platform installed on a lorry with a Radar and a Lidar 4) An Ultra Light Aircraft with Raman Lidar (WALI) 5) Potentially a tethered stratospheric zeppelin (STRATOBUS) at 20km with a nadir cloud radar (BASTA) The team foresees 2 funded field campaigns with [1] and [2] but in 2019 and 2020 With these means the proposal foresees to contribute to: - the calibration of the CPR Doppler velocity and reflectivity, and the ATLID Mie, Rayleigh, and depolarisation measurements - the validation the EarthCARE ATLID and CPR level 1 products

			- the validation of the following ATLID Level 2a products: FM, AER, ICE, TC, EBD, CTH, ALD - the validation of the following CPR Level 2a products: FMR, CD, TC, CLD - the following L2b products: TC, CAP, COM, 3D, RT
38811	An Italian coordinated contribution to the Validation of EarthCARE products from three atmospheric observatories in the Central Mediterranean Sea.	Gian Luigi Liberti	This team will perform intercomparisons with the following correlative instrumentation: 1) multiple active (and passive instruments at 2 sites in/near Rome and 1 in Lampedusa (with a buoy 15km south of the island). All three have a multichannel RMR lidar with a 355 channel. 2) Possibility to add two mobile vans. 3) Possibility to add the Italian Vulcanair research aircraft to campaigns. 4) error analysis, synergetic processing of observations, optimisation of comparisons, estimation of impact of urban environment
38813	British and Korean lidars for ATLID validation (BAKLAVA)	Detlef Müller	This proposal contributes 2 of the only 3 lidars with capability of multiwavelength spectrometric profiling of Raman scattering and depolarisation of atmospheric constituents. Both have 355nm capability (UK Lidar at 2500mJ), and will deliver attenuated backscatter coefficient up to at least 30km, aerosol backscatter and extinction coefficient, lidar ratio, and depolarisation ratio. These observations will be used to assess accuracy, resolution, and stability of ATLID and its L1b and 2a (FM, AER, TC, EBD, CTH, ALD) and the synergetic 2b (AM-ACD) products. Also sun photometer and pressure and temperature data from soundings will be used (but for correlative lidar data analysis)
38816	Validation of EarthCARE Aerosol products over key REgions with a focus on high latitudes (VECARE)	Gerard Ancellet	This proposal contributes the following activities, focusing on the high latitudes: 1) an analysis of CALIPSO climatology (See also D. Jussiet proposal AOID 38935) 2) a comparison of EarthCARE to (possibly) the following lidars: - Tomsk (Siberia) - IAOOS buoys in the Arctic - ALOMAR (355nm)

			- DDUrville (French Antarctic Station) - possibly airborne observations 3) a statistical analysis of ATLID lidar and depolarisation ratio with MSI data vs. statistical analysis of aerosol type from CALIPSO
38834	CESAR for EarthCARE evaluation (CECARE)	Arnoud Apituley	The proposal consists of the following contributions: 1) Intercomparisons using a 'supersite' with the broadest range of instrumentation (including multi-wavelength Raman Lidar and 355nm depolarisation Lidar, multi-frequency radar, CloudNet) covering most EarthCARE products and auxiliary parameters. In particular the intercomparisons will contribute to the validation of aerosol and clouds (CPR-FMR,CD, TC,CLD and AC-TC, ACM-CAP,COM,3D,RT, and ABCM-DF. The synergetic products in the list above are validated by intercomparison with synergetic correlative products derived from the correlative instruments. 2) A Trans National Access site that could host campaigns. The proposal is related to 38644
38836	ACTRIS-FR proposal for EarthCARE Cal/Val	Philippe Goloub	This proposal contributes the following elements: 1) Data from a subset of instruments of the AECARE proposal (38644) that are operated by French institutions. 2) Evaluation/Analysis activities: - Aerosol properties evaluation - Volcanic Aerosol signature and stratospheric clouds - Cloud properties evaluation - Radar products Cal/Val The proposal is related to 38644
38839	Swedish contribution to ESAs EarthCARE Cal Val activities (SweVal)	Abhay Devasthale	The proposal consists of the following contributions: 1) Intercomparisons with FRM4RADAR (94GHz Radar funded by ESA) 2) Intercomparison with data from MOSAIC campaign with Polarstern (but 2019-2020) 3) Intercomparisons cloud radar, aerosol lidar, soundings at Ny-Ålesund 4) Intercomparisons with Cloud radar, aerosol profile, and in situ measurements from the Ice breaker Oden 5) Intercomparisons with AERONET

			measurements for M-AOT and AM-ACD validation 6) Intercomparisons with CATS, AVHRR, MODIS, VIIRS, potentially SLSTR using CALIPSO collocation software built by SMHI 7) statistical analysis against monthly and seasonal means of cloud property climatologies in CM-SAF, ESA-Cloud-CCI, CATS, CloudSat+Calipso
38841	EarthCARE Cal/Val Using the NASA Micro Pulse Lidar Network (MPLNET)	Ellsworth Welton	The project at present contributes access to the MPLNET dataset and support to interpretation of MPLNET data for use in validation studies.
38909	Airborne and Lidar Validation of EarthCARE (ALIVO EarthCARE)	Michael Gausa	1)EARLINET Tropospheric Lidar (ACTRIS): 355,352,1064, depolarisation capability, and inelastic Raman channel 2) sun/moon/sky photometer 3) cimel and GPS for water vapour 4) radiosoundings 5) Nevzorov probe (and) aerosol-profiling on Airborne platform (Drone) Contributes to ATLID and MSI This proposal is related to 38644
38935	Innovative retrieval methods of aerosol and cirrus cloud optical depth above water clouds and ocean surface, and its application in ATLID cal/val studies.	Damien Josset	1) validation of ATLID L2 aerosol and cirrus optical depth using column integrated AOD derived from ATLID ocean surface backscatter measurements together with collocated CPR ocean backscatter cross section 2) validate ATLID L2 erosol and cirrus optical depth using above-cloud optical depths derived from layer-integrated water cloud ATLID lidar backscatter measurements 3) Validate ATLID L1 data product using lidar backscatter measurements of ocean surface and water clouds when there are no aerosol and cirrus clouds 4) USA part of G.Ancellet proposal
39067	Validation of EarthCARE Product in China	Xiuqing Hu	1) Validation of ATLID L1 backscatter and extinction coefficient vertical profiles by using ground-based lidar systems (2 AMPLE lidars, EARLINET calibration procedure with Naples station) 2) validation of ATLID L2 integrated AOD by using Chinese ground-based sun photometer network (CARSNET, 50 stations, reference instruments recalibrated at Izaña twice per year)

			3) radiometric calibration and validation of MSI visibile and near-infrared bands using Dunhuang China Radiometric Calibration Sites (CRCS) 4) intercomparison between EarthCARE and FY-3 L1/L2 satellite products.
39147	Calibration and Validation for EarthCARE Cloud Profiling Radar (CPR) using Ground Based and Satellite Weather Radar Observations	V. Chandrasekar	The project contributes to calibration and validation of the CPR by means of: 1) 10 dual-polarisation C-band doppler radars 2) 158 NEXRAD radars (Doppler weather) 3) NPOL radar 4) CSU-CHILL radar (transportable) 5) the DPR instrument on the GPM mission
39173	Validation of the EarthCARE ATLID and MSI products using ground-based lidar and sunphotometry measurements in East Asia.	Tomoaki Nishizawa	The project contributes to ATLID L1B and L2A and MSI L2A validation by means of: 1) a subset of AD-NET lidar systems comprising 4 Multi wavelength Raman Lidars based on land and one at sea, one M-HSRL and one M-Raman-HSRL 2) SKYNET radiometer network 3) validation analysis addressing ATL_1B, A-AER, EBD, ALD, M-AOT, AM-ACD
39183	Validation of EarthCARE products towards their homogenization with CALIPSO for consolidating the 3D long-term ESA-LIVAS climatology of aerosols, clouds and radiation (ACROSS)	Vassilis Amiridis	The project contributes by intercomparison with: 1) ground based (multiwavelength lidars (including ESA mobile Raman EMORAL), sun photometers, broadband radiometers, insitu surface sensors, MAXDOAS, Brewer 2) airborne (UAV) sensors 3) satellite sensors from polar (MODIS, VIIRS) and geo (SEVIRI) and CERES+GERB+SEVIRI solar radiation+TOA radiation It will contribute to the validation of A-FM, AER, CTH, ALD, EBD, TC, M-AOD, BM-RAD, BMA-FLX (making use of RTM where needed). It will contribute to the expansion of the ESA-LIVAS database
39184	Statistically based calibration/validation control of ATLID L1 data	Helene Chepfer	The project contributes ATLID instrument verification based on 11 parameters in the ATLID level 1 product. It will assess a) the stability of the detection chain for all three channels b) the accuracy of the cross talk

			distributions c) the stability of day- and night time noise d) the stability of the radiation detection for all atmospheric scenarios and over the whole world The means to achieve the above is the monitoring set of monitoring analyses: 1) stability control using surface backscatter on clear sky ocean surface at 300 K 2) stratospheric noise analysis using backscatter signals at 35 to 40mk 3) Advanced SR histogrammes to address whole range of detected molecular and particular Attenuated Backscatter
39186	Cabauw Lidar observations for ATLID L1 and L2a product evaluation.	David Donovan	The project contributes to the assessment of the outputs of the A-PRO algorithm (L1 attenuated backscatter profiles, L2 cloud/aerosol backscatter, extinction, extinction-to-backscatter ratio and linear depolarisation ratio) It provides correlative observations from Cabauw: 1) a 24/7 depolarisation lidar @355 2) non-continuous observations with a multiwavelength Raman 3)if needed the use of supporting surface radiation, cloud profiling radar, Aeronet and IR ceilometer measurements. The proposal is related to 38644
39205	Calibration and Validation of EarthCAREs Cloud Profiling Radar Data Products	Simone Tanelli	Contributes to the validation of the ESA L2B synergistic product by means of the following: 1) compare CloudSat with EarthCARE to establish a Climate Data Record of Cloud Geometric Propertes 2) acquisition and distribution from prelaunch datasets from JPLs cloud & precipitation airborne radars to validate EC CPR with airborne data from OLYMPEX/RADEX'15, CPEX'17, ORACLES'16 and ORACLES'17 campaigns. 3) post launch collaboration ESA, JAXA, NASA for coordinated deployment of airborne Ku, Ka, and W band radars (in particular APR-3 and airMASTR that have all three bands) 4) using an advanced time-dependent spectral radiative transfer model to

			validated the reliability of the CPR L2a Doppler and Reflectivity products
39211	Evaluation of vertical-profiles and column integrated aerosol properties from EarthCARE in Spain using EARLINET/ACTRIS facilities and airborne data from field-campaigns.	Daniel Perez-Ramirez	This project contributes to the validation of: -ATLID Level 1a -ATLD Level 2a FM, AER, EBD, TC, CTH, and ALD -MSI L2a AOT -AM-CTH and AM-ACD -ACM-RT - ABM-FLX by means of: 1) multiwavelength backscatter from 5 sites, some of which also have night-time Raman systems @ 355nm 2) AERONET calibration centre providing AERONET products from stations in spain and allowing synergetic aerosol-extinction profiles by combining with collocated Lidar data 3) Selected MPLNET systems 4) Mobile Raman lidar and in-situ instrumentation 5) Airborne campaigns, with UAVs/RPAs ('minimum 2 hours of collocated data') and EUropean Facility for Airborne Research (EUFAR) platform The proposal is related to 38644
39214	Cross-scale evaluation of ground precipitation derived from the ACM-CAP data product over Europe	Yannis Markonis	The project will contribute to ACM-CAP validation by intercomparison with surface precipitation gauges from the European Climate Assessment & Dataset (ECA&D)
39217	MMP : Monitoring MSI/EarthCARE L1 performances using concomitant intercalibration and stand-alone approaches	Noelle SCOTT	The project contributes to the monitoring of the MSI performance (and L2 clear/clouds/aerosols flag and surface characteristics assessment as by product) using the following methods: 1) a relative approach where the EarthCARE MSI is 'intercalibrated' on a channel-by-channel basis with similar data from another sensor, e.g IASI 2) a standalone approach where MSI observations are compared to simulations. Tools will be set up before launch, using ongoing reanalysis of Level1 IRR/CALIPSO channels paired with LEO MODIS/AQUA channels and GEO SEVERI/METEOSAT.

