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EarthCARE Scientific Validation Implementation Plan (VIP)

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Author Rob Koopman, VIP Configuration Control Manager	**Signature & Date** Rob Koopman Digitally signed by Rob Koopman Date: 2024.09.20 16:49:41 +02'00' 06/09/2024

ESA-JAXA COLLABORATION VISA

JAXA	**Signature & Date** Takuji Kubota 20/09/2024
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Pre-launch updates to Volumes 2 and 3 in preparation for commissioning	2	0	06/09/2024

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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**
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DISTRIBUTION

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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.

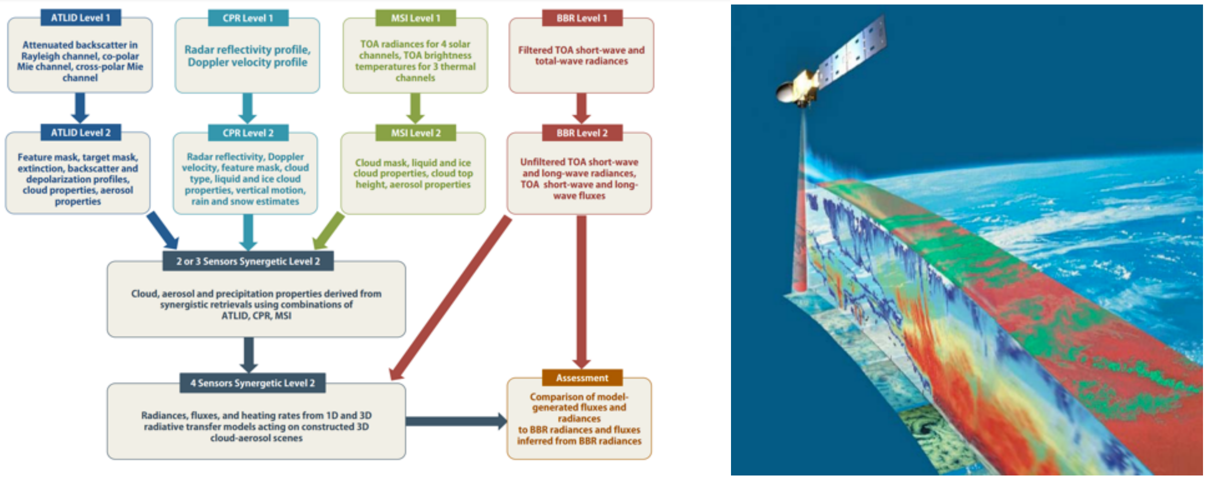

Figure 1 Contributions of multiple remote-sensing techniques towards fulfilling the EarthCARE mission objectives

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.

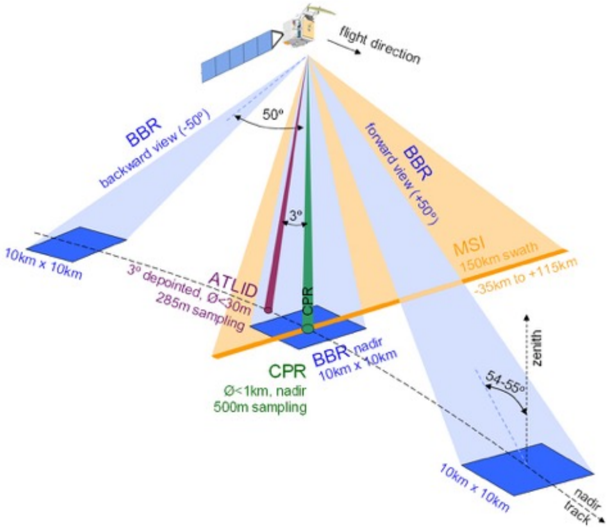

Figure 3: Instruments viewing geometry

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.

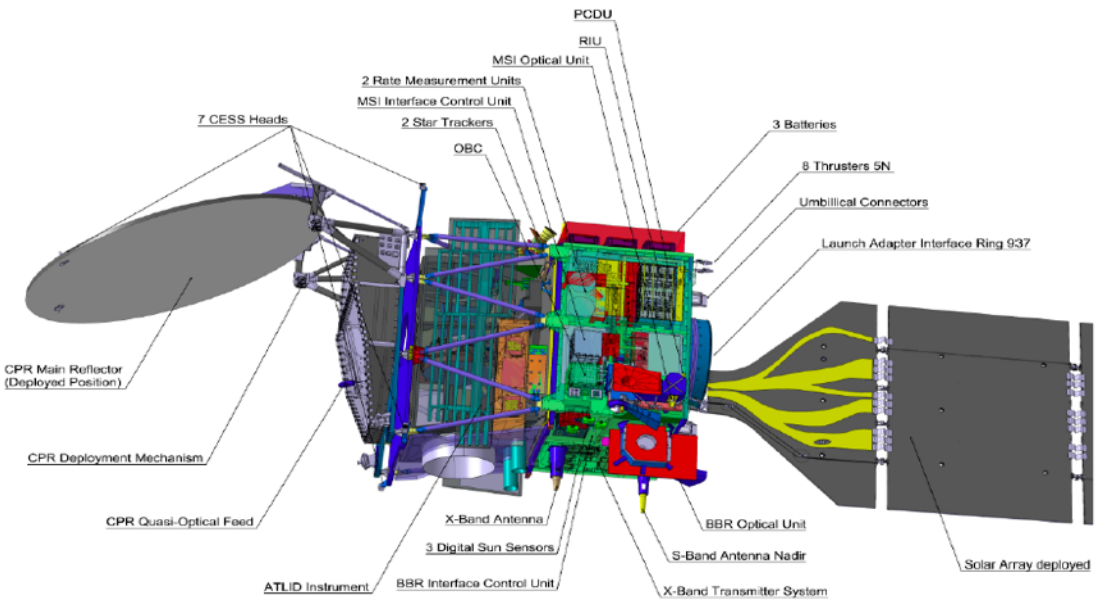

Figure 4: Spacecraft semi-transparent view

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).

- <u>Level 1b science products</u>:

  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.

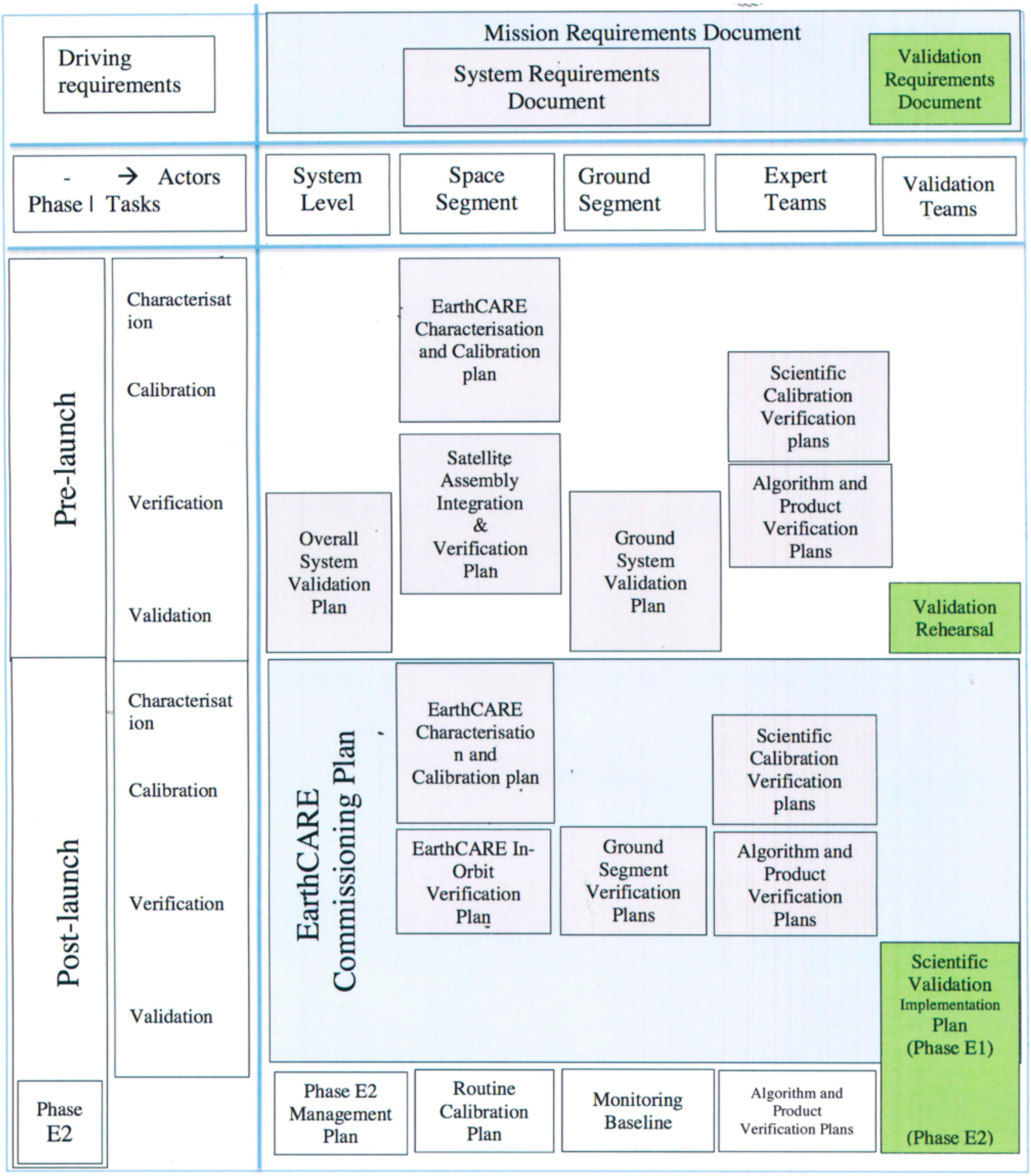

Figure 5 Mapping of the different EarthCARE plans

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.

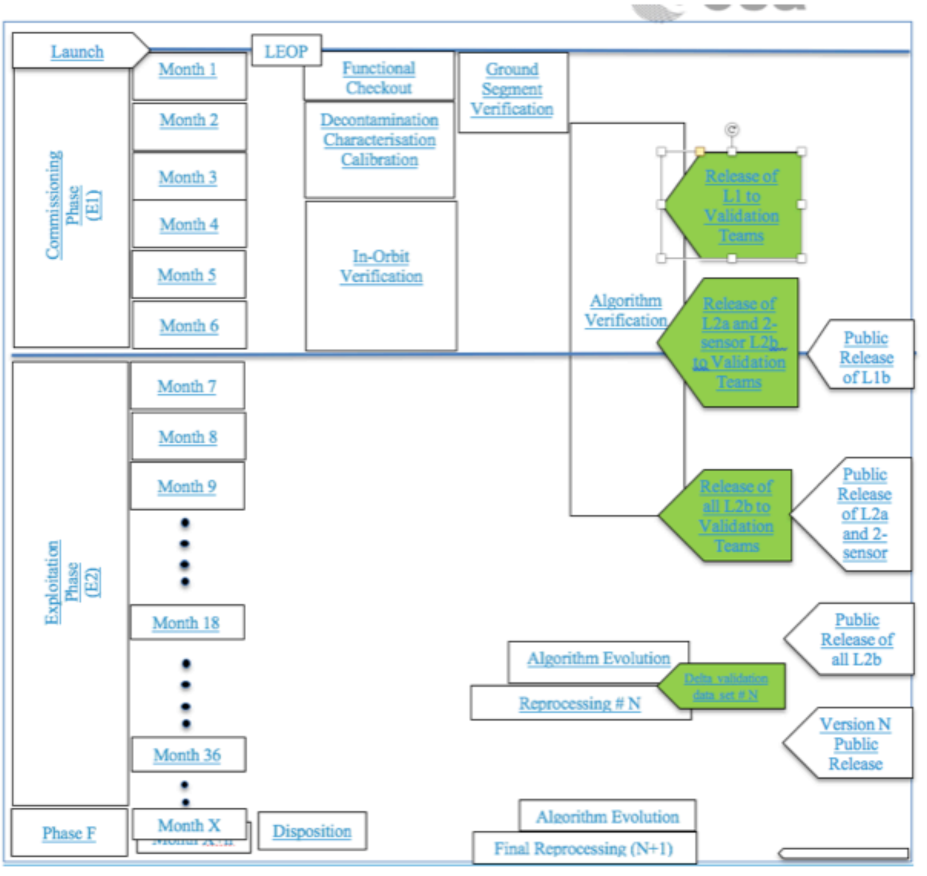

Figure 6 Indicative Timeline for EarthCARE Commissioning, Validation and Data Releases

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 (SVIP)

VOL. 2

Prepared by	**Rob Koopman, Stephanie Rusli, and the EarthCARE team**
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APPROVAL

Title EarthCARE Scientific Validation Implementation Plan (SVIP)	
Author Rob Koopman – EarthCARE Validation Coordinator Stephanie Rusli – Validation Engineer	Stephanie Rusli Digitally signed by Stephanie Rusli Date: 2024.06.11 13:06:44 +02'00' Rob Koopman Digitally signed by Rob Koopman Date: 2024.06.11 13:17:54 +02'00'
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ESA / T. Fehr – EarthCARE Mission Scientist	Digitally signed by Thorsten Fehr Date: 2024.06.21 12:20:25 +02'00'
ESA/ K. Wallace – EarthCARE Project Manager	Digitally signed by Kotska Wallace Date: 2024.06.21 18:01:39 +02'00'

CHANGE LOG

Date	Reason for change
22-01-2021	First version
27-05-2024	Second version with updates to reflect the progress in definition of activities, and updates to plans and specifications

CHANGE RECORD

Release date 27-05-2024		
Reason for change	**Pages**	**Paragraph(s)**
Major revision updating all sections with latest status of products, methods, capabilities, collaborations, plans, team membership, etc.	All	All

DISTRIBUTION

Name/Organisational Unit

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2 VOLUME 2

2.1 Introduction

This document is the second volume of EarthCARE Scientific Validation Implementation Plan. In this document, preparation, timeline, and plans for the validation of ESA EarthCARE products during the Commissioning Phase (E1) and the Exploitation/Routine Phase (E2) are described. Further information about ESA processors, data products, in-orbit verification and calibration plans are included to provide context.

The validation activities for ESA products were solicited via an Announcement of Opportunity issued in 2017. Proposal received from the Cal/Val communities were reviewed. The science teams whose proposals were accepted became members of the ESA EarthCARE Validation Team (ECVT). ESA coordinates the various geophysical validation activities that will be performed and provides the supporting infrastructure to allow ECVT members to complete the validation workflow starting from correlative measurement/overpass planning to data analysis and reporting to ESA.