39266	Plan for EarthCARE/ATLID Calibration and Science Product Validation Using CALIPSO	David Winker	The project contributes to EarthCARE validation by means of the following activities: 1) a global intercomparison of CALIOP and ATLID cloud observations, focusing on three-dimensional cloud occurrence, cloud top height, and cloud ice/water phase, 2) ATLID depolarisation calibration assessment As the CALIPSO mission is assumed to end by 2019, the comparison will be done statistically, using the CALIPSO mean climatology and inter-annual variability.
39821	An assessment of EarthCARE's Cloud Propery Retrival Algorithms for Persistent Ice-phase Clouds in the Canadian Arctic	Howard Barker	The project contributes to the validation of EarthCARE cloud property retrieval algorithms, in particular of persistent ice phase clouds (and aerosols) during the polar night, by means of: 1) Iqualuit site data with Doppler lidars (2x), warer vapour lidar, ceilometer, local radiosonde and Far InfraRed Radiometer (FIRR), doppler weather radar, meteo measurements, surface fluxes 2) Canadian Convair 580 airborne platform data with lidar @355 and radar @94GHz and passive narrow band radiometers & FIRR & in situ measurements - Tentative: an independent proposal was submitted to CSA to fly a FIRR in an nanosatellite.
39873	EarthCARE Calibration and Validation using an Airborne HSRL	Chris Hostetler	The project contributes to the validation of ATLID L1b, ATLID L2a-FM, TC,AT, EBD, ALD, AM-ACD, AM-CTH by means of: 1) particpate in ECVT planning and share experiences 2) perform underflights with NASA's HSRL-2 lidar (@355 @532, with backscatter capability @1064 and polarisation sensitivity at all 3 wavelengths) and with significantly higher signal to noise than ATLID 3) perform calibration and validation assesments e.g. to for validation requirements ATL-CA-1,4,5,6,7. The results may also bridge between the 532nm dataset of CALIOP and the 355nm dataset of ATLID

51515	Validation of Atlid lidar data with ground-based lidars in Northern Sweden	Peter Völger	The project contributes to validation of ATLID backscatter measurements of cirrus clouds and polar stratospheric clouds. It will address validation the A-EBD and A-CTH products. The main lidar used is the one at Kiruna but for specific cases (e.g. mountain lee waves) a second lidar at Esrange will be used
51949	WEGN4CARE – Validation of EarthCARE cloud and precipitation products by the WegenerNet 3D Weather Research Facility in Southeastern Austria	Gottfried Kirchengast	The objectives of the project are to: 1) validate C-TC: cloud-base height against the WEGN climate research facility IR radiometers; simplified convective classification against WEGN X-band radar; optionally melting layer base and top heights against the WEGN X-band radar in campaign mode. 2) validate ACM-CAP: Liquid Water Content (LWC) and LWPath against WEGN radiometer data; rain rate, rain water content, rain normalised number concentration(*), median raindrop diameter(*), rain classification and convective classification against WEGN weather radar and ground precipitation data. *=under conditions of moderate to heavy precipitation
60799	Validate Cloud Profiling on EarthCARE against Aircraft Observations of Cirriform Cloud	Vaughan Phillips	The project will validate CPR in-cloud vertical velocity using aircraft measurements of ice morphology and ice size distributions to derive a reflectivity weighted fall speed for comparison with CPR for the specific case of cirriforrm ascent. All microphysical parameters used by the EarthCARE algorithm to infer reflectivity-weighted fall speed will be directly compared to aircraft measurements. A further validation step is to model the storm at high-resolution, validate the model with aircraft data, and apply the model to the EarthCARE data to achieve statistical validation.

2.10.2 Top level coverage analysis

The following table provides an analysis of the projects in terms of the EarthCARE instrument to which they contribute, the platform they use for the acquisition of correlative data, and the geographical region that they address.

Table 4: instruments, platforms, and regions addressed by projects

AOID	PI	Validation targets				Independent validation sources					Vert.prof.	Geographical region
		ATLID	BBR	CPR	MSI	Sat	Surface routine	Surface Campaign	Airborne Campaign	Model		
37730	Clerbaux		✓			✓						Global
38018	Marenco	✓		✓					✓	✓	✓	Global (NWP), Alaska, Indonesia, Sweden, Iberian Peninsula (FAAM)
38188	Wandinger	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Global
38623	Genthon	✓		✓	✓			✓			✓	Antarctic
38644	Apituley	✓	✓	✓	✓		✓	✓			✓	Europe
38709	Loeb		✓			✓						Global
38757	Landulfo	✓					✓	✓			✓	South America
38768	Moisseev	✓		✓			✓				✓	Finland
38809	Renard	✓							✓		✓	Global
38810	Delanoe	✓		✓				✓	✓		✓	Barbados, Arctic
38811	Liberti	✓		✓	✓		✓	✓	<✓		✓	Italy
38813	Müller	✓					✓	✓			✓	Korea and UK
38816	Ancellet	✓				✓	✓	✓	✓		✓	Siberia, Arctic, Norway (Lidars&Aircraft), High-Latitudes (CALIOP)
38834	Apituley	✓	✓	✓	✓		✓	✓			✓	Netherlands
38836	Goloub	✓		✓			✓				✓	France (incl La Reunion) and Dakar
38839	Devasthale	✓		✓		✓	✓	✓			✓	Sweden, Global (Satellite)
38841	Welton	✓					✓				✓	Global (highest concentration in USA)
38909	Gausa	✓			✓		✓	✓	✓			Norway
38935	Josset	✓							<✓	✓		Global
39067	Hu	✓	✓		✓		✓	✓			✓	China
39147	Chandrasekar			✓		✓	✓	✓				Finland , USA
39173	Nishizawa	✓			✓		✓	✓			✓	East Asia
39183	Amiridis	✓	✓	✓	✓		✓	✓			✓	Greece
39184	Chepfer	✓										Global
39186	Donovan	✓					✓	✓			✓	The Netherlands

39205	Tanelli			✓		✓			✓		✓	Global (Campaings)
39211	Perez-Ramirez	✓			✓		✓	✓	<✓		✓	Iberian Peninsula (+EUFAR international campaigns)
39214	Markonis	✓		✓	✓		✓					Europe
39217	Scott				✓	✓				✓		Global
39266	Winker	✓				✓					✓	Global
39821	Barker	✓	✓	✓	✓	(✓	✓		✓		✓	Arctic/North America
39873	Hostetler	✓			✓				✓		✓	Global (Campaings)
51515	Völger	✓					✓				✓	Sweden
51949	Kirchengast	✓		✓	✓		✓				✓	Austria
60799	Phillips			✓					✓	✓	✓	North America
TOTAL	32	30	8	17	15	10	22	17	14	5	27	

2.10.2.1 EarthCARE data products

The following table presents a high-level overview to assess coverage in terms of data products. A deeper assessment is presented in 2.10.4

Table 5 Coverage of projects per data product

Level	Product	Processor	Number of validation projects					
			ground	airborne	satellite	model	balloon	statistical
1b	A-NOM	A-L1	10	3	1			1
1b	M-NOM	M-L1	2		2			
1b	B-NOM	B-L1			2			
2a	A-FM	A-FM	9	2	1			
2a	A-CTH	A-LAY	10	2	1			
2a	A-ALD	A-LAY	13	2	2	1		
2a	A-TC	A-PRO	13	4	1			
2a	A-EBD	A-PRO	14	2	1		1	
2a	A-AER	A-PRO	14	2	1	1		
2a	A-ICE	A-PRO	8	3	1			
2a	M-AOT	M-AOT	8		3	1		
2a	M-CM	M-CLD	3		3			
2a	M-COP	M-CLD	4		3			
2b	AM-CTH	AM-COL	2	2				
2b	AM-ACD	AM-COL	6	2	2	1		
2b	BM-RAD	BM-RAD	1		3	1		

2b	BMA-FLX	BMA-FLX	1	1	3	1		
2b	ACM-3D	ACM-3D	4	2	1			
2b	ACM-COM	ACM-COM	4	2	1			
2b	ACM-RT	ACM-RT	4	2	1			
2b	ACMB-DF	ACMB-DF	3					
2a	C-FMR	C-PRO	7	2	2			
2a	C-TC	C-PRO	9	3	2			
2a	C-CD	C-PRO	7	2	2			
2a	C-CLD	C-CLD	9	3	3			
2b	AC-TC	AC-TC	5	4	1			
2b	ACM-CAP	ACM-CAP	7	3	1			

2.10.2.2 Airborne platforms and instruments

The following table summarises the airborne platforms and payloads that will be used in the context of EarthCARE validation

Table 6 Airborne platforms and instruments

Platform	Instruments
FAAM	CTH/Aerosol LIDAR, MARSS radiometer, various in-situ
HALO	WALES LIDAR, Cloud radar, imager, various in-situ, Cloud radar, MWR, solar radiation,
DLR Falcon	in-situ cloud probes , hygrometer, dropsondes, etc.
LOAC Voltaire	Light Optical Particle Counter
Strateole	BeCOOL lidar, backscatter tethered sonde, etc.
ATR42	RASTA and BASTA radars, LNG Lidar (355nm), ALIAS LIDAR (355nm) Radiometers, in-situ samplers (2DS etc).
STRATOBUS	BASTA
Polar 6	in-situ probes, MIRAC RADAR (95), AMALI LIDAR (355nm)
Vulcanair (TBC)	Nd-YAG system at 532 (TBC)
TBC	355 lidar (CNES – Russia collaboration) (TBC)
Norwegian Aircraft	Nezerov probe (LWC, TWC)
NASA LaRC Aircraft	HSR Lidar
NASA JPL Aircraft	Precipitation and Cloud Radar
EUFAR (TBC)	Various Lidars (TBC)
Canadian Convair	94GHz cloud radar, (355nm) backscatter Lidar
various UAVs	Various instruments , including WALI Lidar, etc.

2.10.2.3 Airborne campaign locations

The campaign areas proposed are as follows:

Table 7: Airborne campaign areas

Airborne Campaign Areas		
Cape Verde	Aire sur l'Adoure (F) (launch location for balloons)	Norway
Indonesia	Kiruna (S) (launch location)	North America
Sweden	Timmins (CND) (launch location)	NASA JPL areas TBD
Iberian Peninsula	Equatorial site (40 balloons)	NASA LaRC areas TBD
North Atlantic	Barbados	EUFAR (TBC) areas TBD
Arctic (3 campaigns)	Siberia	Alaska

The above campaigns were indicated in the AO proposals, but many of them will have finished before the present launch date. New campaign opportunities are presently being identified, and will be documented in the pre-launch update of this document.