This document has been prepared with inputs from the validation subgroup leaders (2.7.2 Table 3), the Principal and Co-Investigators of the validation team, the data assimilation team, the algorithm development teams, the members of the Mission Advisory Group, the instrument principal engineers, and processor and ground-segment engineers.

2.2 ESA Applicable / Reference Documents (volume 2)

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)

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, v8
[RD-5.] ESA EarthCARE Product List, EC-ICD-ESA-SYS-0314, v6.0
[RD-6.] 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 landmarks 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. 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. The baseline duration for the decontamination phase is 2 weeks but it may be extended to 4 weeks depending on the dark current check results. In the baseline scenario, the end of ATLID decontamination is expected approximately 4 weeks after launch.

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: 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, coarse and fine spectral calibration mode to allow setting of the optimum laser frequency. Functional verification of ATLID is performed in this phase, verifying the correct operations and commandability of all its subsystems.
The overall duration of the ATLID switch-on is 3-4 weeks.

Phase 3 - Performance verification

Essential ATLID performance parameters are verified in this phase where ATLID is in its nominal mode:

- Spectral cross-talk
- Polarisation cross-talk
- Background subtraction accuracy
- Accuracy of the attenuated backscatter for the three ATLID channels

These activities mostly require science data processing by ECGP and inspection. The overall duration of the ATLID In-Orbit Performance phase covers the rest of the commissioning period.

As soon as the calibrations affecting the instrument settings have been completed and the instrument is routinely in nominal mode, correlative measurements can start. For ATLID, this is approximately 6 weeks after launch.

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 that is estimated to last 12 hours. At the end of this phase (expected 2 weeks after launch), 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 performance verification

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

The IOV for MSI is split into 3 phases :

Phase 1 - MSI Decontamination and switch on.

This initial phase consists of a transition from the OFF State to the Nominal Operational mode. Only the nominal side of the MSI instrument will be commissioned. During this phase, Active Thermal Control (ATC) is checked and adjustments are also performed.
At this stage, the instrument is generating science data, but these are meaningless as neither VNS and TIR camera has valid flat-filed offset table. The overall duration of the switch-on (17 days) and the decontamination period (21 to 30 days) is estimated 38 days at a minimum.

Phase 2 - MSI Characterization, Calibration & Verification.

This phase starts with VNS and TIR calibration operations in which flat field offset is collected and applied. At this point, the VNS and TIR cameras have valid flat-filed offset table and the instrument generates meaningful science data. After the calibration, TIR (Thermal Infrared) Sensitivity Assessment, TIR Calibration Maintenance, and VNS (Visible, Near-, and Shortwave Infrared) Calibration Maintenance follows. The duration of this phase is expected to last 20 days.

Phase 3 - MSI Performance verification.

Activities performed regularly in this phase include:

(i) Regular Flat-Field Offset Calibrations

Following calibration of each camera at switch-on, the MSI can be left to run for 16 orbits; it will generate science data continually along with ancillary HKTM communicated within the ICU AUX packets for trending. Repetitively after 16 orbits (approximately one day), the operator must initiate new camera calibrations using the OBCPs (On Board Calibration Procedures) at specific times (including out-of-sight of ground). The two cameras, TIR, VNS, must be calibrated and Flat Field applied on successive orbits.

(ii) Diffuser Degradation Monitoring (Monthly)

In addition to the Daily VNS Calibration utilizing the (Diffuser2) outline here above, a VNS calibration utilizing the Reference Diffuser (Diffuser 1) needs to be performed by the operator. This will allow to track degradations in both the VNS optical transmission and the daily diffuser as an offline analysis. This is performed once per month.

As soon as the calibrations affecting the instrument settings have been completed and the instrument is routinely in nominal mode, correlative measurements can start. For MSI, this is approximately 6 weeks after launch.

2.3.5 Level 2 product verification

Different activities are planned for the scientific verification of the in-flight L2 data products during the Commissioning Phase. These activities are of course critical to identifying failures in the L2 processor chain and bugs (or significant biases) in the retrieved level 2 geophysical quantities (small biases will likely not be detected at this stage, without correlative data). The verification activities should start as soon as L2 data can be generated by the PDGS. The verification priority will of course be given to the L2a products before the synergy L2b products, thus to the : (CPR) C-FMR, C-CD, C-TC, C-CLD, (ATLID) A-FM, A-AER, A-ICE, A-TC, A-AEB, A-CTH, A-ALD, and (MSI) M-CM, M-COP. The verification of the BM-RAD product, strictly of level L2b, should also have high priority during the commissioning phase.

For each of the 4 EarthCARE instruments, the foreseen verification activities cover different monitoring, visual inspection, and detailed investigations, on a per-granule basis. Furthermore, a series of statistical verification will be applied over many granules and may include comparisons between L2 data products. The L2 team has developed an approach to verification that defined 2 levels of inspection for the L2 granules: intensive or flagged. In the intensive mode, visual inspection of all the granules will be carried out. This mode shall be selected e.g. after any changes of instrument status or after update of upstream processors (including L1 processors). Intensive inspection will also be carried out during the commissioning to verify data quality during satellite maneuvers like the regular small delta-v that are needed to maintain the orbit. In the second mode, the flagged inspection mode, the granules will be selected for visual inspection either periodically, or due to flags being activated in the L2 processor or upstream L1 processors.

The visual approach is complemented with a statistical analysis approach. Given the novelty of the EarthCARE payload, all the specific issues cannot be necessarily anticipated. For this reason, statistical verification takes the form of a series of checks on the input and output variables for each of the level 2 processors. The checks can be either internal consistency checks (e.g. of the data formatting, data flagging, …) or intercomparative checks against other L1 and L2 data products of EarthCARE (e.g. scatterplots of L2 product versus L1 input). The level 2 team has defined the following, non-exhaustive, list of examples of verification checks:

- check that input variables, noise and uncertainties, are in the expected statistical range.
- check that the geolocation and auxiliary data are consistent with the input variables (e.g. CPR surface return versus DEM),
- check the frequencies of missing/empty/NaN output variables,
- check that the product metadata are nominal,
- check that the retrieved output quantities are in the expected statistical range, as well as their uncertainties and quality flags.
- when comparable L2 product exist, check that retrieved quantities are broadly consistent.

Given the complexity of the EarthCARE ground segment, the preparation of the L2 verification has highlighted the importance of assigning a pragmatic priority to any problems discovered in the L2 products. This priority has to account for the expected effects of the problem on the downstream processors and products. Similarly, an efficient verification plan of the L2 products should consider the implementation of clear workflows (e.g. via a ticketing system) and efficient communication way between the L2 teams and with the Agency.

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.

More specifically, the absolute geolocation of the visible band of the MSI will firstly be verified with respect to a set of identified coastlines. In a second step, the co-registration of the other MSI spectral bands with respect to the visible band, will be performed by optimization of the inter-band correlation. The idea here is that a precise co-registration of the different MSI bands is crucial not only for the MSI L2a cloud and aerosol products but also for almost all the EarthCARE L2b synergy products. For the active instruments (ATLID and CPR), the coastlines will be used for the absolute geolocation, as for the MSI, but the analysis will be complemented by matching the instruments' returns with respect to a Digital Elevation Model. Different co-registration tests are also foreseen between the ATLID, CPR and MSI data. Concerning the BBR, the absolute geolocation will not be verified directly, but indirectly via co-registration of the 3 BBR views with the MSI. For these different geolocation and co-registration tests, software tools have been implemented to optimize the correlation in the along and across track directions. This should be sufficient to detect (and possibly correct in the Calibration and Characterisation Database) the most likely alignment problems, for instance due to instrument mis-pointing following the launch (vibrations, shocks). It is however possible that the instruments' pointings will be affected by more complex geolocation error, for instance due to thermo-elastic effects along the orbit. In this case dedicated analysis will be necessary.

Another example of synergy between the instruments that will be exploited during the commissioning is the generation of BBR-like short-wave and long-wave radiances from the MSI M-RGR product via a process called narrowband-to-broadband conversion. Comparing such BBR-like product with the actual BBR L1 file (or L2B BM-RAD file) is a efficient way to verify the accurate subtraction of the short-wave component in the total-wave channel of the BBR. The BBR-like data can also be used in the BBR/MSI co-registration.

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.

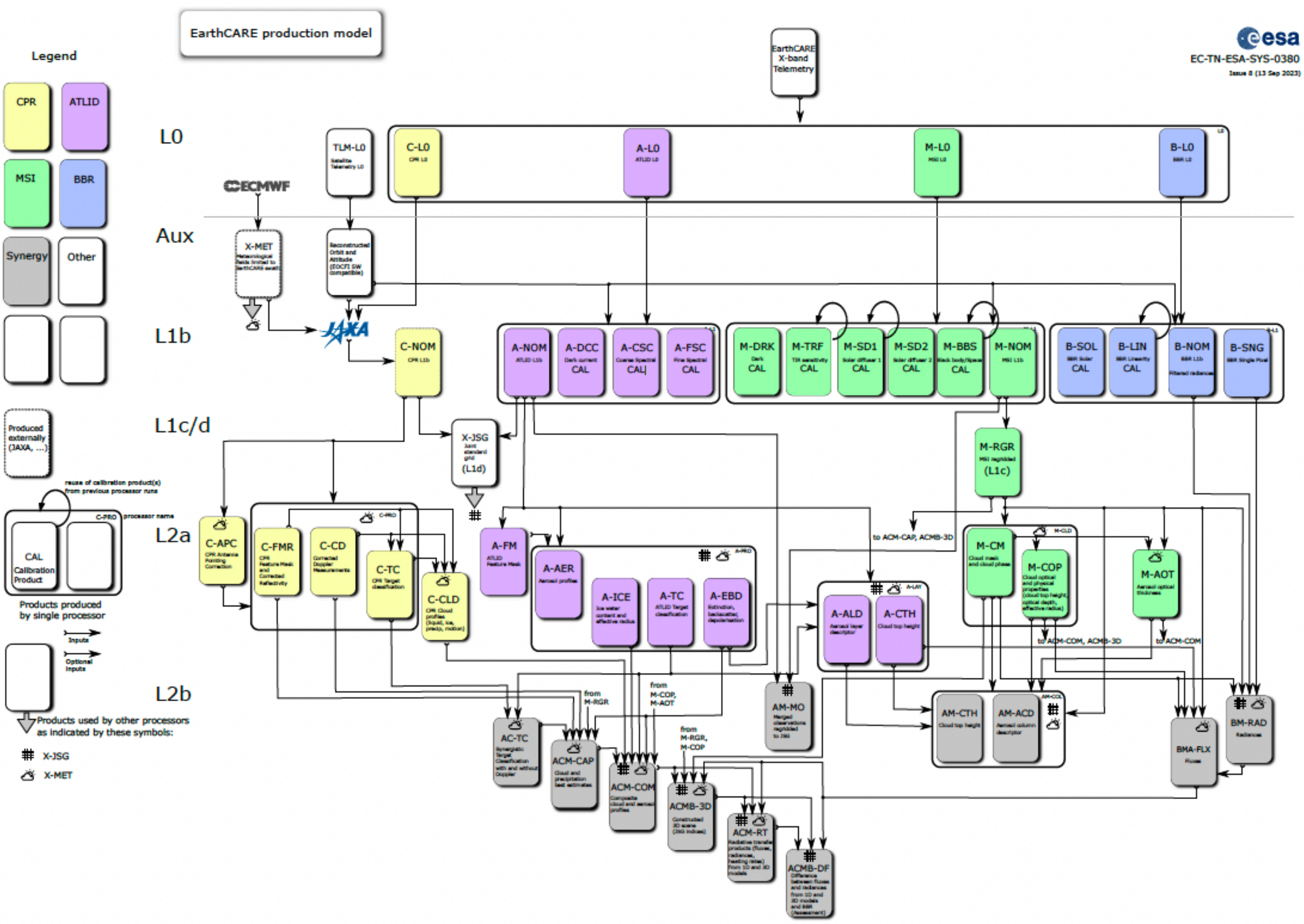

Figure 1: Production Model

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-6.] .

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.

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.

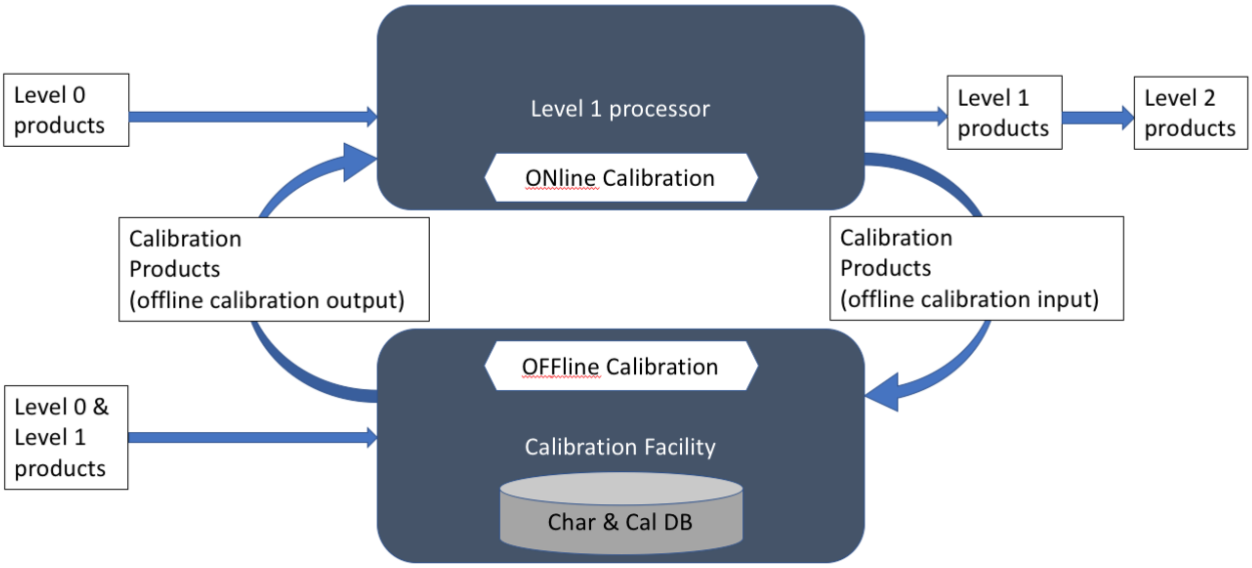

Figure 2: online and offline calibrations

2.4.3.1 ATLID offline calibration

For ATLID a complex set of offline calibrations has been defined. These calibrations can be divided into three groups: initial adjustments, routine operations, and drift. The calibrations within these groups roughly (but not completely) correspond to the operational modes of ATLID, and for some 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 will 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.

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 using a shutter 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 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.

2.4.5 Level 2a and 2b data processing and products

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 instruments 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.

Detailed description of the ESA L2 processor algorithms and products are published in the Atmospheric Measurement Techniques Special issue “EarthCARE Level 2 algorithms and data products” (https://amt.copernicus.org/articles/special_issue1156.html). Table 1 summarizes the content of the ESA L2 products in geophysical terms.

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.

Table 1: Geophysical parameters retrieved by L2 processors and the corresponding L2 products

	Cloud-top, vertically integrated and layerwise retrieval product			Vertical profiles at nadir	
	Quantity	**At nadir**	**Across-track**	**Quantity**	**Products**
Macrophysics	**Cloud-top height**	M-COP, A-CTH, *A-TC*, C-TC, AC-TC	M-COP, AM-CTH	**Cloud/precipitation fraction**	A-TC, C-TC, AC-TC
	Cloud-top phase & type	M-CM, A-TC, C-TC, AC-TC	M-CM, AM-CTH	**Cloud/precipitation classification**	A-TC, C-TC, AC-TC
	Aerosol layer height/depth	A-ALD, A-TC	AM-ACD	**Aerosol fraction**	A-TC, ACM-COM
	Aerosol layer classification	A-ALD, A-TC	AM-ACD	**Aerosol species**	A-TC, ACM-COM
Ice cloud & snow	**Optical thickness**	M-COP, A-EBD, ACM-CAP	M-COP	**Extinction**	A-EBD, ACM-COM, ACM-CAP
	Effective radius	M-COP, A-ICE, ACM-CAP	M-COP	**Effective radius**	A-ICE, ACM-COM ACM-CAP
	Water path	M-COP, A-ICE, C-CLD, ACM-CAP	M-COP	**Water content**	A-ICE, ACM-COM, ACM-CAP
	Surface snow rate	C-CLD, ACM-CAP		**Snow rate**	C-CLD, ACM-CAP
				Snow median diameter	C-CLD, ACM-CAP
				Extinction-to-backscatter ratio	A-EBD, ACM-CAP
Liquid cloud	**Optical thickness**	M-COP, A-EBD, ACM-CAP	M-COP	**Extinction**	A-EBD, ACM-COM, ACM-CAP
	Effective radius	M-COP, ACM-CAP	M-COP	**Effective radius**	ACM-COM, ACM-CAP
	Water path	M-COP, ACM-CAP	M-COP	**Water content**	C-CLD, ACM-COM, ACM-CAP
Rain	**Surface rain rate**	C-CLD, ACM-CAP		**Rain rate**	C-CLD, ACM-CAP
	Rain water path	C-CLD, ACM-CAP		**Rain water content**	C-CLD, ACM-CAP
				Median drop size	C-CLD, ACM-CAP
Aerosol (per species)	**Aerosol optical thickness**	M-AOT, A-ALD, A-AER, A-EBD, ACM-CAP	M-AOT, AM-ACD	**Aerosol extinction**	A-AER, A-EBD, ACM-COM, ACM-CAP
	Layer-mean extinction-to-backscatter ratio	A-ALD		**Extinction-to-backscatter ratio**	A-AER, A-EBD, ACM-CAP
	Layer-mean particle linear depolarisation ratio	A-ALD		**Particle linear depolarisation ratio**	A-AER, A-EBD
	Ångström exponent	M-AOT (670/865nm), AM-ACD (355/670nm)	M-AOT (670/865nm), AM-ACD (355/670nm)		
Radiation	Broadband radiances at TOA		BM-RAD, ACM-RT	Broadband radiances	ACM-RT
	Radiative fluxes at TOA		BMA-FLX, ACM-RT	Radiative fluxes	ACM-RT
				Heating rates	ACM-RT

2.5 ESA Product Validation Needs

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 overarching 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 mature 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 deemed 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. The same applies to the synergistically retrieved (Level 2b) products AM-CTH, AM-ACD, AC-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 products mentioned in the previous two paragraphs.

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

Specific needs for validation arise from uncertainties faced in L2 retrieval algorithms. Table 2 provides a compilation of these uncertainties, the affected L2 data products and how these uncertainties can be addressed by means of dedicated validation activities using ground-based, shipborne, and airborne measurements.

Table 2: Specific validation needs from the perspective of L2 retrieval algorithms

	Uncertainty	Locations/scenes/regimes	Correlative Measurements needed	Products
Macrophysics	Aerosol layer detection & classification	•Multiple aerosol layers •Aerosol layers with strong internal structure •Attributing aerosol plumes at nadir to features in the across-track imagery	•Ground-based (& scanning?) lidars •Collocated in-situ aerosol sampling	A-ALD, AM-ACD, A-TC
	Aerosol/cloud discrimination	•Cloud embedded in aerosol layers	•Ground-based lidars •Collocated in-situ aerosol sampling	A-ALD, AM-ACD, A-TC
	Cloud layer detection and structure	•Multiple cloud layers •Cirrus over liquid cloud •Non-precipitating liquid clouds	•Ground-based (& scanning?) lidars & radiometers	M-CLD, AM-CTH, A-TC, C-TC, AC-TC
	Liquid clouds not fully resolved by radar/lidar synergy	•Physical depth of liquid clouds (i.e. cloud base height) •Mixed-phase layers embedded in ice •Liquid (& liquid-topped mixed-phase) clouds below optically thick ice clouds •Warm liquid clouds within cold rain	•Ground-based ceilometers/lidars •Multiple-frequency radars to constrain W-band attenuation •Microwave radiometers for LWP •Aircraft profiles of LWC	A-TC, C-TC, AC-TC
	CPR surface clutter removal	•Range of surface types	•Ground-based radars	C-TC, C-FMR
Ice cloud & snow	Snow microphysics (e.g. PSDs, microwave scattering, density & fallspeed)	•Stratiform vs convective •Rimed snow	•Bulk precipitation and particle imaging measurements at surface •Profiles of in-situ particle properties in ice clouds	C-CLD, ACM-CAP
	Ice microphysics (e.g. PSDs, ice optics, mass-size rel'n)	•Cloud-tops across range of temperatures, locations & cloud types	•In situ aircraft measurements •Visible & IR radiances	A-ICE, ACM-CAP
	Surface snow rate	•Range of meteorological conditions	•Ground-based radars and in-situ at surface	C-CLD, ACM-CAP
Liquid cloud	How to account for radiatively-important liquid clouds not detected by ATLID	•Deep ice clouds: embedded mixed-phase layers •Layered cloud scenes •Warm liquid clouds within cold rain	•Microwave radiometer for LWP •Profiles of liquid water content	ACM-CAP
Rain	Relation between rain rate and drop size distribution	•Warm rain (maritime) •Convective/stratiform rain	•Ground-based multiple-frequency radars •Dual-pol weather radars over ocean	C-CLD, ACM-CAP
	Melting layer structure & radar attenuation	•Dependence on snow properties aloft •Continuity of mass flux & size distributions across melting layer	•Ground-based & airborne multiple-frequency radar	C-CLD, ACM-CAP
Aerosol	Large AOT uncertainties over land; sensitivity to aerosol classification	•Range of different land classes (biomes) & ocean •Range of different aerosol classes	•Ground-based, e.g. AERONET(-OC) •Ship-based sun photometers, e.g. MAN •Satellite imagers, e.g. MODIS, VIIRS, 3MI	M-AOT
Radiation	Detection of and/or representation of fluxes over snow-covered surfaces	•Range of snow-covered surfaces	•High-latitude ground stations	BM-RAD, BMA-FLX

2.6 Validation Approaches and Common Practice Convergence

The validation of the geophysical variables related to aerosols, clouds, and precipitation obtained from space-borne profilers present unique challenges due to differences in the available instrumentation, the sampling strategies and scenarios, and the comparison methodologies. To meet these challenges, with ESA support, scientists from the international community involved in past and ongoing Earth Observation missions have collaborated to document their validation experience, lessons learned, and expertise on various aspects, such as

- correlative site and instrument selection,
- data processing and quality control,
- criteria for targeted Cal/Val campaigns,
- the configurations, scenarios, and collocation methods,
- methodologies on the comparisons between satellite observations with the reference measurements or assimilated datasets.

Apart from the common practices for the validation of the aerosols, cloud, and precipitation observations from spaceborne high-resolution profilers, the document also addresses lessons learned and identifies areas where convergence on the different approaches is beneficial. In addition, the statistical relevance of the comparisons, guidelines, and recommendations for inter-calibration between networks are thoroughly discussed.

The content of the document is as follows

- a generic introduction (Chapter 1)
- a description of the available products from the past, current, and future missions for aerosol, cloud, and precipitation profiling (Chapter 2),
- a description of available instruments and networks that are (or recently have been) available for correlative data collection along with challenges related to the data usage, provision, and formats (Chapter 3)
- a discussion on the considerations for correlative metadata and the FAIR data principles (Chapter 4),
- guidance for performing validation exercises using reference measurements for lidar/aerosol products (Chapter 5) and for radar/cloud/precipitation products (Chapter 6)
- a description of the use of statistical validation approaches (Chapter 7)
- monitoring numerical model methods via data assimilation (Chapter 8),
- gaps and challenges related to the validation of space profilers for aerosol, cloud, and precipitation that have been identified during the preparation of the document (Chapter 9).

The first draft of the best practice document was released in February 2024 for review, which is followed by revisions and delivery to the Committee on Earth Observation Satellites (CEOS) foreseen for the second quarter of 2024. Once endorsed, it will be available at https://calvalportal.ceos.org/methods-guidelines-good-practices .

2.7 EarthCARE Validation Coordination

This section describes the interfaces between the ESA EarthCARE Validation Team (ECVT; see Vol 1), ESA, teams and instrument and algorithm experts.

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 includes:

- 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.

A joint pre-launch workshop to foster scientific interaction has been organized at ESRIN, Frascati, Italy in the week 13-17 November 2023 (see 2.8.1.1).

2.7.2 ECVT 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.

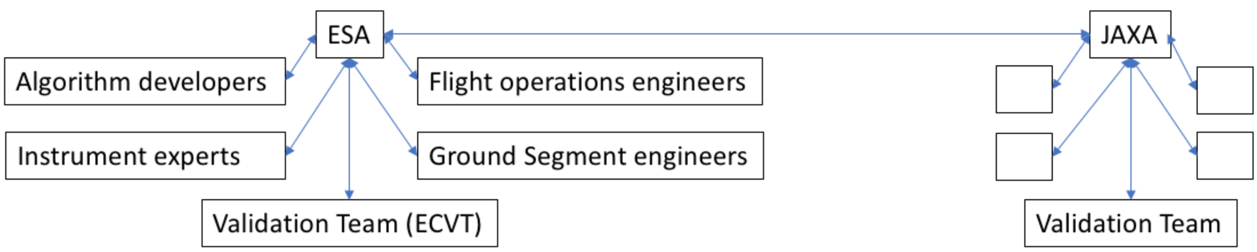

Figure 3: Interactions between ESA and JAXA for validation coordination

In order to foster collaboration and efficient exchanges between scientists working on similar domains, the ECVT is organised to several topical subgroups (). Each subgroup has at least one ESA coordinator. For the Data Analysis subgroups there is at least one scientific coordinator. Principal Investigators/PIs of the EarthCARE Validation Team can have representation (Co-Investigators/Co-Is) in multiple subgroups. Members of ECVT (Principal Investigators and Co-Invetigators) will be invited to interact among themselves and with the subgroup leaders primarily in the “Collaboration” zone in the interactive ECVT portal and in ECVT discussion forum (see 2.13.1).

Table 3: ECVT structure

Theme	Subgroup	Subgroup leaders
Data Acquisition	**Campaigns**	Jonas von Bismarck (ESA)
	Networks	Jonas von Bismarck (ESA)
Data Analysis	**ATLID L1**	Holger Baars (TROPOS) Fabien Marnas (ESA) Michael Eisinger (ESA)
	MSI L1 and Radiation (includes BBRL1)	Almudena Velazquez (RMIB) Nicolas Clerbaux (RMIB) Olivier Defauchy (ESA)
	Clouds and Precipitation (includes CPRL2A)	Eleni Marinou (NOA) – acting: Kelly Voudouri (NOA) Vasileios Tzallas (ESA)
	Aerosol	Holger Baars (TROPOS) Timon Hummel (ESA)

2.8 ESA Schedule

Table 4: Timeline of ESA validation activities

Validation Plan 1.0	Jan 2021
2nd ESA Validation Workshop (2.8.1.1)	May 2021
Funding convergence	2021-2024
Development of Methods and tools (2.8.1.2)	2021-2024
ESA EarthCARE webinar series (2.8.1.1)	Jun-Sep 2023
ESA-JAXA pre-launch science and validation workshop (2.8.1.1)	Nov 2023
Validation Rehearsal (2.8.1.3)	Feb 2024
Rehearsal/Validation Readiness Review (2.8.1.4)	Mar 2024
Validation Plan 2.0	May 2024
Launch	May 2024
Preliminary Validation Results Review part 1 (2.8.2.4)	Dec 2024
Long-term Validation Phase (2.8.2.5)	Dec 2024->
Preliminary Validation Results Review part 2 (2.8.2.5)	Mar 2025
Preliminary Validation Results Review part 2 (2.8.2.5)	Dec 2025

2.8.1 Pre-launch Activities

2.8.1.1 Workshops and webinars

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

The second validation workshop was held online in May 2021. The objective of this workshop was 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. Many recommendations from the workshop came down to the need of convergence on validation best practices (see section 2.6). The workshop report is available on https://earthcare-val.esa.int/display/EEVP/2nd+ESA+EarthCARE+Validation+Workshop

In June and September 2023, ESA organized a series of webinars to inform ECVT about EarthCARE data products and infrastructure/tools/services (sections 2.4.2, 2.4.5 and 2.13) prepared to facilitate validation activities. The webinar series included presentations from algorithm/tool developers, service providers, and facility operators, covering the following topics:

- L1 processing and products
- L1 suborbital-to-orbital conversion tool
- ESA L2 processing and products
- Orbit and swath tools
- ESA Atmospheric Validation Data Center
- EarthCARE data discovery and dissemination facility
- Tools for intercomparison/validation analysis

During each webinar, there were ample opportunities for questions and discussions. To ensure that the webinars will be accessible also to future ECVT members, the presentations were recorded. All webinar materials (slides, recordings, Q&A summaries) have been collected and made available to ECVT members in the restricted validation portal (section 2.13.1).