2.10.2.4 Ground-based instrumentation

The suite of ground-based instruments contributing through the EarthCARE Cal/Val AO is as follows:

Table 8 Ground-based instrumentation

instrument			
(Multiwavelength) Raman-(polarisation) Lidar	(Profiling) Cloud radar	(Microwave)/infra red/(visible) radiometer	Optical distrometer
Backscatter Lidar	Weather radar	(Pandora)(Precision) spectrometer	(Optical) Particle (Counter)/(Sampler)
Doppler Lidar	(micro) rain radar (profiler)	Pyrometer	Aethalometer
(multi channel) (multi-wavelength) RMR Lidar	Precipitation radar	Pyranometers and Pyrgeometers	Nephelometer
Aerosol Lidar	Radar wind profiler	Sun photometer	Radiosonde
Micro-Pulse Lidar		Sun sky radiometer	Rain gauge
Ceilometer			

2.10.2.5 Location of ground-based instruments

The following map shows the distribution of Radars and Lidars. (note that systems from dense networks (e.g. MPLnet, Aeronet) are not shown, for map readability.

Figure 4 Locations of Lidars and Radars (dense networks not shown)

2.10.2.6 Other Satellites used for intercomparison

The suite of satellite instruments that will be compared with ATLID, BBR, CPR, or MSI through the contributions to the EarthCARE Cal/Val AO is as follows:

Table 9 Satellites

Mission and/or Sensor	
AVHRR	GERB
CALIPSO (*)	GPM/DPR

CATS	SCARAB
CERES	SEVERI
CLARREO	Sentinel 3 (OLCI+SLSTR)
CloudSat	VIIRS
MODIS	

(*) several proposals will use CALIPSO even in case there would be no mission overlap. In that case the CALIPSO dataset will be used in a statistical manner.

2.10.2.7 Models

The suite of models that will be used in support of identification of biases is as follows:

Table 10 Models

Model name	Parameters
IFS(ECMWF)	4D Var Aerosol, and simulates backscatter
Met Office NWP	4D-Var Cloud&Aerosol
EURAD-IM	4D-Var Aerosol
ICON-LEM (DKRZ HD(CP)2)	Cloud
4A/OP	Brightness Temperatures (for MSI)
AC (INES)	Simulates cloud microphysical, radiative, and electric properties

ECMWF is developing tools to routinely ingest EarthCARE products for systematic quality screening during Phases E1 and E2.

2.10.3 Detailed description of validation activities

This section provides the format for harmonised information about each of the activities contributing to ESA EarthCARE Validation. The full tables will be consolidated on the interactive validation portal and subsequently published on http://earthcare-val.esa.int.

Table 11 Detailed Project Metadata

EVID	AOID	Title	PI Name	PI Insitution

Project Summary

AOID is Announcement of Opportunity IDentifier, a unique a unique number that identifies a team in order of proposal submission. As other Announcements of Opportunity where ongoing in parallel, the AOIDs of the EarthCARE proposals are not sequential and consist of 5 digits. For ease of reference a second ID unique to the ECVT has been created, the EVID or EarthCARE Validation team IDentifier. In contrast to AOIDs, EVIDs start at 1 and are sequential.

Table 12: Subgroup participation

Data Acquisition subgroups:	Campaigns		Network		Models (TBC)
	Y/N		Y/N		Y/N
Data Analysis subgroups:	MSI L1	ATL L1	Aerosols	Cloud	Radiation
	Y/N	Y/N	Y/N	Y/N	Y/N

An ECVT validation project will participate in at least one subgroup.

Table 13 Correlative instruments vs. EarthCARE data products

	A- FM	A-AER	A-ICE	A-TC	A-EBD	A-CTH	A-ALD	C-FMR	C-CD	AC-TC	ACM-CAP	ACM-COM	ACM-3D	ACM-RTD	BM-RAD	BMA-FLX	A- FM	A-AER
Instrument type 1	D or i or emtpty	D or i or emtpty	D or i or emtpty	etc														
Instrument type 2	D or i or emtpty	D or i or emtpty	D or i or emtpty	etc														

In the table above, "D" refers to directly comparable geophysical measurements, "i" refers to indirect parameters such as ancillary information, or parameterisation variables (used as a basis for classifying the comparison statistics, e.g. "discrepancy as a function of solar zenith angle ="i")

Table 14 Correlative instruments and locations

Instruments	Location 1	Location 2							
Instrument type 1	y	n							
Instrument type 2	n	y							

Table 15 project context information

Methods that will be applied

Expected results from the activity
Relation to other activities
EarthCARE data needs:
other ESA data needs:
Third Party Mission data needs:
non-ESA non-TPM data needs (e.g. EUMETSAT, NASA, NOAA,)

2.10.4 Mapping of ESA EarthCARE CAL/VAL activities to the CAL/VAL requirements

2.10.4.1 Coverage Matrix

The following table presents the format of the matrix of coverage. As such it includes the EarthCARE parameters but not yet the coverage in terms of validation activities. The full table is being consolidated on the interactive validation portal (2.11.1). In final form, it will be published on https://earthcare-val.esa.int .

Table 16 coverage matrix

Product	Conditions	Parameter to be validated	Validation condition	AO acitivities		
				Ground	Air	Sat
A-FM		geolocation of detected features	Exact collocation			
A-FM		lidar surface altitude	Exact collocation			
A-AER	Aerosol regions only, low spatial resolutio	Extinction coefficient (profile)				
A-AER	Aerosol regions only, low	Backscatter coefficient (profile)				

	spatial resolutio					
A-AER	Aerosol regions only, low spatial resolutio	Depolarisation ratio (profile)				
A-AER	Aerosol regions only, low spatial resolutio	Aerosol classification (profile)				
A-ICE		Ice water content (profile)				
A-ICE		Ice effective radius (profile)				
A-TC		Hydrometeor/aerosol type (profile)				
A-EBD	All regions, Instrument resolution	Extinction coefficient (profile)				
A-EBD	All regions, Instrument resolution	Backscatter coefficient (profile)				
A-EBD	All regions, Instrument resolution	Depolarisation ratio (profile)				
A-EBD	All regions, Instrument resolution	Particle optical depth (profile)				
A-CTH		Cloud top height				
A-ALD		Aerosol layer(s) top and base heights				
A-ALD		Aerosol layer(s) optical thickness				
A-ALD		Aerosol layer(s) mean extinction				
A-ALD		Aerosol layer(s) mean backscatter				
A-ALD		Aerosol layer(s) mean depolarisation				

A-ALD		Aerosol optical thickness (layer sum)				
A-ALD		Aerosol optical thickness (total column)				
C-FMR		Significant Detection Classification				
C-FMR		Reflectivity corrected for gaseous attenuation (Profile; NB: this includes all corrections to reflectivity)				
C-FMR		Path-integrated attenuation (PIA) over sea				
C-CD		Unfolded Doppler Velocity (V_T)	Best Estimate Sedimentation Velocity - the final Doopler product including all corrections (antenna mispointing, non uniform beam filling, variable length integration , folding) and suitable to be used in retrieval algorithms. This is V_T velocity after removing the vertical motion and estimated using a power law relationship between reflectivity and Doppler velocity. We plan to			

			indroduce this new velocity product in the C-PRO version 5.			
C-TC		The height of the base of melting layer				
C-TC		The height of the top of melting layer				
C-TC		The height of the base of the observed hydrometeor layer				
C-TC		The height of the top of the observed hydrometeor layer				
C-TC		Hydrometeor classification (Profile)				
C-TC		Doppler Velocity Classification (Profile)				
C-CLD	Retrieved quantities	Retrieved Water Content (Profile)				
C-CLD	Retrieved quantities	Retrieved Characteristic Diameter: mean mass weighted (melted) equivalent diameter (Profile)				
C-CLD	Derived from retrieval	Normalized number concentration parameter No* of the normalized (melted) PSD (liquid/solid precipitation parameter; Profile)				
C-CLD	Derived from retrieval	Mass flux (liquid/solid precipitation parameter; Profile)				
C-CLD	Derived from retrieval	Sedimentation Velocity (Profile)				
C-CLD	Deduced from retrieval, ice properties only	Physical dimension of retrieved mean mass weighted (melted) eq. diameter (solid precipitation parameter; Profile)				

C-CLD	Deduced from retrieval, ice properties only	Ice/snow water path				
C-CLD	Derived from retrieval, rain properties only	rain liquid water path				
C-CLD	Liquid cloud retrieval variables	Retrieved liquid water content (Profile)				
C-CLD	Liquid cloud retrieval variables	Effective radius (Profile)				
C-CLD	Liquid cloud retrieval variables	Liquid cloud water path				
C-CLD	Liquid cloud retrieval variables	Retrieved drizzle mass flux at cloud base				
M-CM		Cloud mask				
M-CM		Cloud type (ISCCP)				
M-CM		Cloud thermodynamic phase				
M-COP		Cloud optical thickness				
M-COP		Cloud effective radius				
M-COP		Cloud water path				
M-COP		Cloud top height (/pressure/temperature)				
M-AOT		Aerosol optical thickness at 670 nm				
M-AOT		Aerosol optical thickness at 865 nm (ocean only)				
M-AOT		Angstrom parameter 670 to 865 nm (ocean only)				

AM-CTH		Cloud top height across swath				
AM-ACD		Aerosol optical thickness at 355/670/865 nm (ocean only for 865 nm)				
AM-ACD		Angstrom parameter 355 to 670 and 670 to 865 nm (ocean only for 670 to 865 nm)				
AM-ACD		Aerosol type				
AC-TC		Hydrometeor/aerosol type (profile)	We do expect a certain consistency between radar and lidar categorisations. If the radar and lidar detections are not in agreement or the result is undefined we need to flag it. Example, lidar says aerosol and radar rain: radar should take over (as rain) but we could consider the result as questionable.			
ACM-CAP	Liquid	Liquid Droplet Total Number Concentration (Profile)				
ACM-CAP	Liquid	Liquid Water Content (Profile)				
ACM-CAP	Liquid	Visible Extiction Coefficient (Profile)				
ACM-CAP	Liquid	Liquid Cloud Visible Optical Depth				

ACM-CAP	Liquid	Vertically-integrated liquid water content (Liquid Water Path)				
ACM-CAP	Liquid	Liquid Effective Radius (Profile)				
ACM-CAP	Ice	Visible Extinction Coefficient (Profile)				
ACM-CAP	Ice	Ice Lidar Backscatter to Extinction Ratio (Profile)				
ACM-CAP	Ice	Ice Water Content (Profile)				
ACM-CAP	Ice	Ice Effective Radius (Profile)				
ACM-CAP	Ice	Median Volume Diameter (Profile)				
ACM-CAP	Ice	Ice Mass Flux / Snowfall Rate (Profile)				
ACM-CAP	Ice	Ice Cloud Optical Depth				
ACM-CAP	Ice	Vertically-integrated Ice Water Content (Ice Water Path)				
ACM-CAP	Rain /Melting Ice	Rain Rate (Profile)				
ACM-CAP	Rain /Melting Ice	Rain Normalised Number Concentration (Profile)				
ACM-CAP	Rain /Melting Ice	Rain Water Content (Profile)				
ACM-CAP	Rain /Melting Ice	Median Rain Drop Diameter (Profile)				
ACM-CAP	Rain /Melting Ice	Two-way 94 GHz Attenuation through Melting Layer				
ACM-CAP	Aerosol	Aerosol Total Number Concentration (Profile)				
ACM-CAP	Aerosol	Aerosol Extinction (Profile)				
ACM-CAP	Aerosol	Aerosol Mass Content (Profile)				
ACM-CAP	Aerosol	Aerosol Median Volume Diameter (Profile)				
ACM-COM	cloud property profiles	cloud liquid water content				

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ACM-COM	cloud property profiles	effective radius of cloud droplet size distribution				
ACM-COM	cloud property profiles	cloud ice water content				
ACM-COM	cloud property profiles	effective diameter of cloud crystal size distribution				
ACM-COM	cloud property profiles	Binary mask indicating if cloud is present or not				
ACM-COM	cloud property profiles	Rain water content				
ACM-COM	cloud property profiles	Snow water content				
ACM-COM	aerosol property profiles	aerosol extinction coefficient at 355nm				
ACM-COM	aerosol property profiles	Ångström coefficient				
ACM-COM	aerosol property profiles	Aeorosol type				
ACM-RT	1D heating rate profiles (each JSG column in L2-plane)	1D SW heating rates for pristine-sky				
ACM-RT	1D heating rate profiles (each JSG column in L2-plane)	1D SW heating rates for clear-sky				
ACM-RT	1D heating rate profiles (each JSG column in L2-plane)	1D SW heating rates for all-sky				

ACM-RT	1D heating rate profiles (each JSG column in L2-plane)	1D LW heating rates for pristine-sky				
ACM-RT	1D heating rate profiles (each JSG column in L2-plane)	1D LW heating rates for clear-sky				
ACM-RT	1D heating rate profiles (each JSG column in L2-plane)	1D LW heating rates for all-sky				
ACM-RT	1D upwlling flux profiles (each JSG column in L2-plane)	1D SW upwelling flux for pristine-sky				
ACM-RT	1D upwlling flux profiles (each JSG column in L2-plane)	1D SW upwelling flux for clear-sky				
ACM-RT	1D upwlling flux profiles (each JSG column in L2-plane)	1D SW upwelling flux for all-sky				
ACM-RT	1D upwlling flux profiles (each JSG column in L2-plane)	1D LW upwelling flux for pristine-sky				
ACM-RT	1D upwlling flux profiles (each JSG column in L2-plane)	1D LW upwelling flux for clear-sky				
ACM-RT	1D upwlling flux profiles (each JSG	1D LW upwelling flux for all-sky				

	column in L2-plane)					
ACM-RT	1D downwelling flux profiles (each JSG columne in L2-plane)	1D SW downwelling flux for pristine-sky				
ACM-RT	1D downwelling flux profiles (each JSG columne in L2-plane)	1D SW downwelling flux for clear-sky				
ACM-RT	1D downwelling flux profiles (each JSG columne in L2-plane)	1D SW downwelling flux for all-sky				
ACM-RT	1D downwelling flux profiles (each JSG columne in L2-plane)	1D LW downwelling flux for pristine-sky				
ACM-RT	1D downwelling flux profiles (each JSG columne in L2-plane)	1D LW downwelling flux for clear-sky				
ACM-RT	1D downwelling flux profiles (each JSG columne in L2-plane)	1D LW downwelling flux for all-sky				
ACM-RT	3D SW surface irrandiance (each 3D assessment domain)	3D SW direct-beam surface irradiance fluxes for all-sky				

ACM-RT	3D SW surface irrandiance (each 3D assessment domain)	3D SW diffuse beam surface irradiance fluxes for all-sky				
ACM-RT	1D SW surface irradiance (each JSG cell)	1D SW direct-beam surface irradiance fluxes for all-sky				
ACM-RT	1D SW surface irradiance (each JSG cell)	1D SW diffuse beam surface irradiance fluxes for all-sky				
ACM-RT	mean 3D SW heating rate profiles (or each 3D assessment domain)	3D SW heating rates				
ACM-RT	mean 3D SW flux profiles (for each 3D assessment domain)	3D SW upwelling fluxes				
ACM-RT	mean 3D SW flux profiles (for each 3D assessment domain)	3D SW downwelling fluxes				
ACM-RT	mean 3D LW flux at reference altitude (for each 3D assessment domain)	3D LW upwelling flux at reference altitude				
ACM-RT	mean 3D radiances (for each 3D	3D SW radiances				

	assessment domain)					
ACM-RT	mean 3D radiances (for each 3D assessment domain)	3D LW radiances				
BM-RAD		solar_radiance L_SW^SA (for all four spatial resolutions: Standard, Full, Small and Assessment Domain)				
BM-RAD		thermal_radiance L_LW (for all four spatial resolutions: Standard, Full, Small and Assessment Domain)				
BM-RAD		solar_radiance L_SW^SA (for JSG resolution)				
BM-RAD		thermal_radiance L_LW (for JSG resolution)				
BMA-FLX		Solar_top_of_atmosphere_flux (for each one of the three telescopes)				
BMA-FLX		Solar top-of-atmosphere TOA flux obtained from the combination of the three BBR views				
BMA-FLX		Thermal_top_of_atmosphere_flux (for each one of the three telescopes)				
BMA-FLX		Thermal top-of-atmosphere TOA flux obtained from the combination of the three BBR views				
ACMB-DF		COMMENT: ACMB-DF is not to be validated. The product itself provides statistics data to assess the consistency of the retrieved cloud-aerosol profiles against the BBR radiation and flux observations.				

2.10.4.2 Areas of improvement

All the contributions proposed through the EarthCARE Cal/Val AO have been individually and collectively assessed during the 1st ESA EarthCARE Cal/Val Workshop from 13 to 15 June 2018 in Bonn. The workshop conclusions are available in a separate document EC-RP-ESA-SYS-983. In summary, the workshop conclusion was that the combination of all proposed contributions would form an adequate calibration and validation programme for EarthCARE, with the following areas requiring attention:

- The sum of all contributions is needed in full to avoid gaps. It is imperative that full funding is achieved.
- Better coverage is needed for the Tropical regions
- Whereas the geographical coverage of Lidars is considered good, the coverage of Cloud Profiling Radars is not comparable and could benefit from additional instruments
- Many of the Cloud Profiling Radars are not equipped with Weather Radars for context. "Weatherisation" of such sites would help with reduce the representativity error that affects the comparison between EarthCARE and independent instrumentation
- Openly available datasets (historic airborne campaigns, and global network data including the public Baseline Surface Radiation Network) are an excellent resource in support of EarthCARE Cal/Val that is at present not covered sufficiently.
- Ground-based radars for precipitation and snowfall validation are hampered by attenuation of wet radomes.

2.11 Validation Support Functions

2.11.1 Validation Portal

The interactive EarthCARE Validation portal is one of the most important validation support functions. Its functions include:

- Public information on EarthCARE validation (e.g. general mission news, validation requirements document, scientific validation implementation Plan (this document), Workshop Reports), at http://earthcare-val.esa.int
- Restricted-access (Principal and Co-Investigators of the validation teams, algorithm teams, instrument engineers) interactive section (at https://ecvt.esa.int) with:
  - Detailed information on mission status, instrument status, processing chain status, algorithm status, ground-segment status.
  - Once in orbit, it will also provide information on calibration planning, instrument maintenance and anomalies, processing changes and anomalies
  - Validation programme timeline
  - Links to EarthCARE data repository, EVDC, Correlative Metadata Standard (GEOMS), Intercomparison/Analysis tools, Overpass planning tools
  - An area for each PI to provide status reports

- Interactive discussion areas (plenary, algorithm/product-group-specific, subgroup specific, etc.)

The use of the interactive discussion areas instead of traditional emails has the following advantages:

- better traceability of feedback to the initial interaction
- greatly facilitates sharing of findings, answers and feedback to the broader team
- facilitates integration of new Co-Investigators to the validation team (by pointing to the knowledge exchanged on the forums instead of forwarding many emails with explanations)
- structures the interaction with the algorithm teams, the instrument experts and the ground segment experts. The ESA subgroup coordinator (**Error! Reference source not found.**) will make the connection between issues (findings, questions) raised on the forum and these external experts, allowing priorities to be set and commonalities to be identified in the issues to avoid redundant interactions
- Facilitates the collection and handling of similar, structured information from each team, e.g. tables of collocated measurements performed, etc

2.11.2 Preliminary EarthCARE data access function

The present baseline is that the Validation Teams will access preliminary EarthCARE data through the same operational ground-segment interface that will later on be used for the consolidated public data. Such preliminary data will only be made available to the validation teams. The target timeline for the release of preliminary data differs per product group and is described in Volume 1.

2.11.3 Overpass prediction support service and tools

All validation teams with instruments that have a fixed geolocation will be provided with overpass tables as soon as the definitive orbit is known. For the pre-launch validation rehearsal, a simulated orbit scenario will be selected and the corresponding overpass tables will be provided with the caveat that the actual overpass tables for the post-launch period will likely be different. For airborne campaigns, an interactive overpass calculation tool will be provided, but teams operating aircraft are invited to also contact ESA for planning support services. Also an orbit propagation and visualization tool will be made available on the EVDC

2.11.4 Validation Data Centre

The ESA atmospheric Validation Data Centre (http://evdc.esa.int) is being adapted for use by EarthCARE. This involves agreement with each PI on the definition of Metadata for his/her instrument types, and signature of a protocol that protects the rights of correlative data owners. All correlative data that is collocated with EarthCARE by the ESA EarthCARE Validation Team members is shared via the EVDC within the same ECVT, whilst respecting the rights of data originators, as per EVDC protocol. During the Validation Rehearsal the interaction with the EVDC is to be tested, by both uploading one's own correlative data and downloading data from other teams. Another action of the rehearsal is downloading simulated EarthCARE data (see 2.8.1.3), but this does not involve the EVDC but the EarthCARE ground segment.

2.11.5 Inter-comparison Analysis Support Tools

ESA is developing a software tool, the Atmospheric Virtual Lab, that can be used by the Principal Investigators. The libraries facilitate intercomparison between EarthCARE data and correlative data, both to quantify deviations, and to characterise dependencies of such deviations as a function of environmental parameters. Also, an environment for remote analysis of EarthCARE data, EDAV, is under development.

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EarthCARE Scientific Validation Implementation Plan (VIP)

VOL. 3

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Reference	**EC-PL-ESA-SYS-1049 Vol-3**
Date of Issue	**22/01/2021**
Status	**Final**

APPROVAL

Title EarthCARE Scientific Validation Implementation Plan (VIP)	
Issue Number 1	**Revision Number**
Author JAXA	**Date** 22/01/2021
Approved By	**Signature & Date of Approval**
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CHANGE LOG

Date	**Reason for Change**
22-01-2021	First version

CHANGE RECORD

Release Date 22-01-2021		
Reason for change	**Pages**	**Paragraph(s)**
First version	All	All

DISTRIBUTION

Name/Organisational Unit

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3 VOLUME 3

3.1 Introduction

3.2 JAXA Applicable / Reference Documents (volume 3)

Reference Documents

RD-1. EarthCARE JAXA Product List (NDX-110003E)

RD-2. EarthCARE Cloud Profiling Radar (CPR) In Orbit Verification Plan (SEC-090008 D)

3.3 JAXA In-Orbit Characterisation, Calibration and Verification

3.3.1 Scope of the In-Orbit Verification (IOV)

The purpose of the CPR in-orbit verification in Commissioning and CAL/VAL Phase (COM, E1) and in the beginning of Measurement/Operation phase (MOP, E2) is to perform the following activities[AD-].

(1) To verify CPR switch-on.

(2) To verify CPR health status & function check (initial checkout)

(3) To verify soundness of the Ground Segment data acquisition and data processing

(4) To verify CPR characterization & calibration

(5) To verify that CPR meets specifications in orbit through a proper calibration

(6) To verify initial CPR Level 1 performances and performances stability

(7) To verify initial CPR Level 2 / Synergy performances and performances stability

(This task will be done at the beginning of Measurement/Operation phase by Science group)

(8) To identify the CPR operation constraints for routine operation, if necessary.