The last workshop in the pre-launch phase is a joint ESA-JAXA Pre-launch science and validation workshop in November 2023. The workshop was held at ESRIN, Frascati. The objective of this joint workshop was to foster scientific exchange between members of the ESA and JAXA validation teams and also the ESA and JAXA algorithm teams. The oral and poster presentations were published on the workshop website https://www.earthcare-science-validation-2023.org. A report of the validation sessions of the workshop is also available on that website.

2.8.1.2 Developments of methods and tools

Prior to the validation rehearsal, the validation teams were expected 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.

During the validation rehearsal (2.8.1.3), the validation teams performed intercomparison using their own dedicated tools and the results were shown at the rehearsal review meeting (2.8.1.4) that followed. The convergence of methodologies has been achieved through the international effort that documents validation common practices (section 2.6).

2.8.1.3 Validation Rehearsal

Validation rehearsal was carried out in a two-week period 12-23 February 2024. For this event, ESA prepared a set of simulated EarthCARE data that covered 1 full repeat cycle and was generated using the latest processor version at the time. The data were placed on the dissemination system that ECVT members will use in the EarthCARE operational phase. To guide PIs and coIs in finding overpass opportunities, EarthCARE orbit files, orbit tools, and overpass tables were provided. During the rehearsal, ECVT members were invited to familiarize themselves to various validation support functions (section 2.11) and rehearse the entire validation workflow. The full workflow includes planning and execution of correlative measurements, EarthCARE data discovery and download, discovery and upload of GEOMS-compliant correlative data to ESA Atmospheric Validation Data Center (EVDC), ingestion and intercomparison of EarthCARE against correlative intercomparison using dedicated tools (see 2.8.1.2). Apart from the primary dissemination system for EarthCARE data, all other facilities continue to be available after the rehearsal, allowing PIs and coIs to continue using them beyond the 2-week period. At the end of the rehearsal activities, ECVT members were requested to fill out rehearsal questionnaire meant to inform validation facility operator of user feedback.

2.8.1.4 Validation Rehearsal and Readiness review

The simulated analysis findings are to be exchanged within the EarthCARE Calibration and Validation Team and any difficulties encountered are to be reported to ESA in the context of the Validation Rehearsal and Readiness Review. For this purpose, all rehearsal participants were invited to a review meeting that was held online on 21 March 2024.

Rehearsal participants included not only PIs and co-Is, but also algorithm developers, providers and operators of validation facilities and support functions. PIs and coIs that represent 70% of the validation teams followed the rehearsal and presented their rehearsal findings and feedback at the meeting. Some feedback from PIs and Co-Is were communicated already in the rehearsal questionnaire for the facility providers/operators to address during the meeting. In general, there was no blocking issues found for the operational implementation of validation workflow. There was however some room for improvement on certain aspects, which were noted and will be addressed as much as possible prior to EarthCARE launch.

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 EarthCARE validation portal (see 2.13.1), 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 2.13.1). In addition, each PI will present his/her Commissioning-Phase findings at the Preliminary Validation Results Workshop part 1 (online at L+6) and on a best-effort basis at *ad hoc* meetings.

2.8.2.4 ESA-JAXA Validation workshop part 1

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. According to the current plan, the second and third parts of Preliminary Validation Results Workshop will be held at L+9 in Europe and L+18 in Japan.

2.9 ESA Validation Plans per AO project

The activities of the ESA validation have been solicited by an Announcement of Opportunity (AO) 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) . Since 2018, several more proposals for EarthCARE validation have been received, reviewed, and accepted. The following sections provide top-level meta-data and a brief textual summary of the projects proposed and accepted, the coverage of validation activities in terms of instrument types, geographical regions, and geophysical parameters.

2.9.1 Summary of validation proposals

At the time of writing, there are 40 projects resulting from accepted Announcement of Opportunity proposals. In this section, the metadata and the summary of the projects are presented.

1. EVID01 (AOID 37730)

Title	EarthCARE BBR L1 and L2 Products Assessment
PI Name	Nicolas Clerbaux
PI institution	Royal Meteorological Institute of Belgium

Project summary:

BRR instrument performance and product quality will be thoroughly assessed by a series of validation activities. These will establish the quality of the level 1 instrument radiances at both the nominal 10x10km2 spatially integrated scale (B-NOM) and at detector level (B-SNG). Assessment will address spatial and radiometric accuracy, consistency, stability, noise and anomalous behaviour. Both level 1 and level 2 product assessment will use Earth reference targets including deep convective clouds and coastlines and co-incident MSI observations to inform the analysis. The evaluation of the level 2 products (BM-RAD and BMA-FLX) will also involve comparisons against independent broadband measurements from CERES, GERB or ScaRaB. Level 2 evaluation will provide assessment of both the level 2 processing and the quality of the underlying level 1 data.

The 18-month pre-launch period will be used to develop tools and techniques and to plan data acquisition. This will build on the expertise of the partners in calibration /validation of the GERB, CERES and ScaRaB instruments, adapting existing tools and techniques and developing new ones where needed. An “EarthCARE Validation Plan” detailing the proposed validation studies will be delivered 4 months before launch at the Cal/Val Readiness Review.

Assessment during the 6 months commissioning phase will put primary focus on the level 1 data to establish basic data integrity, noise characteristics, gain stability and the effect of chopper drum speed on the science products. Results will inform discussions on the optimum operating configuration and provide recommendations for the lifetime of the mission. A preliminary BBR validation report will document the results for the Commissioning Phase review.

Over the 3 year mission, products will be further evaluated and monitored, with changes to instrument response regularly assessed. Dedicated analysis of level 2 products may result in recommendations for updates to the level 2 processing (e.g. BBR radiance unfiltering or radiance to flux conversions). All findings will be consolidated in a BBR validation report provided to ESA at end of the project, 3 years after commissioning.

The team has extensive expertise in calibration/validation and operation of broadband radiometer instruments and access to existing tools which will support the planned validation studies. The proposed work outline is written with the expectation of being able to secure national and institutional funding if this proposal is accepted. However, as many of the proposed activities are complementary to ongoing programs in which we are involved a proportion of the work will be supported by existing resources within these programs and can be carried out even in the absence of this additional resource.

2. EVID03 (AOID 38188)

Title	German Initiative for the Validation of EarthCARE (GIVE)
PI Name	Ulla Wandinger
PI institution	Leibniz Institute for Tropospheric Research TROPOS

Project summary:

The German Initiative for the Validation of EarthCARE (GIVE) aims at the validation of the entire chain of EarthCARE L1 and L2 products as well as the evaluation of related algorithms and instrument calibrations. The approaches include EarthCARE-to-ground, EarthCARE-to-aircraft and EarthCARE-to-satellite comparisons, supported by cloud, aerosol and radiative-transfer modelling. Validation activities will include dedicated campaigns as well as long-term support over the mission lifetime. The Cal/Val activities make use of a number of opportunities emerging from planned campaigns, in particular airborne experiments with the German HALO during PERCUSION in the tropical Atlantic in 2024 and HALO-South in the Southern Ocean in 2025. For the first campaign, the HALO will be equipped with an EarthCARE-like payload (radar, lidar, radiometer and spectrometer), whereas for the second campaign, an extended in-situ instrumentation is planned. Direct underpasses beneath the EarthCARE track will be performed during the campaigns.

Long-term support of the EarthCARE mission is planned through a number of German ground-based facilities with aerosol and/or cloud remote sensing instrumentation. Four sites in Germany (Juelich, Melpitz, Lindenberg and Munich), the Barbados Cloud Observatory, stations in Cabo Verde, Cyprus, and Tajikistan, and the mobile aerosol and cloud observation facilities LACROS and OCEANET will contribute to these activities.

Cross-satellite validation activities will enable the global assessment of EarthCARE products. These experiments will make use of data from SEVIRI, FCI, MODIS, OLCI, SLSTR, AVHRR and other sensors to validate EarthCARE aerosol, cloud and radiation flux products. In-house developments of German partners, e.g., regarding ice water path retrievals or specific co-location procedures, will allow for unique validation options involving independent satellite observations.

It is envisaged to synergistically explore ground-based, airborne and satellite-based measurements in order to validate the EarthCARE product chain and the radiation closure concept as a whole. These activities will be supported by aerosol, cloud and radiation modelling aiming at the connection of observations and the investigation of spatial and temporal variances of the measured parameters.

All obtained data, results and findings will be made available to ESA as soon as possible. Near-real-time data provision is planned for all continuously running facilities. Regular reporting, discussion of results with the EarthCARE Cal/Val team, active participation in Cal/Val workshops, presentations at conferences and publication of results in peer-reviewed journals are assured by the team.

The team is composed of well-experienced scientists from 10 German institutions with expertise in satellite, airborne and ground-based remote sensing as well as cloud, aerosol and radiation modelling. Several team members are involved in EarthCARE Level 2 algorithm developments.

3. EVID04 (AOID 38623)

Title	SPACECARE (Study of Precipitation in the AntarctiC with EarthCARE)
PI Name	Christophe Genthon
PI institution	The National Centre for Scientific Research (CNRS), France

Project summary:

SPACECARE (Study of Precipitation in the AntarctiC with EarthCARE) will evaluate EathCARE's level 2 precipitation products in Antarctica. There are very few places in Antarctica where precipitation is continuously measured. This is because Antarctica is a very sparsely populated continent and because difficult logistics and extreme conditions strongly limit the operation of any instrument. On the top of that, the classic instruments (capture gauges) fail in the interior of the continent because the precipitation rates are extremely small and at the periphery because of very strong winds and blowing snow. Alternate less traditional methods must be used. To our knowledge, the longest continuous consistent series of snowfall observation in Antarctica is obtained at Dumont dUrville (DDU) station in coastal Adelie Land. This is obtained with a K-band vertically profiling radar which was scaled and calibrated during an intensive observation campaign in the austral summer 2015-16 using a combination of other instruments including a Xband dual polarization scanning radar, The K-band radar has been continuously operated since and is expected to continue operation after EarthCARE is launched and begins producing data. As precipitation is stratiform rather than convective, observation at DDU has large spatial significance. The 1st order comparison between the surface and space observations when the satellite overflies close enough to DDU will be straightforward, as both surface and space radars provide post-processed data of direct estimates of precipitation rates: the priority request to ESA for this project is the CPR L2a precipitation rates (C-TC, C-CLD, ACM-CAP) estimates over Antarctica. Further, more detailed comparison will address vertical profiles of reflectivity and estimates of aerometeors characteristics as the surface radar profiles to 3000 m, expecting a fair intersection with the surface part of EarthCARE CPR soundings high enough

to be unaffected by ground clutter. If data are granted, support for the project will be seeked from the French polar institute IPEV (extension and reconfiguration of current ongoing IPEV 1143 Antarctic Precipitation, Remote Sensing from Surface and Space (APRES3) project to continue the monitoring of precipitation) for logistical support, the French space agency CNES and Swiss EPFL for funds and other supports. France (Institut des Géosciences de l'Environnnement, Grenoble) and Switzerland (Laboratoire de Télédétection Environnementale, Lausanne) are already collaborating within the APRES3 project and have provided the 1st evidence that precipitation in Antarctica is even more complex than initially thought because a significant part re-evaporates in a dry surface air layer before reaching the ground. As a major issue with antarctic precipitation is that it feeds the ice sheet and any change in the future will affect the ice mass stored and thus global sea-level, accurately assessing and monitoring Antarctic precipitation down to the surface is a crucial issue. As other satellites do not have the right sensors or do not overfly Antarctica, CloudSat with the CPR has provided the 1st model independent climatology of Antarctic precipitation over he largest part of the ice sheet (to 82°S), with the limit that ground clutter (the blind zone) prevents seeing the evaporation layer. As CloudSat is failing, it is essential that EarthCARE's CPR takes over and is thus quickly evaluated over Antarctica, and in particular the evaporation layer assessed, using in situ observations. This is the main objective of the program. In order to evaluate the full chain of events leading to precipitation, it is also planned to use synergetic A-TRAIN DARDAR products (developed at LATMOS, Paris, France) to evaluate cloud properties from AC-TC product. The AWACA radars will start doing measurements by late 2024.

4. EVID05 (AOID 38644)

Title	ACTRIS for EarthCare L2 product evaluation (AECARE)
PI Name	Holger Baars
PI institution	Leibniz Institute for Tropospheric Research TROPOS
Project summary: Objective This proposal focuses on assessment of the validation and representativity of EarthCARE observations of aerosol and cloud products using pan-European ground-based observations from ACTRIS stations with aerosol and cloud profiling capabilities plus associated EARLINET and Cloudnet stations. According to the current status, the main focus will be the provision of correlative data to EVDC. Limited data analysis might be performed in the frame of ATMO-ACCESS. Methods In this Cal/Val activity, all observatories participating in ACTRIS profiling, EARLINET, Cloudnet and ATMO-ACCESS pilot are considered. The proposed work in AECARE is aimed at the long-term validation of the EarthCARE L2 data products through building a long-term collocated database from ground-based	

observations at ACTRIS stations. The aerosol and cloud measurements made at ACTRIS sites are particularly suited for this purpose, since very similar techniques are being used at the ground and from space (i.e., quantitative aerosol lidar, cloud radar). Therefore, the data products can often be compared directly, and auxiliary and redundant ACTRIS observations from the ground serve to further clarify differences. Furthermore, the distribution of ACTRIS stations over Europe (and in addition a number of ACTRIS stations in overseas areas), the harmonised processing, and the common data formats make the ACTRIS research infrastructure particularly suited for EarthCARE validation.

A coordinated EarthCARE Cal/Val preparation in the framework of the ATMO-ACCESS pilot activities for internal stakeholders has been carried out by ACTRIS facilities and stations, including associated EARLINET and Cloudnet stations, leading to 'validation readiness' already prior to launch (see also section 2.10.3.1). Thus, correlative measurements can immediately delivered once EarthCARE is measuring in orbit!

Noting that the EarthCARE ground track is likely to pass the closest ground-based stations at distances that can increase up to tens of kilometres, which are large compared to the (in-)homogeneity of aerosol and cloud structures, representativity in space and time is an issue to be considered in the validation. This will be addressed through clustering of ACTRIS stations and comparison of statistics of aerosol and cloud observations.

AECARE will validate EarthCARE L2 products by

1. Comparison of EarthCARE and ACTRIS aerosol and cloud profiles using observations from close proximity overpasses. Observations at ACTRIS stations that are not running continuously will be triggered by an alerting system based on predicted EarthCARE ground tracks.

2. Comparison of synergistic EarthCARE products by comparing them to similar products build up from ground-based observations at ACTRIS stations.