JAXA plans to change the observation height according to the latitude automatically with MIX mode which is one of the sub-modes of the observation mode. However, as an activity in IOV, JAXA will take continuous 3 full-orbit observation data for same observation height with sub-mode High(20km), Middle(18km), and Low(16km) respectively.

3.3.2 CPR Instrument and L1 Products

The IOV for CPR is roughly split into following phases [TBC]:

Phase 1: MREF deployment confirmation

The antenna main reflector (MREF) of the CPR has been folded until the satellite is launched and reach orbit. MREF shall be deployed before giving power to CPR. In this phase, it is verified that MREF deployment is completed.

Phase 2: Instrument switch-on and mode transition activities
After switching-on the Signal Processor Unit (SPU) of CPR by the S/C commanding, CPR mode transition and switch-on/off for CPR components can be controlled by CPR commanding. In this phase, mode transition including components' switch-on shall be done step by step. And the CPR status, power consumption, temperatures shall be checked quickly by housekeeping telemetry.

Phase 3: in-orbit characterization
In this phase, science telemetry, which is produced not only in observation mode, but also in 3 calibration modes (see Phase 4), are confirmed to check the function of science data acquisition. And science telemetry and housekeeping telemetry are confirmed to characterize each component's soundness, thermal control, power consumption, datation, and so on. Phase 2 and phase 3 correspond to CPR initial checkout activities in JAXA.

Phase 4: in-orbit calibration
CPR has special operation modes in order to acquire the calibration data;

(1) Internal calibration
CPR internal calibration will be performed in CPR internal calibration mode. Input output characteristic of the log detector, ADC, IQ detector are measured in order to get the SPU calibration data.

(2) External calibration (ARC calibration)
CPR external calibration will be performed in CPR external calibration mode. JAXA will set active radar calibrators (ARCs) on the ground in Japan so that the CPR measures reflected signal for calibration.

(3) Sea surface calibration
CPR sea surface calibration will be performed in CPR sea surface calibration mode. The sea surface calibration requires satellite role maneuver so that the CPR measures the sea surface scattering echo over the broad incidence angle. One sea surface calibration consists of twice role maneuvers.

These CPR calibration data including ARC data will be used not only to calibrate the CPR observation data at that time but also to check the stability of the specification of CPR in long time span by continuing the calibration data acquisition in regular interval.

And CPR obtains the following calibration data during observation mode without any interruption to the nominal observation; the reference of the zero-Doppler velocity, the output power of the log detector when input-port terminated, and hot/cold noise power.

Phase 5: Peformance verification and L1 product
After Phase 1 to 4, JAXA evaluates CPR performance such as the minimum radar detectable, dynamic range and linearity, antenna beam width, peak transmission power, Doppler measurement accuracy, etc.

NICT validates the doppler relevant parameters of the calibrated CPR observation data by using ground radar observation data. And the CPR L1b product is released officially after reflection of the result of the validation by NICT.

3.3.3 Level 2 products

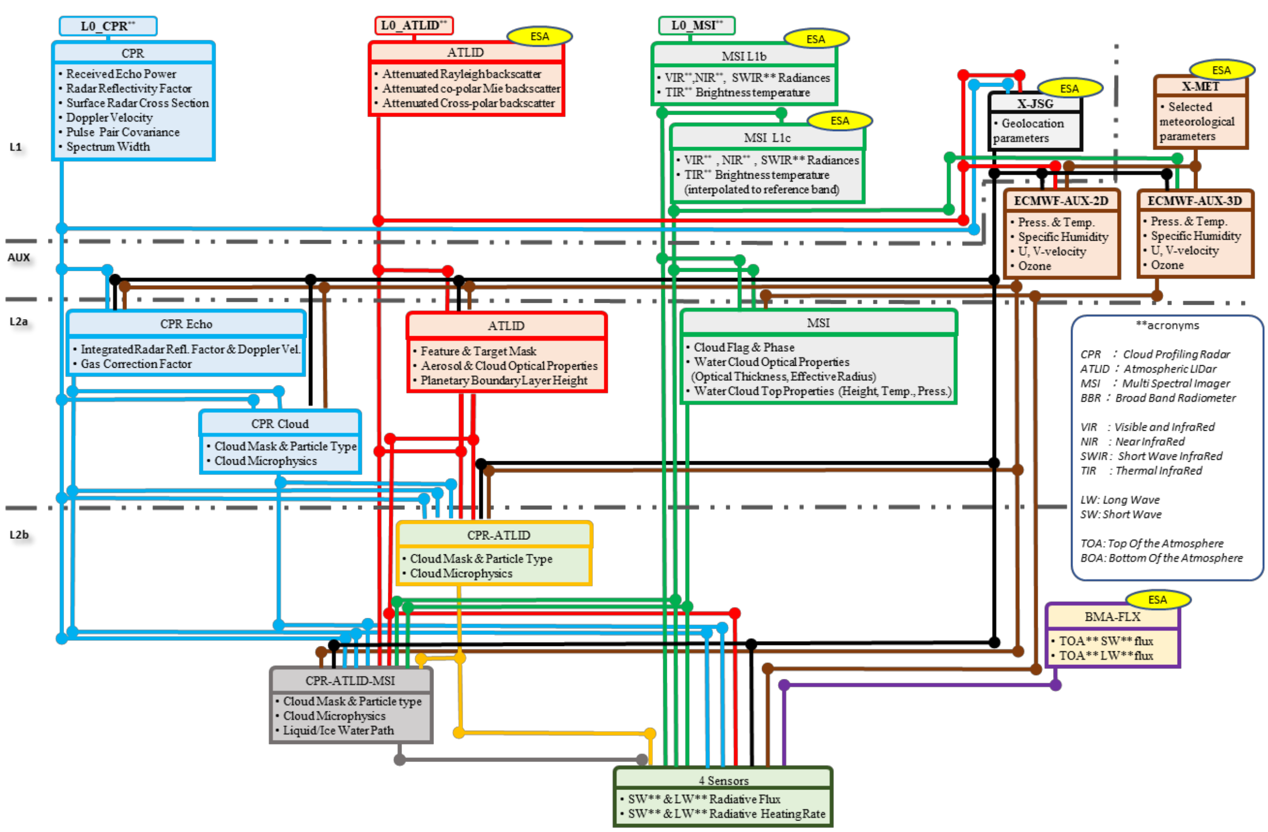
In a future release, a summary of the verification approach will be described.

3.4 JAXA EarthCARE Data Processing and Product Description

3.4.1 Production Model

The Production Model for EarthCARE Level 1 and Level 2 products generated by JAXA is shown in a figure as follows. The figure indicates all JAXA products*1 and some ESA products that have interfaces with JAXA products, and the dependencies between them. Rectangular boxes represent products and their main parameters. The ESA products are marked with yellow tags of "ESA" on upper right of the rectangular boxes.

*1: JAXA products consists two categories, which are "Standard Product" and "Research Product", but in this document only the standard products are focused. Therefore, the JAXA products in the figure are only the standard products.



3.4.2 Data Processing to Level 1b

Raw instrument data (instrument science packets) as downlinked by the satellite are separated per instrument, divided into frames of length 1/8 orbit, sorted in time, and stored together with a descriptive product header into level 0 data products. Level 0 data delivered from ESA GS side to JAXA GS side. These are then processed by CPR Level 1b processor which turn the raw data in engineering units into calibrated parameters such as received echo power and doppler velocity, stored in Level 1b data products. Geolocations, quality information, and error descriptors are added to the Level 1b products as well.

CPR L1b processor makes L1b product for the data observed by Nominal observation mode, Contingency mode, and External Calibration Mode. Invalid values are stored under the effective observation altitude in the L1b product of Nominal observation mode. In the case of External calibration Mode, Invalid values are stored in the region higher than 18km.

CPR L1b processor makes performance analysis file with L1b product simultaneously. This file includes results of performance analysis from Science TM and HK TM and it will be one of the sources for the evaluation of

3.4.3 Technical evaluation in orbit

JAXA Ground System (GS) continues the trend monitoring and limit check in orbit. And JAXA GS make monthly CPR operation report including the operation status information. JAXA CPR Project team regularly analysis CPR L1b product and evaluate the soundness of the system and tendency to deterioration of equipment. Following parameters are some of representatives for trend monitoring from L1 product.

- PulseWidth
- NoiseFloorPower
- TransmitPower
- RadarCoefficient
- SigmaZero

As the result the analysis and evaluation, some of calibration table of the CPR L1b processor or parameters of on-board software may be updated in order to ensure the quality of CPR L1b product. The followings are common examples which may be updated as the result of evaluation.

<CPR L1b processor>

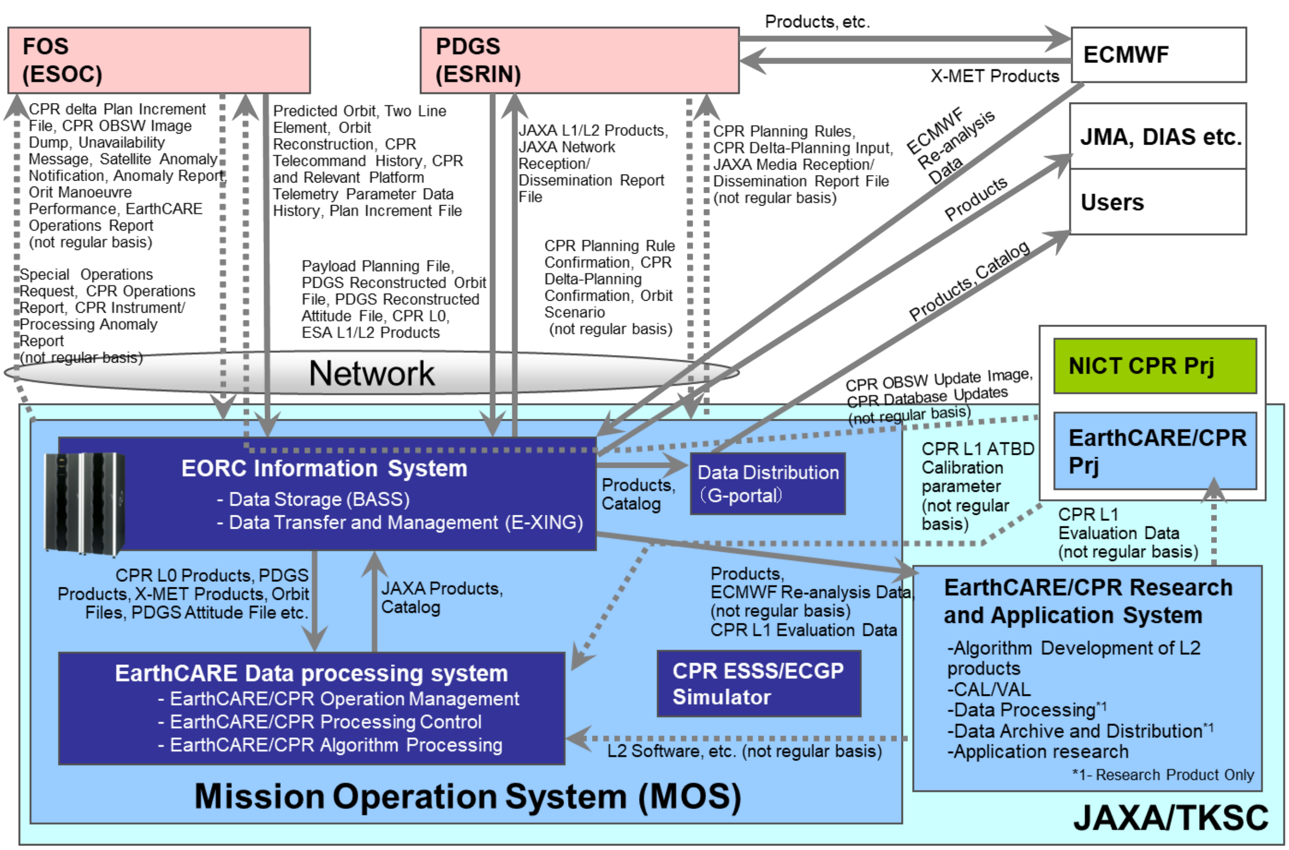
- Calibration tables related to Timing.
- Calibration tables related to Sensitivity
- Calibration tables related to Doppler Velocity
- Calibration tables related to Antenna Beam Pointing
- PRF table

<CPR on-board Software >

- PRF table
- Observation height selection table
- SPU Variable table
- Dynamic Offset table

3.4.4 Level 2a and 2b Data processing

The JAXA Level 2 products will be processed by the mission operation system on JAXA Tsukuba Space Center (JAXA/TKSC) and will be distributed by G-portal that is a data distribution system for any JAXA satellites. Overview of the JAXA mission operation system and interface with other systems are illustrated in the figure below.