The work proposed in AECARE will consider the broadest range of atmospheric conditions realistically possible, e.g. from clear-sky up to overcast and multi-layered clouds. Although direct validation of products will not be possible under all atmospheric conditions, the added value in this approach is that the EarthCARE observations suffer from similar limitations as those from the ground. Therefore, the resulting cloud and aerosol (typing) masks, should be studied to understand their representativeness - for the atmospheric state observed - and usability with relation to these specific atmospheric conditions. The analysis on any significant anomalous discrepancies between the ground-based observations and the corresponding EarthCARE products will be facilitated by the AECARE-teams in-depth knowledge of the EarthCARE algorithms and the ability to use the EarthCARE simulator in order to test hypothesis related to the causes of the observed differences (e.g. instrument calibration issues or specific algorithm issues). AECARE is the overall contribution of ACTRIS and associated partners to the EarthCARE validation to the AO call focussing on delivering of correlative measurements in near-real time. Since national funding is needed to execute the activities, additional AO proposals have been and will be put in place that are aligned or partially overlapping with AECARE from various countries or individual research groups that are member of ACTRIS.

Deliverables

• Long-term data set of ground based observations of clouds and aerosols from selected clusters of ACTRIS stations based on observing capabilities, geographical coverage and clustering of stations (see detailed description) suitable for direct comparison and representativity studies of EarthCARE L2 products (e.g. aerosol backscatter, aerosol extinction, aerosol lidar ratio, cloud geometrical parameters and geophysical parameters, e.g., LWP, LWC, IWC). • Evaluation reports

5. EVID06 (AOID 38709)

Title	Evaluation of EarthCARE Radiances and Fluxes with CERES Data Products
PI Name	Norman Loeb
PI institution	NASA Langley Research Center

Project summary:

The work proposed here is based upon the assumption that when EarthCARE instruments start taking measurements, at least one of the Clouds and the Earth's Radiant Energy System (CERES) instruments on Aqua, S-NPP and JPSS-1 is operational. The proposed work consists of four parts,

1) evaluation of broadband radiances observed by the BBR instrument with co-located broadband radiances observed by CERES instruments,

2) evaluation of broadband top-of-atmosphere (TOA) fluxes derived from BBR radiance observations with co-located CERES- and geostationary-derived TOA fluxes,

3) evaluation of EarthCARE computed TOA and surface fluxes with fluxes derived from CERES algorithms and surface observations, and

4) evaluation of EarthCARE cloud properties with cloud properties derived from Moderate Resolution Imaging Spectroradiometer (MODIS) and geostationary satellites with the CERES cloud algorithm, and evaluation of other input variables such as surface albedos and temperature and humidity profiles used in flux computations.

The first part directly addresses the calibration of the BBR instrument relative to calibration of CERES instruments. The second part of the proposal examines how angular distribution model differences lead to TOA flux differences. Because EarthCARE uses shortwave and longwave angular distribution models that differ from those used by CERES, TOA flux differences will likely significantly exceed instrument calibration differences.

The third part compares computed TOA fluxes derived from the EarthCARE and CERES algorithms. In addition, downward shortwave and longwave surface fluxes derived from the EarthCARE algorithm will be compared with surface observations. Currently, forty-six buoys and thirty-six land observation sites are used for evaluation of CERES surface fluxes.

In part four, the computed TOA and surface flux differences between EarthCARE and CERES will be evaluated in the context of how the inputs used by both groups compare with one another. These include: cloud properties, surface albedos, surface emissivities, and

temperature and specific humidity profiles. Input comparisons are needed in order to understand the causes of TOA and surface flux differences. The above four proposed activities also provide an opportunity to evaluate the CERES radiance and flux products. The radiance comparisons provide an independent check on CERES calibration. Because BBR provides broadband radiances at three different angles from the same geolocation over its ground track, BBR observations are unique and provide an ideal dataset to test CERES angular distribution models. In addition, BBR-derived TOA fluxes provide an evaluation of TOA fluxes inferred from geostationary satellite imagers using narrowband to broadband conversions. Comparisons of surface fluxes and inputs used for flux computations also enable evaluation of CERES surface fluxes and inputs. Because the EarthCARE overpass time (2 pm daytime) is different from the Aqua and S-NPP overpass times, the comparisons enable evaluation of cloud properties and surface fluxes derived from geostationary satellite imagers as well as MODIS and VIIRS. Furthermore, the computed surface flux comparisons provide the evaluation of surface fluxes over polar regions where surface observations are scarce.

6. EVID07 (AOID 38757)

Title	LALINET EARTHCARE CAL/VAL
PI Name	Eduardo Landulfo
PI institution	Instituto de Pesquisas Energéticas e Nucleares (IPEN), Brazil
Project summary: LALINET is a leading network in quantitative aerosol profiling performing a schedule of routine measurements and presently consists of 09 stations distributed over South America. The construction of an un-biased spatio-temporal database of vertical profiles of aerosol optical properties on a regional scale for climate and air quality research is the main objective of LALINET and is accomplished by the application of Raman lidars. Raman lidars, like HSRL, are capable of providing vertically resolved aerosol and cloud backscatter and extinction profiles as well as the lidar ratio without critical assumptions. The perspectives from space observations and ground based measurements are complementary: from space a global overview is obtained, built up from snap-shot like observations over different locations, while a temporal development over one place is obtained from a ground based station. A network of ground-based stations, therefore, has the ability to provide spatio-temporal development of aerosol fields and offers a unique opportunity for validation of observations from space. These notions are the basis for this proposal. The main objectives of this proposal are: 1) Validation of EARTHCARE products of aerosol and cloud profiles of backscatter, extinction and lidar-ratio,	

2) Assessment of spatio-temporal representativeness of EarthCare aerosol and cloud products.

The objectives will be accomplished through correlation between ground based lidar data from LALINET stations. For this, data will be used from:

1) The (historical) LALINET database,

2) Correlative measurements performed by selected LALINET stations during close proximity EarthCare overpasses. LALINET stations perform regular lidar measurements simultaneously at three fixed instances a week, guaranteeing unbiased data collection: one daytime measurement around noon, when the boundary layer is well developed, and two night-time measurements per week, in low background-light conditions, to perform Raman extinction measurements. Since the launch of CALIPSO in April 2006, LALINET maintains a correlative measurement schedule that takes advantage of the network structure. This is done so that close overpasses are captured by a particular station and also by its nearest-neighbour stations to capture the spatio-temporal variability. It is proposed to use a similar strategy for the validation of EarthCare. Deliverables are:

1) Vertical profiles of aerosol optical properties (backscatter, extinction and lidar ratio) obtained from routine network observations,

2) Vertical profiles of aerosol optical properties obtained from correlative observations.

3) Report The routine LALINET measurement programme is run on National/Institutional funding obtained by the individual partners and is secured by individual stations. Since most of the LALINET lidar instruments cannot measure unattended, substantial effort is involved in special and additional/correlative measurements, for which additional funding is needed. National/international agencies will be approached to cover these costs.

7. EVID08 (AOID 38768)

Title	Validation of EarthCARE level2 radar products in high-latitude and Arctic climates
PI Name	Dmitri Moisseev
PI institution	University of Helsinki

Project summary:

The current project is aiming to carry out ground validation of level 2 CPR products using Finnish cloud profiling stations located in Hyytiälä (61°51´N, 24°17´E) and Pallas-Sodankylä (67°58'N, 24°07'E). The stations are part of the national and European Aerosols, Clouds, and Trace gases. Research Infrastructures (ACTRIS). The cloud profiling part of the infrastructure include W- and Ka- band cloud radars, humidity and temperature profiling radiometer, Doppler lidar and ceilometers. In addition to the cloud profiling capabilities, comprehensive measurements of precipitation, both frozen and liquid, are carried out at the Hyytiälä station. This station is also part of NASA Global Precipitation Measurement Mission ground validation network.

8. EVID09 (AOID 38809)

Title	Balloon Aerosols Instruments for the Validation of EarthCare (BAIVEC)
PI Name	Jean-Baptiste Renard
PI institution	LPC2E-CNRS, France

Project summary:
We propose to validate EarthCare extinction profiles, using suitable during good temporal and spatial coincidence between spaceborne measurements and balloon-borne measurements. These measurements will be obtained during two already existing/planned balloon campaigns: LOAC-Voltaire and Strateole 2. The balloon-borne instruments are aerosols counters, backscatter sonde and lidar.

The LOAC-Voltaire campaign consists of regular flights under weather balloons up to an altitude of about 30 km, with the light optical particle counter (OPL) LOAC (Light Optical Aerosol Counter), launched at mid-latitude from Aire sur l'Adour, south-west of France (43.706242°N, - 0.251423°E). These flights, conducted by the French space Agency CNES, are mainly dedicated to the monitoring of the aerosol loading in the upper troposphere and stratosphere, but measurements are also available in the lower troposphere. LOAC is a light and compact optical counter/sizer designed to perform measurements of liquid and solid particles, to retrieve the vertical profiles of the concentrations for 19 size classes between 0.2 and 100 micrometers, and to estimate the main nature of the particles (liquid, salt, mineral, carbonaceous particles, ice particles) when the medium is relatively homogeneous. Since weather balloons are easy to launch, we propose to adapt the date and the time of the LOAC-Voltaire campaign launches to ensure a very good coincidence with the EarthCARE measurements. The criterion could be a time difference less than 1 hour and a location difference less than 50 km between the launching base of Aire sur l'Adour and the satellite measurement. Flight opportunities can be foreseen from CNES zero-pressure balloon launching bases (Timmins in Canada and Kiruna in Northern Sweden), in case of better coincidences with the satellite or specific geophysical events (e.g. presence of polar stratospheric clouds). Also, occasional flights from Orléans and Ury (near Paris) would be managed by LPC2E and the MeteoModem private company.

Strateole 2is an international scientific project (France, USA). Its primary objective is to provide observations of the equatorial upper troposphere and lower stratosphere (UTLS), i.e. between 16 and 20 km of altitude, to better understand dynamical and transport processes in this region. The uniqueness of the project comes from the use of stratospheric balloons developed by CNES (called superpressure balloons), which are able to fly for several months at targeted altitudes.

During the campaigns, each balloon will be carried by the winds and circumnavigate the Earth a few times close to the Equator. Strateole includes two major campaigns in boreal winters 2020- 2021 and 2023-2024, with 20 balloons in each of those campaigns. These campaigns will be preceded by a smaller 5-balloon campaign in late 2018. Strateole contribution to EarthCARE cal/val activities will be mostly based on the use of in-situ, high-accuracy pressure and temperature sensors, flight-level aerosol counters, backscatter sonde, and backscattering lidar.

Based on former long-duration balloon trajectories in the tropics and current characteristics of EarthCARE orbit, the estimated number of precise and statistical colocations are of the order of ~101102 and ~104105 per balloon and per month.

9. EVID10 (AOID 38810)

Title	MORECALVAL : MObile Radar-Lidar-Radiometer EarthCare CAL/VAL project
PI Name	Julien Delanoë
PI institution	LATMOS, France

Project summary:

Mobile platforms are ideal to complete the fixed ground-based systems allowing direct satellite underpasses. Fixed devices can provide a large statistic over one location for months or even years but it requires a statistical approach as the polar orbiting satellite will rarely fly exactly above the site. On the other hand, mobile facilities allow direct comparisons with satellite measurements. Even for a short period (a few minutes), it is a unique manner to directly compare radar and lidar measurements. Mobile facilities are indeed very useful for processes and case studies and therefore widely involved in scientific campaigns with most of the time similar objectives to EarthCare. As a result, it is envisioned here to propose to use these opportunity campaigns to contribute to the calibration (similar payload to EarthCare or even more sensitive instruments) and the validation of the EarthCare products (through a combination of multiwavelength instruments and in-situ data). We will cover a large variety of EarthCare products with this combination of measurements and the capability to explore different locations. We will focus on several field campaigns (PRE-MAESTRO, MAESTRO, PERCUSSION, BACCOPA, NAWDIC) but we will make the most of any other campaigns.

German and French aircraft, respectively HALO and French ATR42 have very complementary payloads and are perfectly designed for the calibration and the validation of EarthCare. Airborne instruments are generally working at higher resolution (vertical and horizontal). In many cases these direct underpasses have been very valuable for assessing CloudSat and CALIPSO data for years. The Team is very experienced in conducting field campaigns all over the world with a clear ability to perform successful under flights. These aircraft board a high spectral resolution lidar (355nm on the ATR42 and 532 nm on the HALO), a very powerful Doppler radar at 36 GHz (HALO) and two multi beam 95 GHz radars (ATR42) and in-situ measurements. At European level they are the most complete possible setup to mimic and to complete EarthCARE payload. Furthermore, the associated scientific teams have a very large experience in algorithm development, especially synergistic radar-lidar retrieval for cloud and aerosol retrieval. Within the cal/val activities the airborne platforms are expected to provide EC like measurements (i.e. Wband and 355 nm HSR), which will contribute to better understand the unprecedented nature of EC measurements and will bring material for testing/validating L2 algorithms. This unique combination provides the community with an EC like data set supported by extra radar-lidar radiometry measurements airborne systems at different wavelengths (HSRL at 532nm, powerful Doppler Cloud radar at 35GHz). In addition to the aircraft measurements, we also propose to use stratospheric balloon (operated by CNES) with a 95GHz cloud radar and 808nm lidar and ultramobile radar-lidar ground-based platforms.

Objectives:

- In collaboration with appropriate International Scientists and Agencies, design, plan and conduct several field campaign extensions to the existing experiment dedicated to the

calibration and the validation of EC.c- To provide EC like measurements (W-band radar and 355 nm HSRL), with a higher resolution than the EC mission. - To provide the most possible independent measurements of cloud, precipitation and aerosol and then compare to the EC retrievals. - Perform EC underpasses during scientific field campaigns, including remote sensing and in-situ measurements. - To provide spectral (nadir) radiance observations related to cloud cover, particle size and other EC relevant parameters.

10. EVID11 (AOID 38811)

Title	An Italian coordinated contribution to the Validation of EarthCare products from three atmospheric observatories in the Central Mediterranean Sea.
PI Name	Gian Luigi Liberti
PI institution	ISMAR-CNR, Italy
Project summary: The objective of this proposal is to take full advantage of available instrumentation and knowhow from 3 Italian atmospheric observatories in Central Mediterranean to provide high quality correlative data for EarthCARE L1 and L2 products validation. The observatories are located in the Island of Lampedusa (35.5°N, 12.6°E), in the Rome city center (BAQUNIN 80 aslm 41.90°N,12.50°E) and in its outskirts (CIRAS 110 aslm, 41.84°N,12.65°E) allowing the sample of different regimes/processes of interest for EarthCARE validation. Lampedusa observatory (www.lampedusa.enea.it), located south of Sicily at more than 100 km from mainland, is composed by atmospheric and oceanographic sections, the latter represented by an instrumented buoy in open ocean, about 15 km SW of the atmospheric observatory. At this site, data are collected since 1997, and are mainly representative of clean maritime regime. The geographical position of the island allows to investigate several specific processes, relevant for aerosol-radiation, and aerosol-cloud-radiation interactions (e.g. Saharan dust transport, ship emissions, long range transport of anthropogenic aerosols). The two sites in Rome are equipped with twin active and passive instrumentation. They are representative of typical near-coastal Mediterranean conditions. Their relative position can provide useful information on the impact of the urban environment. All sites are characterized by high probability of clear sky during summer season. The different longitude of observatories will increase the probability of a match-up with satellite observations. They share similar instrumentation and homogeneous processing will be carried out thanks to a well established collaboration with exchange of knowhow, personnel and instruments. The proponent team has a documented experience on atmospheric measurements including instrument development, processing algorithm, participating to experimental campaigns and atmospheric monitoring networks (NDACC, Skynet, AERONET, Pandonia, ACTRIS/EARLINET, etc.). The team has been involved in several activities in the	

development of satellite missions at different levels from feasibility studies, SAG and MAG participation, algorithm development and implementation, operational processing (e.g. H-SAF, CMEMS). In particular, the team is involved in the validation of satellite missions (e.g. ERS-1, ERS-2, ENVISAT, GPM,S3). In addition, the team can employ an instrumented van certified to carry scientific instrumentation.

The team will provide, in the required format, routine measurements and ad-hoc periodic lidar and 24 and 35 GHz profiling radar measurements based on overpass schedule and meteorological conditions. In addition to the methodology for match-up suggested in the requirements documents, alternative approaches to compare statistical properties of the variables will be explored based on the analysis of acquired long term datasets. Rigorous estimation of ground based observation uncertainties, including product/site dependent estimation of spatio-temporal representativity, will be applied, documented and exploited in the validation exercises. In the framework of this validation activity, synergistic processing algorithms could be developed to take full advantage of the information carried by the different instruments. The impact of urban environment on the EarthCARE products will be investigated.

In terms of deliverables the project will produce.

- Instruments and algorithms description, including the estimation of uncertainties.
- Statistical description of the geophysical variables of interest for a statistical comparison.
- Data sets of paired ground based and satellite observations.
- Validation results.

Personnel and operational costs from the proponents will be partly covered by the institutions. The Italian Space Agency (ASI) provides potential additional funding.

11. EVID12 (AOID 38813)

Title	LITES lidar in UK for validation of ATLID Profiles (LUK-AP)
PI Name	Detlef Mueller
PI institution	University of Hertfordshire

Project summary:

Measurements with a unique spectrometric aerosol Raman lidar located in the United Kingdom (51.75° N; 0.24° W) will be conducted during EarthCARE overpasses to validate the aerosol and cloud profile products obtained from ATLID observations.

The Lidar Spectroscopy Instrument (LiSsI, Tesche et al., 2017) is the central instrument of LITES (Lidar Innovations for Technologies and Environmental Sciences, Tatarov and Müller 2021) at the University of Hertfordshire (UH), Hatfield, UK. LiSsI is one of only two instruments worldwide that allow for multiwavelength spectrometric profiling of Raman scattering and depolarisation of atmospheric constituents. LiSsI has been designed for measurements of gaseous and particulate pollution, while a second lidar with spectrometric capabilities, RAMSES of the German Met Service (Reichardt et al., 2016), focuses on the detection of the Raman spectrum of water molecules in the atmosphere.

Objectives

The objective of this proposal is to carry out validation measurements of ATLID observations with the LITES lidar located in the United Kingdom. Apart from its spectrometric capabilities, this instrument stands out as it features one of the most powerful lasers (repetition rate of 10 Hz with a pulse energy of as high as 2.5 J at 355 nm) that has ever been implemented into a ground-based aerosol lidar.

Method

We will perform regular validation measurements during EarthCARE overpasses in the vicinity of the lidar site in the UK following the protocol established by the European Aerosol Research Lidar Network (EARLINET) for the validation of measurements with the lidar aboard the Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite (Pappalardo et al., 2010; Schwarz, 2016). Validation measurements will be performed within a time window of about 3 h around an EarthCARE overpass. The measurement time window will be shifted depending on the distance and location of an individual overpass. Co-location will be assured using the trajectory approach outlined in the CALIPSO validation study of Tesche et al. (2013). The measurements of elastically and inelastically scattered light will be analysed as described in Ansmann and Müller (2005) and provide aerosol profile products for the validation of ATLID measurements. The spectrometric measurements will be analysed following Tatarov et al. (2010). Aerosol and cloud base and top heights will be obtained by detecting strong gradients in the range-corrected signal at 1064 nm using the wavelet covariance transform method of Brooks (2003).

Deliverables

The parameters of relevance for the validation of ATLID data products will be delivered from measurements with LiSsI and include profiles (all at 355 nm) of the attenuated backscatter coefficient (up to an altitude of at least 30 km), aerosol backscatter and extinction coefficients, lidar ratios and the particle linear depolarisation ratios. The instrument also provides the base and top heights of aerosol layers as well as the base height of optically thick cloud layers, and the base and top heights of optically thin cloud layers. In addition, the measurement capabilities of the instrument allows for the retrieval of aerosol types – by the conventional method of using optical parameters (Groß et al., 2015) and by means of spectrometric measurements of Raman scattering of selected chemical compounds (Tatarov et al., 2010).

12. EVID14 (AOID 38834)

Title	CESAR for EarthCARE evaluation (CECARE)
PI Name	Arnoud Apituley
PI institution	Royal Netherlands Meteorological Institute

Project summary:
Objective

This proposal focuses on assessment of the validation and representativity of EarthCARE observations of aerosol and cloud products using comprehensive observations at the Cabauw Experimental Site for Atmospheric Research (CESAR) in the Netherlands.

Methods

The proposed work in CECARE is aimed at the long-term validation of the EarthCARE L2 data products and will look into the overall EarthCARE mission goals through building a long-term collocated database from the CESAR Observatory. The unique combination of profiling, column integrated and in-situ observations carried out at CESAR make the dataset particularly suited for studying the very same subjects as those underlying the EarthCARE mission concept, i.e. study of the Earths' radiation balance by studying radiation, radiative forcing (direct, indirect) and feedbacks.

While EarthCARE will be making global observations form a polar orbit, taking snapshots of particular location with a recurrence over the same site in the order of several days, the detailed ground based observations cover long time periods over a fixed location. Therefore, the ground based and space borne perspectives should be considered complimentary.

The aerosol, cloud and radiation measurements made at CESAR are particularly suited for this purpose, since very similar techniques are being used at the ground and from space. Therefore, the L2 data products can often be compared directly, and auxiliary and redundant CESAR observations from the ground serve to further clarify differences.gNoting that the EarthCARE ground track is likely to pass over CESAR at distances that can increase up to tens of kilometres, which are large compared to the (in-)homogeneity of aerosol and cloud structures, representativity in space and time is an issue to be considered in the work.gWe remark here that in case the EarthCARE ground track would be configured such that CESAR would be a preferred location would uniquely enable to study individual profiles and scenes, as well as representativity over larger spatial and temporal domains.tCECARE will validate EarthCARE L2 products byt1.Comparison of EarthCARE and CESAR aerosol and cloud profiles and radiation products using observations from close proximity overpasses. Observations at CESAR that are not running continuously will be triggered by an alerting system based on predicted EarthCARE ground tracks.

2.Comparison of synergistic EarthCARE produts by comparing them to similar products build up from ground based observations at CESAR.

The work proposed in CECARE will consider the broadest range of atmospheric conditions realistically possible, e.g. from clear-sky up to overcast and multi-layered clouds. Although direct validation of products will not be possible under all atmospheric conditions, the added value in this approach is that the EarthCARE observations suffer from the same limitations as those from the ground. Therefore, the resulting cloud and aerosol (typing) masks, should be studied to understand their representativity - for the atmospheric state observed - and

usability with relation to these specific atmospheric conditions. The analysis on any significant anomalous discrepancies between the ground based observations and the corresponding EarthCARE products will be facilitated by the CECARE-team's in-depth knowledge of the EarthCARE algorithms and the ability to use the EarthCARE simulator in order to test hypothesis related to the causes of the observed differences (e.g. instrument calibration issues or specific algorithm issues). Deliverables •Long-term database of ground based observations of aerosols, clouds and radiation CESAR suitable for direct comparison and representativity studies of EarthCARE L2 products (e.g. aerosol backscatter, aerosol extinction, lidar ratio, cloud geometrical parameters, LWP, LWC, IWC, etc.). •Evaluation reports

13. EVID15 (AOID 38836)

Title	ACTRIS-FR proposal for EarthCARE Cal/Val
PI Name	Philippe Goloub
PI institution	CNRS/University of Lille

Project summary:

Objectives:

This proposal is an ACTRIS-FR (French Research Infrastructure dedicated to support aerosol, cloud and reactive trace gas research) contribution to the calibration/validation of Earth-CARE for aerosols and cloud properties. The core activity of the proposal consists in performing a multi-site calibration/validation based on ground-based active (LiDAR/Radar) and passive (photometer, radiometer) remote sensing observations performed at the main French atmospheric stations. The stations involved are located in the Tropics (La Réunion (OPAR), Dakar (LOA/IRD)), in the Arctic (Alomar, LATMOS), and in the mid-latitudes (Southern France, rural: OHP, LATMOS; central France, mountainous: CO-PDD, LaMP; Northern France, Urban: Palaiseau, SIRTA, IPSL, and Lille, LOA).

The main objectives of this ACTRIS-FR contribution are (i) the evaluation of aerosol properties, (ii) evaluation of the optical signature of volcanic aerosols and stratospheric clouds and (iii) evaluation of cloud properties.

Methods:

Accumulation of relevant collocated ground-based and satellite data at multiple stations and archiving them at a unique Data Center (AERIS). The centralisation of the data will optimize resources allocated to the global project and simplify the access to and use of, and application/development of common tools. Following national rules, each laboratory will have access to the data to perform its tasks as defined in their objectives and working plan.

Each atmospheric station will produce aerosols and/or clouds profiles based on Lidar and/or Radar measurements as well as column integrated properties. All stations are contributing to European and international networks, therefore fitting QA criteria, so as to provide, for example, reference profiles, for the purpose of calibration/validation.

Results and Deliverables:

The deliverables will be reporting, presenting and publishing (i) on the data used and the methodologies for the validation, (ii) the results of comparison studies between coincident ground-based and satellite data/products, based on multiple overpasses at 6 locations., (iii) a database managed AERIS National Data Center.

Main funding sources:

At national level, the main funding sources come from CNES (supporting for example, EECLAT project), co-funding instrumented sites and calibration sites). ACTRIS-FR, CNRS and Universities are supporting instrument upgrades at stations, etc, PIA2 is supporting several Laboratories of Excellence (Labex) such as L-IPSL, CaPPA, ...), and finally supports from the regions in which the stations are located.

14. EVID16 (AOID 38839)

Title	Swedish contribution to ESAs EarthCARE Cal Val activities (SweVal)
PI Name	Abhay Devasthale
PI institution	Swedish Meteorological and Hydrological Institute

Project summary:

In comparison to passive sensors, the history of space-borne active lidar and radar for atmospheric sensing is relatively recent. Ever since the launch of CALIOP-CALIPSO and CPRCloudSat in 2006, unprecedented global views of cloud and aerosols are obtained. They not only challenge our understanding of cloud and aerosol properties derived from the traditional sensors, but they also question very definitions of cloud and aerosol layers and the sensitivity of various sensor systems. A significant part of this enormous scientific progress made in the last decade in the era of CALIPSO+CloudSat can be undoubtedly attributed to numerous validation and comparison activities done by research groups across the world while focusing on different aspects of validation.

In this context, ESA's EarthCARE satellite will not only take the degree of our scientific understanding to the next higher level, but it will also pose new challenges, given the highly advanced lidar and radar onboard. Simultaneously, the demand from the user community in characterizing uncertainties, biases and differences among different observational system is also ever increasing. As the EarthCARE poses to be the next de facto reference for cloud and aerosol retrievals, validating EarthCARE retrievals is of paramount importance. Over the years, we have also learned that no single validation approach can fully characterize strengths and weaknesses of a particular observing system. It can rather be argued that the combination of various approaches, such as insitu-to-satellite, satellite-to-satellite, flight-to-satellite, are needed in this context.

Therefore, the proposed Swedish initiative will contribute to fulfil two specific objectives of the EarthCARE's Cal Val activity. 1) Comparison of cloud and aerosol properties with

independent ground based observations and 2) Comparison with other space-borne sensors (at the instantaneous level and statistical). The ground based measurements from a potential cloud radar site in Sweden together with other campaigns in the Arctic will be used, thus focusing primarily on the high latitude regions. The second objective will be met in the framework of EUMETSAT's NWCSAF and CMSAF projects, thus focusing on European as well on global scales. The deliverables will include sharing and publication of validation/comparison results through report and peer-reviewed articles. The proposed project is expected to run 3 years from 2019-2021. A part of the funding will be sought from the Swedish National Space Board (SNSB, Swedish Space Agency), while the other part will be made available in the framework of EUMETSAT's NWCSAF and CMSAF projects, wherein SMHI will carry out routine validation/comparison studies as a part of the respective project requirements.

15. EVID17 (AOID 38841)

Title	EarthCARE Cal/Val Using the NASA Micro Pulse Lidar Network (MPLNET)
PI Name	Ellsworth Welton
PI institution	NASA Goddard Space Flight Center

Project summary:

The NASA Micro Pulse Lidar Network (MPLNET) is a global network of Micro Pulse Lidar (MPL) instruments and was designed to provide data on aerosol and cloud vertical structure and properties for studies of climate change, assessment of aerosol and cloud models, aerosol forecasting of air quality, and calibration and validation of satellite sensors. MPLNET began in 2000 and has deployed over 80 long and short-term sites worldwide. Twenty-six long-term sites are currently operating with approximately 10 more in planning or proposal stages. Sites span all latitudinal bands from the South Pole to the Arctic. MPLNET was built upon the successful approach pioneered by the NASA Aerosol Robotic Network (AERONET): a federated network utilizing standardized commercially available instrumentation, standard calibration protocols, operations, and centralized data processing and archiving with full open access to all data. MPLNET has contributed to over 100 publications, several theses and dissertations, and provided calibration and validation support for NASA satellite sensors (ICESat, MODIS, TOMS, and CALIPSO) as well as support for numerous large scale international modeling efforts (Aerocom, ICAP, SDS-WAS). MPLNET is a member of the WMO GAW Aerosol Lidar Observation Network (GALION), which helps to coordinate our activities with other lidar networks.