JAXA Level 2 products consists four kinds of Level 2a products and three kinds of Level 2b products (see [RD-1]). The Level 2a products are retrieved by the Level 1 product of each single sensor of CPR, ATLID and MSI. The Level 2b products are produced by synergy algorithms of the two sensors (CPR and ATLID), the three sensors (CPR, ATLID, and MSI), and the four sensors onboard the EarthCARE. The primary parameters, the grid spacings, and the spatial resolution of the Level 2a and Level 2b products are in tables below.

Sensor (s)	Processing Level	Product ID	Product Name	Primary Parameter	Grid Spacing Horizontal	Grid Spacing Vertical	Spatial Resolution Horizontal	Spatial Resolution Vertical
CPR	L2a	CPR_ECO	CPR One-sensor Echo Product	Integrated Radar Reflectivity Factor	1km	0.1km	1km	*0.5km*
							10km	
				Integrated Doppler Velocity			1km	
							10km	
				Gas Correction Factor			1km	
							10km	
CPR	L2a	CPR_CLP	CPR One-sensor Cloud Product	Cloud Mask	1km	0.1km	1km	*0.5km*
							10km	
				Cloud Particle Type			1km	
							10km	
				Liquid Water Content			1km	
							10km	
				Ice Water Content			1km	
							10km	
				Effective Radius of Liquid Water Cloud			1km	
							10km	
				Effective Radius of Ice Water Cloud			1km	
							10km	
				Optical Thickness		-	1km	-
							10km	
ATLID	L2a	ATL_CLA	ATLID One-sensor Cloud and Aerosol Product	Feature Mask	L1b minimum unit	0.1km	L1b minimum unit	*0.1km*
					1km		1km	
					10km		*10km*	
				Target Mask	1km		1km	
							10km	
				Aerosol Extinction Coefficient			*10km*	
				Aerosol Backscattering Coefficient				
				Aerosol Lidar Ratio				
				Aerosol Depolarization Ratio				
				Cloud Extinction Coefficient			1km	
							10km	
							1km	

				Cloud Backscattering Coefficient			*10km*	
				Cloud Lidar Ratio			1km *10km*	
				Cloud Depolarization Ratio			1km *10km*	
				Planetary Boundary Layer Height		-	1km *10km*	-
MSI	L2a	MSI_CLP	MSI One-sensor Cloud Product	Cloud Flag including Cloud Phase	0.5km	-	*0.5km*	-
				Optical Thickness of Liquid Water Cloud				
				Effective Radius of Liquid (1.6 µm)				
				Effective Radius of Liquid (2.2 µm)				
				Cloud Top Temperature				
				Cloud Top Pressure				
				Cloud Top Height				

Sensor(s)	Processing Level	Product ID	Product Name	Primary Parameter	Grid Spacing Horizontal	Grid Spacing Vertical	Spatial Resolution Horizontal	Spatial Resolution Vertical
CPR + ATLID	L2b	AC__CLP	CPR-ATLID Synergy Cloud Product	Cloud Mask	1km	0.1km	1km	*0.5km*
							10km	
				Cloud Particle Type			1km	
							10km	
				Effective Radius of Liquid Water Cloud			1km	
							10km	
				Effective Radius of Ice Water Cloud			1km	
							10km	
				Liquid Water Content			1km	
							10km	
				Ice Water Content			1km	
							10km	
				Optical Thickness		-	1km	-
							10km	
CPR + ATLID + MSI	L2b	ACM_CLP	CPR-ATLID-MSI Synergy Cloud Product	Cloud Mask	1km	0.1km	1km	*0.5km*
							10km	
				Cloud Particle Type			1km	
							10km	
				Effective Radius of Liquid Water Cloud			1km	
							10km	
				Effective Radius of Ice Water Cloud			1km	
							10km	
				Liquid Water Content			1km	
							10km	
				Ice Water Content			1km	
							10km	
				Optical Thickness		-	1km	-
							10km	
				Liquid Water Path			1km	
							10km	
				Ice Water Path			1km	
							10km	
CPR ATLID MSI BBR	L2b	ALL_RAD	Four Sensors Synergy Radiation Budget Product	SW Radiative Flux	10km*1	-	*10km*	-
				LW Radiative Flux				
				SW Radiative Heating Rate		0.5km*1		0.5km
				LW Radiative Heating Rate				

*1 : The values shown are defined at the time of JAXA CDR. In future, the values may change if there are strong scientific requirements.

3.4.6 Auxiliary files

Auxiliary products generated by JAXA are AUX-2D and AUX-3D that contain meteorological data. In operational data processing, the AUX-2D products are produced by X-MET, X-JSG and ATLID Level 1b products, and AUX-3D products are produced by X-MET, X-JSG and MLS Level 1c products. The primary parameters and the grid spacing of AUX-2D and AUX-3D are as follows (see [RD-1]):

Product ID	Product Name	Primary Parameter	Grid Spacing	
			Horizontal	Vertical
AUX_2D	ECMWF-AUX-2D Product	Pressure	1 km	0.1 km*1
		Temperature	1 km	0.1 km*1
		Specific Humidity	1 km	0.1 km*1
		Ozone Mass Mixing Ratio	1 km	0.1 km*1
		2 m Temperature	1 km	-
		10 meter U-velocity	1 km	-
		10 meter V-velocity	1 km	-
		Total Column Ozone	1 km	-
AUX_3D	ECMWF-AUX-3D Product	Pressure	10 km	1 model layer*2
		Temperature	10 km	1 model layer*2
		Specific Humidity	10 km	1 model layer*2
		Ozone Mass Mixing Ratio	10 km	1 model layer*2
		2 m Temperature	10 km	-
		10 meter U-velocity	10 km	-
		10 meter V-velocity	10 km	-
		Total Column Ozone	10 km	-

*1: The vertical grid will be in JSG vertical grid
*2: Depends on the resolution of ECMWF data that JAXA will receive by the time of launch

3.5 JAXA Product Validation Requirements

In order to assess achievements of requirements in the Japanese communities, JAXA defined the accuracy criteria in the list of the products. Validation approaches of the accuracy criteria will be described in Section 2.6.

Sensor(s)	Product ID	Product Name	Primary Parameter	Release Accuracy	Standard Accuracy	Target Accuracy
L2a						
CPR	CPR_ECO	CPR One-sensor Echo Product	Integrated Radar Reflectivity Factor	-	-	-
			Integrated Doppler Velocity	-	≦ 1.3m/s	< 0.2m/s
			Gas Correction Factor	-	-	-
CPR	CPR_CLP	CPR One-sensor Cloud Product	Cloud Mask	±30%	±10%	±5%
			Cloud Particle Type	±100%	±50%	±20%
			Liquid Water Content	-	±100%	±50%
			Ice Water Content	-	-	-
			Effective Radius of Liquid Water Cloud	-	-	-
			Effective Radius of Ice Water Cloud	-	-	-
			Optical Thickness	-	±100%	±50%
ATLID	ATL_CLA	ATLID One-sensor Cloud and Aerosol Product	Feature Mask	±100%	±40%	±10%
			Target Mask	±100%	±40%	±10%
			Aerosol Extinction Coefficient	±60%	±40%	±20
			Aerosol Backscattering Coefficient	±90%	±70%	±50%
			Aerosol Lidar Ratio	±150%	±110%	±70%
			Aerosol Depolarization Ratio	±150%	±130%	±100%
			Cloud Extinction Coefficient	±50%	±30%	±15%
			Cloud Backscattering Coefficient	±90%	±70%	±50%
			Cloud Lidar Ratio	±140%	±100%	±65%
			Cloud Depolarization Ratio	±150%	±100%	±100%
			Planetary Boundary Layer Height	±500m	±300m	±100m
MSI	MSI_CLP	MSI One-sensor Cloud Product	Cloud Flag including Cloud Phase	±15% Ocean ±20% Land	±15%	±10%
			Optical Thickness of Liquid Water Cloud	±10%	±100% (converting to LWP)	±50% (converting to LWP)
			Effective Radius of Liquid (1.6 μm)	±30%		
			Effective Radius of Liquid (2.2 μm)			
			Cloud Top Temperature	±1K	±3K	±1.5K

			Cloud Top Pressure	-	-	-
			Cloud Top Height	-	-	-
L2b						
CPR + ATLID	AC__CLP	CPR-ATLID Synergy Cloud Product	Cloud Mask	-	root mean square of errors of one-sensor products	-
			Cloud Particle Type	-		-
			Effective Radius of Liquid Water Cloud	-		±2μm
			Effective Radius of Ice Water Cloud	-		-
			Liquid Water Content	-		
				-		
			Ice Water Content	-		±30%
			Optical Thickness	-		-
CPR + ATLID + MSI	ACM_CLP	CPR-ATLID-MSI Synergy Cloud Product	Cloud Mask	-	root mean square of errors of one-sensor products	-
			Cloud Particle Type	-		-
			Effective Radius of Liquid Water Cloud	-		±2μm
			Effective Radius of Ice Water Cloud	-		-
			Liquid Water Content	-		±20%
			Ice Water Content	-		±30%
			Optical Thickness	-		-
			Liquid Water Path	-		-
			Ice Water Path	-		-
CPR + ATLID + MSI + BBR	ALL_RAD	Four Sensors Synergy Radiation Budget Product	SW Radiative Flux	-	±25W/m2	±10W/m2
			LW Radiative Flux			
			SW Radiative Heating Rate	-	-	-
			LW Radiative Heating Rate	-	-	-

3.6 JAXA Validation Approaches and Common Practices

JAXA is responsible for validation of its products and confirmation of the accuracy criteria described in Section 2.5. Validation approaches of the JAXA products are described in this section.

Validation approaches for the MSI product are summarized as follows.

The release accuracy of the Cloud Flag including Cloud Phase is evaluated by comparing other satellite imager's products. Its standard accuracy is evaluated by comparing Sky Camera data, using data only completely cloudy and clear.
The release accuracy of the Optical Thickness of Liquid Water Cloud and the Effective Radius of Liquid is evaluated by comparing other satellite imager's product, with a limitation to mid-latitude ocean area. Their standard accuracy is evaluated by comparing liquid water path (g/m2) obtained from ground-based Microwave Radiometer. (TBD T- and A-window size).
The release accuracy of the Cloud Top Temperature is evaluated simply defined by brightness temperature error of the 11μm channel. Its standard accuracy is evaluated by Aircraft and/or sonde measurements for moderately thick water clouds.

Validation approaches for the ATLID product are summarized as follows.