The MPL was developed at NASA Goddard Space Flight Center (GSFC) in the early 1990s as the first eye safe, green lidar designed for long-term autonomous operation in the field. The MPL was patented and licensed to industry, and since then hundreds of MPL systems have been sold worldwide. The MPL is an elastic backscatter lidar at 532 nm, and provides profiles of backscattered photon counts from aerosols, clouds, and the molecular atmosphere at variable temporal and vertical resolutions from the surface to 60 km effective range. The usable range of the data are typically 0 – 30 km. The original MPL design was unpolarized, but a new polarized MPL model is now in use throughout MPLNET, providing additional information on the shape of the scattering particles.

MPLNET Level 0 (raw) data are collected continuously, day and night, at 30-second or 1-minute temporal resolutions, and 15, 30, or 75 meter vertical resolutions. All Level 0 data are sent to our MPLNET data center, archived and automatically processed into standardized Level 1 signal data. Level 1 signal data are produced at 1 minute temporal, and 30- or 75-meter vertical resolutions and include profiles of range corrected, energy normalized signals, the volume depolarization ratio, and all diagnostic data. The MPLNET Version 3 processing system became operational in 2021. Level 1 retrieved products include cloud and aerosol layer heights, extinction profiles, optical depths (layer and column), cloud phase, and the mixed layer depth of the boundary layer. All data are archived, processed, and available in near real time (< 1 hours from collection). Level 1.5 near real time quality assured products are also available, these are the same as Level 1 but with quality assurance screening provided. Final Level 2 quality assured products, with post calibrations applied, will be available starting in 2024. Older MPLNET Version 2 archived results from 2000 – 2016 are available for retrospective analysis.

This proposal will serve as a means to coordinate NASA MPLNET cal/val support for the ESA EarthCARE mission. MPLNET data are publicly available on our website with an open data policy (with offers of co-authorship). Data from any available site may be used for cal/val studies, and MPLNET will support use of our data as with any research request since this already falls within our funded activities. We will also support the deployment of MPLNET instruments for intercomparison studies with other lidar and ceilometer networks dependent upon funding. Specific EarthCARE cal/val studies will be accomplished using custom designed Level 3 MPLNET products consisting of monthly, diurnal statistics of aerosol, cloud, and mixed layer height properties coincident with EarthCARE overpasses. These Level 3 data will be used in comparison studies to assess the representativeness of EarthCARE Level 2 products in relation to MPLNET ground-based observations.

16. EVID18 (AOID 38909)

Title	Cloud and EarthCARE caL/vaL Observations (CELLO)
PI Name	Robert David
PI institution	University of Oslo
Project summary: CELLO plans to contribute to the calibration and validation of EarthCARE through a two-part approach: (1) Validation of cloud products using airborne data and (2) direct validation of aerosol and cloud products from ground-based lidar measurements in Andenes, Norway. We will use our expertise in conducting in-cloud flights during three flight campaigns: joining the international ORCESTRA initiative in Cape Verde (CELLO-ORCESTRA, August to September 2024), a campaign in the Norwegian Arctic with planned flights over the ground-based lidar in Andenes, Norway (CELLO-Arctic, August 2025), and the EU funded STEP-CHANGE campaign out of Palau (CELLO-Palau, July to August 2026). The campaigns are planned such that they provide an opportunity to validate EarthCARE in a myriad of cloud regimes and over a wide span of its expected lifetime.	

The in situ airborne measurements will be performed using the INCAS King Air, which is equipped with two underwing combination cloud probes, namely a CAPS (DMT) and Hawkeye (SPEC). These probes measure the number concentration and size distribution of hydrometeors ranging from 1 µm to 6.4 mm as well as provide information on the particle habit using 2D imaging.

Simultaneously, Andøya Space's tropospheric lidar at the ALOMAR observatory in Andenes (69°N, 16°E) measures aerosol (backscatter, extinction, and depolarization) and cloud properties at 3 different wavelengths including ATLID's 355 nm. Due to its high latitude location, the ALOMAR lidar allows for frequent cal/val activities during EarthCARE overpasses.

These activities will be a stepping stone to an extensive use of validated EarthCARE data products for scientific purposes with associated benefits ranging from capacity-building to educating the next generation of space scientists in Norway.

17. EVID19 (AOID 38935)

Title	Innovative retrieval methods of aerosol and cirrus cloud optical depth above water clouds and ocean surface, and its application in ATLID cal/val studies.
PI Name	Damien Josset
PI institution	NRL

Project summary:

The investigators developed two innovative concepts of deriving aerosol and cirrus cloud optical depths from lidar measurements of ocean surface and water clouds, and validated the techniques against airborne HSRL measurements and CALIPSO clear air measurements.

This international team of investigators, supported by NASA, would like to propose applying these techniques to validate ATLID Level 2 aerosol and cirrus cloud optical depth product.

Specifically, we propose to:

•Improving the CALIPSO based technique so that it can be applied to ATLID;

•Validate ATLID L2 aerosol and cirrus cloud optical depth data product using column integrated atmospheric optical depths derived from ATLID ocean surface backscatter measurements together with collocated cloud radar ocean surface backscatter cross section and/or wind speed measurements;

•Validate ATLID L2 aerosol and cirrus cloud optical depth data product using above cloud optical depths derived from layer integrated water cloud ATLID lidar backscatter measurements;

•Validate ATLID L1 data product using lidar backscatter measurements of ocean surface and water clouds when there are no aerosol and cirrus clouds.

•Compare with the database elaborated using CALIPSO based technique

These different activities will provide a quantification of the accuracy of L1 and L2 data that ESA will be able to use in future quality assessments.

This work will rely on current NASA funding of the investigators and on a future submission to the NASA call “U.S. participating investigator”. An internal NRL proposal has been submitted which proposes to use Earthcare data. The details are not publicly available at the moment but this research effort would help ATLID cal/val activities.

As the only team with expertise using data from both the LATMOS Leandre Nouvelle Generation (Josset 2009, Mioche et al. 2010) and the NASA LaRC High Spectral Resolution Lidar (Josset et al. 2011) for CALIPSO cal/val activity, we will also actively pursue funding and collaboration to use data of these two airborne instruments in the frame of the EARTHCARE validation activities.

This will allow us to establish an independent supplemental validation of the Rayleigh and Mie channel.

18. EVID21 (AOID 39147)

Title	Calibration and Validation for EarthCARE Cloud Profiling Radar (CPR) using Ground Based and Satellite Weather Radar Observations
PI Name	V. Chandrasekhar
PI institution	Finnish Meteorological Institute

Project summary:

The objective of this proposal is to provide Cal/Val activities for EarthCare mission. We have more than 20 years of Cal/Val experience in GPM and CLOUDSATE missions. In calibration and validation activities with EarthCare, we propose to use GPM DPR radar observations, dualpolarization radar network at Finland, NEXRAD radar, CSU-CHILL radar as well as NPOL radar. These activities include but not limited to radar measurements calibration, error specifications, hydrometeor identification cross-validation, and Doppler velocity calibration etc.

Since the CPR is the main EarthCARE sensor capable of providing range-resolved Doppler radar observations. The observations of the CPR can be used to derive hydrometeor locations (CFMR), Doppler velocities (C-CD), target classifications (C- TC) and microphysical retrievals (CCLD).

To be more specific, the objective of this proposal is to provide calibration and validations of the CPR L2a products in the above 4 areas.

We will apply space re-mapping technique to perform coordinate physical validation of vertical structures from different radar systems. We will perform hydrometeor classification algorithms to both space and ground radars and validate hydrometeor types.

We will identify snowfall and cross compare between space and ground radars. We will calibrate Doppler velocity properties available from CPR radar on board the EarthCare satellite.

The plan for deliverables of the project: 1) We will submit quarterly progress reports describing the status of our cal/val activities after the proposal approval. 2) We will prepare a final report at the end of the project period, in accordance with a given format to be defined by the Agency. 3) We will involve in documentation and produce scientific papers.

19. EVID22 (AOID 39173)

Title	Validation of the EarthCARE ATLID and MSI products using ground-based lidar and sunphotometry measurements in East Asia.
PI Name	Tomoaki Nishizawa
PI institution	National Institute for Environmental Studies, Japan
Project summary: The proposed validation exercise covers ATLID and MSI products. It thus prioritizes aerosol-related products. The main target parameters are as follows: (1) ATLID L1B; (2) ATLID-L2A: AAER, A-EBD, and A-ALD; (3) MSI-L2A: M-AOT; and (4) ATLID-MSI L2B: AM-ACD. Two ground-based observation networks will be used in this validation observation. The first is the Asian Dust and Aerosol Lidar Observation Network (AD-Net), a collaborative ground-based lidar network covering a wide area in East Asia. This lidar network uses multi-wavelength lidar instruments synergistically with Mie lidar, a high spectral resolution lidar (HSRL), and Raman lidar (RL) techniques. The other network is a radiation observation network called SKYNET, which covers a wide area in Asia as well as Europe, with skyradiometers measuring and retrieving columnar aerosol optical properties. The primary investigator (PI) and co-investigators (CIs) of this validation observation are familiar with AD-Net and SKYNET because they are the core persons engaged in developing and maintaining the requisite hardware and software. In addition, most of the personnel belong to the EarthCARE science team and are engaged in developing the EarthCARE L2 algorithm for Japanese (JAXA) products. In this validation analysis, we will mainly use data measured by multi-wavelength Raman lidar (MRL), multi-wavelength HSRL (MHSRL), multi-wavelength Raman-HSR lidar (MRHSRL) and sky radiometers at the AD-Net and SKYNET observation sites as well as the AD-Net-related observation sites. The MRL measurements built at three sites in Japan (Fukuoka, Toyama, Hedo) provides extinction coefficients (a), backscatter coefficients (b), and depolarization ratios (d) of particles at 355 and 532nm; attenuated backscatter coefficient (b) at 1064nm (i.e., 2a+3b+2d data) in nighttime; and attenuated backscatter coefficients at the three wavelengths and total depolarization ratios at 355 and 532nm (i.e., 3b+2d) in daytime. After January 2019, similar MRL observations are planned at Koror Island in Palau and over the ocean using the research vessel MIRAI operated by JAMSTEC (Japan Agency for Marine-Earth Science and Technology).	

Furthermore, a MHSRL providing 2a+3b+2d data all day and night will be built at Koganei, Tokyo,Japan, with observations commencing from April 2019. The MRHSRL established at Tsukuba in Japan, which uses both the nitrogen-vibrational Raman lidar technique at 387nm and iodine HSRL technique at 532nm, also provides 2+3+2.

We will use 1a+1b+1d data at 355 nm, derived from the MRL, MHSRL, and MRHSRL measurements for the ATLID L1B and ATLID L2A validation. We will evaluate downward attenuated backscatter coefficients to validate the ATLID L1B data. 1a+1b+1d data of aerosols and clouds at 355nm (ATLID L2A: A-AER and A-EBD) and their layer-integrated (layer-mean) parameters with the lidar ratio (ATLID L2A: A-ALD) estimated from ATLID measurements will be validated with the parameters derived from the ground-based lidar measurements.

The aerosol optical thicknesses (AOTs) at 670 and 865 nm estimated from the MSI measurements (MSI-L2A:M-AOT) and the spectral AOTs from 355 nm to 865 nm inferred from the ATLID-MSI synergy measurements (ATLID-MSI L2B: AM-ACD) will be validated with the parameters derived from the sky radiometer measurements.

We will statistically validate the parameters derived from the ATLID and MSI measurements using ground-based measurement data observed when the EarthCARE satellite passes close to the observation sites in time and space.

The AD-Net and SKYNET observations have been and will be supported primarily by the generous funds provided by MEXT (Ministry of Education, Culture, Sports, Science and Technology, Japan), MOE (Ministry of the Environment, Japan), and partly by grants conferred by institutes and universities that own the instruments. This validation research is possible due to the above-mentioned funds.

20. EVID23 (AOID 39183)

Title	Validation of EarthCARE products towards their homogenization with CALIPSO for consolidating the 3D long-term ESA-LIVAS climatology of aerosols, clouds and radiation (ACROSS)
PI Name	Vassilis Amiridis
PI institution	National Observatory of Athens

Project summary:

The overarching objective of ACROSS is to perform thorough Cal/Val investigations on EarthCARE products over Greece, a region well-known for its complex atmospheric environment.

The experiments will be designed such as to achieve the following core objectives:

(1) to perform a thorough validation of the EarthCARE stand-alone aerosol and cloud products employing sophisticated ground-based remote sensors and space-borne observations derived from passive and active satellite instruments;

(2) to utilize the validated aerosol and cloud products in Radiative Transfer Model (RTM) simulations for depicting radiation and further intercompare with high-quality solar irradiance measurements at the surface (ground-based actinometry) and at TOA (space-borne radiometers, including BBR);

(3) to expand ESA-LIVAS CALIPSO Climate Data Record to include EarthCARE aerosol and cloud products.

The validation activities will involve the following:

- A continuous Cal/Val activity at three monitoring sites in Greece (Antikythera, Thessaloniki, Athens);

- 3 Intensive Observational Periods (IOPs) of 3 months each, at the Pyrgos site in Peloponnese, located at a cross-overpass point of EarthCARE;

The project consortium will use quality-assured instrumentation including multi-wavelength lidar systems and sun-photometers that are part of the ACTRIS RI. During the IOPs in Pyrgos, NOA will deploy its new mobile instrumentation including a multi-wavelength lidar, radars operating at the X/Ka/W bands, a microwave radiometer, a HALO Doppler lidar and disdrometers.

In terms of scientific requirements, the project will be realized by an interdisciplinary group of academic experts on (a) ground-based remote sensing, (b) satellite observations, (c) radiative transfer modeling, (d) solar radiation measurements at surface and (e) earth system modeling and data assimilation.

In terms of funding, most of the monitoring activities are implemented in the framework of NOA's participation in European Networks (EARLINET, AERONET) and the ACTRIS RI. The involved stations operate continuously and are systematically maintained under the auspices of the Greek ACTRIS component (PANACEA). Moreover, the Cal/Val experiments will be synchronized with the experiments scheduled for the needs of European and ESA projects such as the P4CV, Dust DN, AIRSENSE and CERTAINTY. ACROSS will be connected to other activities pending for evaluation/approval (i.e. the ARM NIMBUS experiment, FAAM and light aircraft overflights in Greece).