1) Feature mask

The algorithm mainly uses a particle backscatter coefficient. It assumes thresholds in particle backscatter coefficient to identify molecule-rich, aerosol-rich, or cloud-rich layers. Thus, the retrieval accuracy was set by the accuracies of the particle backscatter coefficient and the assumed thresholds. Difference of release, standard, and target accuracies reflects the accuracy of the particle backscatter coefficients as well as improvement of the thresholds by analyzing actual measured data.

2) Target mask

The algorithm mainly uses a particle extinction coefficient, a lidar ratio, and a depolarization ratio. It assumes thresholds in those optical parameters to identify several aerosol types and cloud types. Thus, the retrieval accuracy was set by the accuracies of the used optical parameters and the assumed thresholds. Difference of release, standard, and target accuracies reflects the accuracy of the optical parameters as well as improvement of the thresholds by analyzing actual measured data.

3) Aerosol Extinction, backscatter, lidar ratio, depolarization ratio

The accuracies were theoretically evaluated from lidar equations and expected signal accuracies (e.g., SN and calibration accuracy).
Release, standard, and target accuracies are set considering that performance of retrieval algorithms will be improved by adjusting for actual observed data (e.g., tuning of noise reduction methods).

4) Cloud Extinction, backscatter, lidar ratio, depolarization ratio

Same as the Aerosol extinction, backscatter, lidar ratio, depolarization ratio, but the retrieval accuracies were set to be somehow better for clouds than for aerosols considering that the SN of backscatter signals are expected to be better for clouds than for aerosols.

5) Planetary boundary layer height

A Planetary boundary layer height is estimated by assessing a vertical gradient of a particle backscatter coefficient. Thus, the retrieval accuracy was set by the accuracies of the particle backscatter coefficient and assumed thresholds. The differences of the accuracies depend on the accuracy of the particle backscatter coefficients as well as improvement of the thresholds by analyzing actual measured data.

Note that the accuracies for the JAXA ATLID products are defined for products with a spatial resolution of 10km.

Validation approaches for the other product are described in later issues.

Following approaches are common practices of the JAXA validation activities.
(i) Utilization of the existing observation network
Long-term/broad coverage data are necessary to validate EarthCARE products. Quantitatively evaluations of the product accuracies will be performed by using data from observation sites and networks with ground instruments.

(ii) Campaign observation
After the launch, JAXA will conduct campaign observations that aim to compare the EarthCARE products. Currently, the Headquarters (HQ) of The National Institute of Information and Communications Technology (NICT) is assumed to be a site for this, and instruments will be collocated in the NICT HQ. The instruments shown in the table are expected to be collocated in the NICT HQ.

W-band cloud radars
L-band wind profiler
X-band Multi Parameter Phased Array Radar (MP-PAR)
Lidar systems including several wavelength and polarization property measurement
Incoherent and coherent Doppler Lidar

(iii) Cross comparison with other satellite data
Cross comparison of the EarthCARE products with other satellite products will provide good evaluations over the global coverages.

3.7 EarthCARE Validation Coordination

3.7.1 ESA/JAXA Validation Teams Coordination

This will be described in later issues.

3.7.2 JAXA Validation Teams Coordination

The JAXA's validation team is constructed by Principal Investigators (PIs) from the Research Announcement, PIs from direct contracts to Universities/Institutes, NICT based upon the MOU cooperation, and the JAXA.

3.8 JAXA Schedule

This will be described in later issues.

3.9 JAXA Validation Campaigns

This will be described in later issues.

3.10 JAXA Detailed Validation Plans

3.10.1 Top level summary of validation activities

The following table shows the scope of activity of each principal investigator.

Proposal ID	Title	Principal Investigator	Scope of the Activity
1	Validation of the EarthCARE L2 cloud products using ground-based radar/lidar and space-borne active sensor data.	Hajime Okamoto	The following ground-based active instruments are used to evaluate EathCARE L2 cloud products; Multiple-field-of-view multiple-scattering polarization lidar (MFMSPL), high spectral resolution lidar and Doppler lidar with NICT ground-based Doppler cloud radar. CloudSat/CALIPSO/Aeolus data are used to evaluate EarthCARE L2 cloud products.
2-1	Validation of the EarthCARE L2 products using ground-based lidar and sunphotometry measurements.	Tomoaki Nishizawa	The project contributes to validation of products on optical properties of aerosols and clouds and surface radiative flux by means of 1) AD-NET lidar systems comprising Mie lidar, Raman lidar, and HSRL with depolarization measurement function established in a wide area in East Asia, 2) SKYNET radiometer network, 3) SAVERNET lidar systems comprising Raman lidar and HSRL with depolarization measurement function established in Argentine and Chille in South America. The validation analysis in this project covers ATLID L2A, ATLID-MSI L2B, CPR-ATLID L2B, and four-sensor synergy L2B products.

2-2	Validation of aerosols and clouds over tropical ocean using ground-based and shipborne lidars	Tomoaki Nishizawa	The project contributes to validation of products on optical properties of aerosols and clouds over tropical ocean, addressing ATLID L2A products. This project will use multi-wavelength Raman lidars with depolarization function installed on research vessel MIRAI (JAMSTEC) and established in Palau which is an island country over the tropical Pacific.
3	EarhtCARE CPR and ATLID product validation using ground base remote sensors at Koganei	Yuichi Ohno	NICT Koganei is a Japanese-proposed main validation site. Many ground based remote sensors are accumulated at Koganei, so constant periodical overpasses of the EarthCARE satellite are demanded. Cloud vertical profiles are measured using W-band cloud radars and a L-band wind profiler including Doppler measurement. 3D-distribution of rain around Koganei is also measured by X-band Multi Parameter Phased Array Radar (MP-PAR). Clouds and Aerosols are measured by several Lidar systems including several wavelength and polarization property measurement. Incoherent and coherent Doppler Lidar are installed and can measure vertical and horizontal wind measurements. Optical multi-scattering property is also measured by one of the Lidar system. CPR, ATLID and their combined L2 products will be validated using those measurement data. [TBD]
4	Validation of cloud discrimination products obtained by the EarthCARE MSI	Takashi Nakajima	This proposal contributes validation of cloud discrimination (clear confidence level) obtained by CLAUDIA algorithm used for the EarthCARE MSI data. Validation will be performed by comparing EarthCARE MSI cloud discrimination with those obtained by ground-based sky camera systems. Tokai University team is maintaining three sky camera systems. They are located on Tomigaya (Tokyo), Mashiki (Kumamoto), and Iriomote Island (Okinawa). Other sky camera systems maintained by JAXA GCOM-C team will be also available. Comparisons of other satellite imager's product such as SGLI/GCOM-C, Terra/MODIS, Aqua/MODIS, Himawari8, 9 [TBD].

5	EarthCARE 4-sensor products validation	Kentaro Suzuki	This proposal contributes to evaluation/validation of the 4-sensor product of radiative fluxes through comparisons with satellite-based (CERES) and ground-based (GEBA) measurement datasets for TOA and SFC radiative fluxes, respectively.
6	In-situ observation to validate ATLID for oceanic aerosols in the tropics	Kazuaki Yasunaga	This proposal contributes to archives of in-situ aerosol observations in the tropical Pacific Ocean for the statistical intercomparison of ATLID L2a products. The aerosol observations have been conducted in the Republic of Palau and various areas over the tropical Pacific Ocean by R/V Mirai of JAMSTEC from 2015.
7	Datasets of in-situ and Ka-band radar observations for the validation of EarthCARE products	Ryohei Misumi	This proposal contributes to validate EarthCARE Cloud Profiling Radar by providing datasets of 1) cloud droplet size distribution, liquid water content, and effective radius of cloud droplets based on the observation from the Tokyo Skytree, and 2) monthly averaged profiles of radar reflectivity, vertical component of Doppler velocity, and polarimetic parameters based on observations by ground-based Ka-band Doppler radars.

AOID	PI	Validation targets				Independent validation sources					Vert.prof.	Geographical region
		ATLID	BBR	CPR	MSI	Sat	Surface routine	Surface Campaign	Airborne Campaign	Model		
1	Okamoto											0
2-1	Nishizawa	✓		✓	✓							East Asia
2-2	Nishizawa	✓										Tropical Pacific Ocean (Parau)
3	Ohno	✓		✓								Japan (Koganei)
4	Nakajima				✓							Japan
5	Suzuki	✓	✓	✓	✓							Global

6	Yasunaga	✓										Tropical Pacific Ocean (Parau)
7	Misumi			✓								Japan
TOTAL	8	5	1	4	3	0	0	0	0	0	0	

3.10.2 Top level coverage analysis

3.10.2.1 EarthCARE data products

The following table presents a high-level overview to assess coverage. A deeper assessment is presented in 3.10.5 (This latter section may not be completed in 1.0 as it involves assessments with the MAG etc)

Level	**Product**	**Processor**	ground	airborne	satellite	model	balloon	statistical
Level 1								
1b	CPR_NOM	L1b	11					
Level 2								
2a	CPR_ECO	L2a	11					
2a	CPR_CLP	L2a	10					
2a	ATL_CLA	L2a	25					
2a	MSI_CLP	L2a	21					
2b	AC__CLP	L2b	7					
2b	ACM_CLP	L2b	7					
2b	ALL_LAD	L2b	17					

3.10.2.2 Airborne platforms and instruments

The airborne platforms and payloads were not proposed in the context of JAXA EarthCARE validation.

3.10.2.3 Airborne campaign locations

The airborne campaign areas were not proposed in the context of JAXA EarthCARE validation.

3.10.2.4 Ground-based instrumentation

The suite of ground-based instruments contributed through the JAXA EarthCARE Validation activity is as follows:

No.	Instrument	Institution
1	W-band cloud radar (SPIDER)	NICT
2	High sensitivity Ground-based SPIDER (HG-SPIDER)	NICT
3	Electronic-Scanning SPIDER (ES-SPIDER)	NICT
4	L-band wind profiler (LQ13)	NICT
5	Multi Parameter Phased Array Weather Radar (MP-PAWR)	NICT
6	2μm coherent Doppler Lidar	NICT
7	355 nm direct detection Doppler Lidar	NICT
8	355 nm Multi-Field of view Multiple Scattering Polarization Lidar (MFMSPL)	NICT
9	355 nm High Spectral Resolution Lidar (HSRL)	NICT
10	905 nm ceilometer	NICT
11	Microwave-Radiometer (MT3000)	NICT
12	Cloud droplet spectrometer (Fog Monitor)	NIED
13	Ka-band scanning Doppler radar	NIED
14	Whole sky camera	Tokai Univ.
15	Mie lidar	AD-Net & SKYNET
16	Sky radiometer	AD-Net & SKYNET
17	Raman lidar	AD-Net & SKYNET
18	HSRL	AD-Net & SKYNET
19	532 nm MFMSPL	AD-Net & SKYNET
20	532 nm wide-FOV HSRL	AD-Net & SKYNET
21	Pyrheliometer	AD-Net & SKYNET
22	Sky camera	NIES
23	Mie-Scattering Lidar	Toyama Univ.

3.10.2.5 Location of ground-based instruments

The following map shows the distribution of ground-based instruments shown in 3.10.2.4.

3.10.2.6 Other Satellites used for intercomparison

The suite of satellite instruments that will be compared with ATLID, BBR, CPR, or MSI through the contributions to the JAXA EarthCARE Validation activity is as follows:

Mission and/or Sensor
SGLI/GCOM-C
Terra/MODIS, Aqua/MODIS
Terra/CERES, Aqua/ CERES
Himawari8, 9
CloudSat
CALIPSO

GPM
Aeolus
GCOM-W

3.10.2.7 Models

The model validations were not proposed in the context of JAXA EarthCARE validation.

3.10.3 Subgroup structure

This is a section that serves as placeholder for the future JAXA subgroup structure. The structure itself is presently under consolidation.

3.10.4 Detailed description of validation activities

This section provides harmonised information about each of the activities contributing to JAXA EarthCARE Validation.

<table>
<tr><td>ID:</td><td colspan="2">TITLE: Validation of the EarthCARE L2 products using ground-based lidar and sunphotometry measurements.</td></tr>
<tr><td colspan="3">PI: Dr. Tomoaki Nishizawa (National Institute for Environmental Studies, NIES)</td></tr>
<tr><td colspan="3">Institutions involved:</td></tr>
<tr><td colspan="2">Project summary</td><td></td></tr>
<tr><td colspan="2">Geolocation summary</td><td>East Asia</td></tr>
<tr><td colspan="2" rowspan="2">Correlative
Instruments</td><td>EarthCARE Level 1 Product</td></tr>
<tr><td>CPR_NOM</td></tr>
<tr><td colspan="2">AD-NET lidar systems</td><td>-</td></tr>
<tr><td colspan="2">SKYNET radiometer network</td><td>-</td></tr>
</table>

SAVERNET lidar systems	-						
Correlative	EarthCARE Level 2 Product						
Instruments	CPR_ECO	CPR_CLP	ATL_CLA	MSI_CLP	AC__CLP	ACM_CLP	ALL_LAD
AD-NET lidar systems	-	-	D	-	D	D	D
SKYNET radiometer network	-	-	D	-	D	D	D
SAVERNET lidar systems	-	-	D	-	D	D	D
In the table above, “D” refers to directly comparable geophysical measurements, “i” refers to indirect parameters such as ancillary information, or parameterisation variables (used as a basis for classifying the comparison statistics, e.g. “discrepancy as a function of solar zenith angle =”i”)							
Instruments	East Asia	Argentine and Chile					
AD-NET lidar systems	y	n					
SKYNET radiometer network							
SAVERNET lidar systems	n	y					
Methods that will be applied							

Expected results from the activity

ID:	TITLE:Validation of aerosols and clouds over tropical ocean using ground-based and shipborne lidars						
PI: Dr. Tomoaki Nishizawa (National Institute for Environmental Studies, NIES)							
Institutions involved:							
Project summary							
Geolocation summary	Tropical Pacific Ocean (Parau)						
Correlative Instruments	EarthCARE Level 1 Product						
	CPR_NOM						
multi-wavelength Raman lidars	-						
Correlative Instruments	EarthCARE Level 2 Product						
	CPR_ECO	CPR_CLP	ATL_CLA	MSI_CLP	AC__CLP	ACM_CLP	ALL_LAD
multi-wavelength Raman lidars	-	-	D	-	-	-	-
In the table above, "D" refers to directly comparable geophysical measurements, "i" refers to indirect parameters such as ancillary information, or parameterisation variables (used as a basis for classifying the comparison statistics, e.g. "discrepancy as a function of solar zenith angle ="i")							
Instruments	The tropical Pacific Ocean	The Republic of Palau					

multi-wavelength Raman lidars	y	y						
Methods that will be applied								
Expected results from the activity								

ID:	TITLE: EarhtCARE CPR and ATLID product validation using ground base remote sensors at Koganei
PI: Yuichi Ohno (National Institute of Information and Communications Technology, NICT)	
Institutions involved:	
Project summary	
Geolocation summary	Tokyo(Koganei), Saitama
Correlative Instruments	EarthCARE Level 1 Product
	CPR_NOM
W-band cloud radar (SPIDER)	D
High sensitivity Ground-based SPIDER (HG-SPIDER)	D
Electronic-Scanning SPIDER (ES-SPIDER)	D
L-band wind profiler (LQ13)	D
Multi Parameter Phased Array Weather Radar (MP-PAWR)	D
2μm coherent Doppler Lidar	-
355nm direct detection Doppler Lidar	-

355nm Multi-Field of view Multiple Scattering Polarization Lidar (MFMSPL)	-						
355nm High Spectral Resolution Lidar (HSRL)	-						
905 nm ceilometer	D						
Microwave-Radiometer (MT3000)	-						
Correlative Instruments	EarthCARE Level 2 Product						
	CPR_ECO	CPR_CLP	ATL_CLA	MSI_CLP	AC__CLP	ACM_CLP	ALL_LAD
W-band cloud radar (SPIDER)	D	D	-	-	D	D	-
High sensitivity Ground-based SPIDER (HG-SPIDER)	D	D	-	-	D	D	-
Electronic-Scanning SPIDER (ES-SPIDER)	D	D	-	-	D	D	-
L-band wind profiler (LQ13)	D	-	-	-	D	D	-
Multi Parameter Phased Array Weather Radar (MP-PAWR)	D	-	-	-	-	-	-
2μm coherent Doppler Lidar	-	-	D	-	-	-	-

355nm direct detection Doppler Lidar	-	-	D	-	-	-	-
355nm Multi-Field of view Multiple Scattering Polarization Lidar (MFMSPL)	-	-	D	-	-	-	-
355nm High Spectral Resolution Lidar (HSRL)	-	-	D	-	-	-	-
905 nm ceilometer	-	-	-	D	-	-	-
Microwave-Radiometer (MT3000)	D	D	-	-	D	D	-
In the table above, “D” refers to directly comparable geophysical measurements, “i” refers to indirect parameters such as ancillary information, or parameterisation variables (used as a basis for classifying the comparison statistics, e.g. “discrepancy as a function of solar zenith angle =”i”)							

Instruments	Koganei	Saitama					
W-band cloud radar (SPIDER)	y	n					
High sensitivity Ground-based SPIDER (HG-SPIDER)	y	n					

Electronic-Scanning SPIDER (ES-SPIDER)	y	n						
L-band wind profiler (LQ13)	y	n						
Multi Parameter Phased Array Weather Radar (MP-PAWR)	n	y						
2µm coherent Doppler Lidar	y	n						
355nm direct detection Doppler Lidar	y	n						
355nm Multi-Field of view Multiple Scattering Polarization Lidar (MFMSPL)	y	n						
355nm High Spectral Resolution Lidar (HSRL)	y	n						
905 nm ceilometer	y	n						
Microwave-Radiometer (MT3000)	y	n						
Methods that will be applied								
Expected results from the activity								

ID:	TITLE: Validation of cloud discrimination products obtained by the EarthCARE MSI						
PI: Prof. Takashi Nakajima (Tokai University)							
Institutions involved:							
Project summary							
Geolocation summary	located on Tomigaya (Tokyo), Mashiki (Kumamoto), and Iriomote Island (Okinawa). Other sky camera systems maintained by JAXA GCOM-C team will be also available.						
Correlative Instruments	EarthCARE Level 1 Product						
	CPR_NOM						
sky camera	-						
Correlative Instruments	EarthCARE Level 2 Product						
	CPR_ECO	CPR_CLP	ATL_CLA	MSI_CLP	AC__CLP	ACM_CLP	ALL_LAD
sky camera	-	-	-	D	-	-	-
In the table above, "D" refers to directly comparable geophysical measurements, "i" refers to indirect parameters such as ancillary information, or parameterisation variables (used as a basis for classifying the comparison statistics, e.g. "discrepancy as a function of solar zenith angle ="i")							
Instruments	Tomigaya (Tokyo)	Mashiki (Kumamoto)	Iriomote Island (Okinawa)				
sky camera	y	y	y				

Methods that will be applied
Expected results from the activity

ID:	TITLE: EarthCARE 4-sensor products validation						
PI: Prof. Kentaro Suzuki (University of Tokyo)							
Institutions involved:							
Project summary							
Geolocation summary	XXX						
Correlative Instruments	EarthCARE Level 1 Product						
	CPR_NOM						
satellite-based (CERES)	-						
ground-based (GEBA)	-						
Correlative Instruments	EarthCARE Level 2 Product						
	CPR_ECO	CPR_CLP	ATL_CLA	MSI_CLP	AC__CLP	ACM_CLP	ALL_LAD
satellite-based (CERES)	-	-	-	-	-	-	D
ground-based (GEBA)	-	-	-	-	-	-	D
In the table above, "D" refers to directly comparable geophysical measurements, "i" refers to indirect parameters such as ancillary information, or parameterisation variables (used as a basis for classifying the comparison statistics, e.g. "discrepancy as a function of solar zenith angle ="i")							
Instruments	XXX	XXX					

satellite-based (CERES)	y/n	y/n					
ground-based (GEBA)	y/n	y/n					
Methods that will be applied							
Expected results from the activity							

ID:	TITLE: In-situ observation to validate ATLID for oceanic aerosols in the tropics						
PI: Prof. Kazuaki Yasunaga (Toyama University)							
Institutions involved:							
Project summary							
Geolocation summary	The Republic of Palau and various areas over the tropical Pacific Ocean by R/V Mirai of JAMSTEC						
Correlative Instruments	EarthCARE Level 1 Product						
	CPR_NOM						
Mie-Scattering Lidar	-						
Correlative Instruments	EarthCARE Level 2 Product						
	CPR_ECO	CPR_CLP	ATL_CLA	MSI_CLP	AC_CLP	ACM_CLP	ALL_LAD
Mie-Scattering Lidar	-	-	D	-	-	-	-
In the table above, "D" refers to directly comparable geophysical measurements, "i" refers to indirect parameters such as ancillary information, or parameterisation variables (used as a basis for classifying the comparison statistics, e.g. "discrepancy as a function of solar zenith angle ="i")							
Instruments	The tropical Pacific Ocean	The Republic of Palau					
Mie-Scattering Lidar	y	y					

Methods that will be applied
Expected results from the activity

ID:	TITLE: Datasets of in-situ and Ka-band radar observations for the validation of EarthCARE products						
PI: Dr. Ryohei Misumi (National Research Institute for Earth Science and Disaster Resilience, NIED)							
Institutions involved:							
Project summary							
Geolocation summary	Fog monitor: Tokyo Skytree (Sumida-ku, Tokyo) Doppler radar: Tokyo (Nishitokyo, Ota-ku), Chiba (Matsudo), Ibaraki (Tsukuba), Saitama (Hidaka)						
Correlative Instruments	EarthCARE Level 1 Product						
	CPR_NOM						
Cloud droplet spectrometer (Fog Monitor)	-						
Ka-band scanning Doppler radar	D						
Correlative Instruments	EarthCARE Level 2 Product						
	CPR_ECO	CPR_CLP	ATL_CLA	MSI_CLP	AC__CLP	ACM_CLP	ALL_LAD
Cloud droplet spectrometer (Fog Monitor)	-	D	-	-	D	D	-
Ka-band scanning Doppler radar	D	D	-	-	-	-	-
In the table above, "D" refers to directly comparable geophysical measurements, "i" refers to indirect parameters such as ancillary information, or parameterisation variables (used as a basis for classifying the comparison statistics, e.g. "discrepancy as a function of solar zenith angle ="i")							

Instruments	Tokyo Skytree	Tokyo (Nishitokyo)	Tokyo (Ota-ku)	Ibaraki (Tsukuba)	Saitama (Hidaka)	Chiba (Matsudo)	
Cloud droplet spectrometer (Fog Monitor)	y	n	n	n	n	n	
Ka-band scanning Doppler radar	n	y	y	y	y	y	
Methods that will be applied							
Expected results from the activity							

3.10.5 Mapping of JAXA EarthCARE CAL/VAL activities to the CAL/VAL requirements

This will be described in later issues.

3.11 Validation Support Functions

This will be described in later issues.