21. EVID24 (AOID 39184)

Title	Statistically based calibration/validation control of ATLID L1 data
PI Name	Helene Chepfer
PI institution	UPMC, France

Project summary:

We propose a set of parameters, which would characterize the behavior of the ATLID lidar system on a day-to-day basis using the L1 data as an input. With the help of this set we will trace:

(a) the stability of the detection chain for ATLID channels (Rayleigh, Mie, and the cross-polarized one);

(b) the accuracy of cross-talk coefficients;

(c) the stability of day- and nighttime noise;

(d) the stability of the radiation detection for all atmospheric scenarios and over the whole globe

using a clustering algorithm applied to the scattering ratio (SR) histograms.

We define 11 parameters: 3 related to surface reflection, 6 related to stratospheric day- and nighttime noise for 3 channels, and 2 related to the SR histogram analysis. We demonstrate the feasibility of the approach using CALIOP L1 data for polarized and cross-polarized attenuated backscatter (ATB) components in 2008-2015.

(i) The stability control using surface backscatter takes advantage of a stable scattering scene providing thousands measurements per day, namely, a clear sky ocean surface at fixed surface temperature (300±1 K). Using CALIOP data, we show that the ATB histograms built over this subset demonstrate a clear maximum, the behavior of which over the years is coherent with laser power degradation. Applied to the ATLID channels, this approach will track the performance of laser, the absolute calibration for each channel, and the cross-talk coefficients.

(ii) For the stratospheric noise analysis, we build histograms of day- and nighttime r.m.s. values of the stratospheric "noise" (35-40 km layer) and analyze them in the same manner as above. For ATLID, this will help tracking issues in the detection path, in the signal treatment chain, and in the cross-talk estimates. Using CALIOP as a reference and knowing the ATLID technical specifications, we define "safe limits" for the day-to-day variability of histogram center values for surface and stratospheric ATB separately for its three channels.

(iii) To address the whole range of the detected molecular and particular ATBs, we use an advanced SR histogram approach based on our previous studies. We take advantage of the day-to-day similarity of physical processes in the atmosphere and quantify the deviation of the SR histograms built for typical scenes from the "reference" ones. To identify these scenes, we use a clustering approach. Using 8 years of CALIOP data, we show that the "clustered SR histograms" do not change dramatically over time for a well-calibrated instrument and that they are sensitive to calibration issues.

The deliverables are:

(1) an operational quality control algorithm adapted to ATLID L1 data processing;

(2) the results of day-to-day quality control for 11 parameters starting from the first day of the mission; (3) a set of daily SR histograms; (4) a Web-interface dynamically updating quality control results for ATLID team. All team members have permanent positions, so their salaries are secured. The total time of theproposed activity is 12 months (6 months of preparation before the launch and 6 months of commissioning phase).

22. EVID26 (AOID 39205)

Title	Calibration and Validation of EarthCAREs Cloud Profiling Radar Data Products
PI Name	Simone Tanelli
PI institution	Jet Propulsion Laboratory
Project summary: The ESA/JAXA EarthCARE mission (Earth Clouds, Aerosols and Radiation Explorer) aims at delivering global vertical profiles of aerosol and cloud properties, and vertically resolved probability distribution functions of mass flux and vertical velocities in clouds (ESA, 2004). EarthCARE is a natural continuation and evolution of the NASA/CSA CloudSat and NASA/CNES CALIPSO missions. EarthCARE will carry a Cloud Profiling Radar (EC-CPR, Kumagai et al. 2003, Ohno et al. 2007), developed by JAXA and NICT (National Institute of Information and Communications Technology, Japan), a Lidar, a Multi-Spectral Imager and a BroadBand Radiometer. EC-CPR is expected to provide the atmospheric sciences community with radar reflectivity measurements at the same frequency, and somewhat improved resolution and sensitivity, as CloudSat's CPR (CS-CPR, Stephens et al. 2002, Tanelli et al. 2008). It is the only instrument of this kind planned for the immediate post-CloudSat era (CloudSat successfully completed Prime Mission in Feb. 2008, and is in Extended Mission since then, the CS-CPR is still on its primary side as of 2017). It therefore represents an irreplaceable asset for the science community in regards to climate change studies. EC-CPR will also be the first spaceborne cloud radar with Doppler capability: mean Doppler velocity measurements can enable algorithms for a more accurate characterization of clouds and precipitation (classification, retrieval accuracy, monitoring of dynamics, etc.). However, the Doppler accuracies required to achieve such breakthroughs present a considerable challenge for EC-CPR in its current and final configuration. Notably, Doppler capability has been recognized as a critical capability in the NRC 'Decadal Survey' (NRC, 2007) for a radar on board the NASA ACE (Aerosol/Cloud/Ecosystems) mission and its implementation is being studied by the ACE mission Science Working Group (ACE SWG). We propose a 4-year effort focusing on the validation of the ESA L2b synergistic product, and in particular on the aspects that are derived primarily from the CPR measurements:	

1.the development of a post-launch collaborative plan to compare CloudSat observations with EarthCARE's to establish a climate data record of cloud geometric profiles (implementation of the plan would be contingent to availability of funding and other resources); 2.The acquisition and distribution of pre-launch datasets from JPL's Cloud and Precipitation airborne radars to validate EC-CPR algorithms with airborne data, with particular emphasis on the assessment of the EarthCARE capability to observe storm dynamics. 3.the definition of a post-launch collaborative plan to study the benefits to ESA, JAXA and NASA of coordinated airborne deployments of Ku-, Ka- and W- band cloud and precipitation radars (together with other remote sensing instruments) to support validation of EarthCARE microphysical and dynamical retrievals; particular focus will be placed on the Airborne Precipitation and cloud Radar 3-rd generation (APR-3, Ku-/Ka-/W-band, mechanically scanning Doppler radar) for pre-launch activities, and on the Airborne prototype of the Multi-Application Triband SmallSat Radar (airMASTR, Ku-/Ka-/W-band, electronically scanning Doppler radar, currently under development) for post-2019 activities. Implementation of the plan would be contingent to availability of funding and other resources. 4.the use of an advanced time-dependent spectral radiative transfer model to validate the reliability of the CPR L2a Doppler and Reflectivity products as they are integrated in the Synergistic product, and to provide an assessment of the effectiveness of algorithms developed by the EarthCARE Science Teams for EC-CPR; This project aims at continuing a long-term collaboration between the CloudSat team and the EarthCARE team and at facilitating the synergy between the EarthCARE community and CloudSat and ACE communities.

23. EVID27 (AOID 39211)

Title	Evaluation of vertical-profiles and column integrated aerosol properties from EarthCARE in Spain using EARLINET/ACTRIS facilities.
PI Name	Alejandro Rodríguez-Gómez
PI institution	Universitat Politècnica de Catalunya - BarcelonaTech
Project summary: This proposal deals with the evaluation of aerosol vertical profiles from EarthCARE using the facilities of the EARLINET/ACTRIS in Spain combined with other instruments and methods used by other participating groups. EARLINET/ACTRIS in Spain includes several multiwavelength backscatter lidar systems that operate continuously, and also some Raman lidar systems during nighttime that are able to provide independent profiles of extinction and backscatter at 355 nm, which is the operational wavelength of ATLID lidar system in EarthCARE. Here we propose to extend EARLINET/ACTRIS records including the use of polarized Micro-Pulse Lidar systems that belong to the MPLNET/GALION network.llMoreover, the University of Valladolid (UVA) operates an AERONET calibration center and is in charge of a portion of the network (about 50 sites) that includes all	

instruments in the Iberian Peninsula and others in Europe and Latin-America. There are stations in the Iberian Peninsula offering continuous data since more than 15 years. The AERONET calibration center at UVA will participate in this proposal maintaining instruments and providing data products following AERONET standards. Data provided during this project will allow the evaluation of ATLID L1b data (Mie cross-polar channel absolute calibration, Rayleigh channel absolute calibration, Mie co-polar channel absolute calibration and spectral cross-talk calibration) and Level 2 products such as A-FM, A-AER, A-EBD, A-TC, A-ALD and A-CTH (mostly for thin clouds). The facilities of AERONET in Spain will allow the evaluation of aerosol optical depth (AOD) and Angstrom exponent from the Multi Spectral Imager (MSI) Level 2a data - particularly M-AOT. This proposal is linked to the proposal 'ACTRIS for EarthCare L2 product evaluation (AECARE)' (EVID05) that includes all the ACTRIS stations for the evaluation of EarthCARE products using ground-based stations with aerosol and cloud profiling activities. AECARE is the overall contribution of ACTRIS to the EarthCARE validation to this AO call. Since national funding is needed to execute the activities, the current proposal is aligned with AECARE main objectives. The consortium of this project is currently funded by different H2020 projects and by national and regional funds.

24. EVID28 (AOID 39214)

Title	Cross-scale evaluation of ground precipitation derived from the ACM-CAP data product over Europe
PI Name	Yannis Markonis
PI institution	Cross-scale evaluation of ground precipitation derived from the ACM-CAP data product over Europe
Project summary: During the last decade substantial improvements have been accomplished in many remote sensing systems. However, the uncertainty in precipitation estimation still persists, since it manifests (a) as measurement error, (b) in the space/time interpolation of a naturally discontinuous and erratic field and (c) in the assumptions made to transform the satellite measurements into a precipitation amounts. While several methodologies have been developed for data comparison and validation, all these efforts, to date, focus mainly on individual variables and spatiotemporal scales. The challenge is thus how to achieve a better coupling between station-derived datasets and remote sensing records, in order to scrutinize observational limitations and/or deficiencies across different spatiotemporal scales. Further extending our previous research, here, we propose a framework for observational data comparison in Earth system sciences that confronts observed patterns across a continuum of scales, rather than focusing on univariate goodness-of-fit criteria or individual spatiotemporal scales. We aim to apply this framework in the validation of the ground precipitation derived from the ACM-CAP data product over the European continent. This includes the combination of both site-specific, i.e. station, and gridded datasets at various scales, and the investigation of their scaling behaviour during the aggregation process.	

The proposed cross-scale data comparison framework is expected to result to pinpoint specific scales across the spatiotemporal continuum that observed patterns match or diverge. This will provide quantitative evidence on current ACM-CAP algorithm deficiencies and highlight potential knowledge gaps.

25. EVID29 (AOID 39217)

Title	MMP : Monitoring MSI/EarthCARE L1 performances using concomitant intercalibration and stand-alone approaches
PI Name	Noelle Scott
PI institution	LMD France

Project summary:

To be fully useful for weather or climate apllications, satellite observations must be qualitatively and quantitatively controlled during the instruments lifetime: any radiometric systematic error in the level1 (L1) radiances, not identified nor quantified, may propagate as errors in the retrieved variables (L2). The aim of our proposal is to contribute to the validation (quality control) of the observations made by the MSI (MultiSpectral Imager) as well as to assess their stability over the instrument lifetime. Our understanding so far is that MSI/EarthCARE, part of the EarthCARE mission (altitude ~400 km, 14h00 mean local solar time in descending node) to be launched in 2019 is a nadir pushbroom seven channels (Vis, SWIR, TIR) imager, sampling 500 m Å~ 500 m at nadir.

The method we propose relies upon two concomitant approaches: (i) a relative (sometimes referred to as inter-calibration) approach and (ii) a "stand alone" approach. They combine observations to observations and simulations to observations comparisons respectively. As early as 1982, we have developed a technique for the calibration of METEOSAT based on LEO/GEO space and time collocations with instruments on-board the NOAA series (Bériot et al J. Appl. Meteor., vol 21, 1982). From the early 90s (ie from our involvement in the TOVSNOAA/NASA Pathfinder Programme) up to now, similar methods were applied to the processing of AIRS/AQUA, IASI/MetOpA and B and IIR/CALIPSO, including LEO/LEO and GEO/LEO collocations. Our findings with IIR/CALIPSO have impacted and guided part of the calibration revisions carried out at CNES, thus contributing to the Version 2 IIR level 1 products publicly released in July 2017. Results are described in Scott, 2009, Garnier et al (2017), Scott et al (2017).

We propose to extend our scientific approach to the Monitoring of MSI/EarthCARE L1 performances (MMP), first for the TIR channels with planned extension to the SWIR channels. The MMP project includes pre-launch and post-launch activities. The proposed work includes all geographical regions and seasons, as well as land/sea/day/night scenes, clear/cloudy/aerosols scenes, thus encompassing a broad range of brightness temperatures.

Data will be processed in delayed mode (e.g. from one to three months depending on the availability of auxiliary datasets) and results made available accordingly. Simulations will be performed with the 4A/OP model fed with adequate descriptions of the atmospheric and surface state (TIGR, ARSA, outputs from analyses/reanalyses runs,).http://ara.abct.lmd.polytechnique.fr/. 4A/OP is the official code selected by CNES for cal/val activities of IASI, Merlin, and MicroCarb.

At pre-launch time, rehearsals based on our ongoing calval reanalysis of L1 IIR/CALIPSO channels paired with LEO MODIS/AQUA channels and GEO SEVIRI/METEOSAT channels will play a key role in setting up a MSI/EarthCare Prototype and Error-Simulator.

Throughout the project, we will maintain contact with MSI/EarthCARE operator to collect up-todate information on the orbit, spatial and spectral characteristics. Through deliverables, and/or any other preferred means, we will maintain readiness for timely availability of information on models, data and tools involved in our project. Results will be shared with the L1 and L2 cal/val EarthCARE community.

Funding: Our ongoing cal/val activities related to various instruments (IASI, AIRS, IIR, etc.) are currently supported by CNES (one CDD engineer, publication fees, conferences, travel, etc.) and also by INSU/CNRS. Additional technical support is required within the frame of this new GEO/LEO configuration to enhance data acquisition and processing, computation and archiving facilities. All related requests will follow the standard procedures in force at the time they have to be presented: e.g. TOSCA/CNES frame, AERIS data poles and high-performance computing centers IDRIS/CNRS, ECMWF.

26. EVID30 (AOID 39266)

Title	Plan for EarthCARE/ATLID Calibration and Science Product Validation Using CALIPSO
PI Name	David Winker
PI institution	NASA Langley Research Center

Project summary:
CALIOP cloud observations have been used extensively as a reference dataset for the evaluation of cloud products derived from passive sensors. These comparisons have shown lidar to provide the highest accuracy and the best vertical resolution for evaluating cloud fraction and height. The CALIPSO team is now in the process of constructing Level 3 cloud data products which will serve as benchmark climate data records over the period of the CALIPSO mission. The climate community has an interest in extending this type of data record to multi-decadal scales, as a more accurate active-sensor analogue to the ISCCP dataset. Characterizing the consistency of cloud data from the CALIOP and ATLID instruments is a necessary step in this development. Therefore our objective is to globally intercompare cloud observations from CALIOP and ATLID, focusing on three-dimensional cloud occurrence, cloud top height, and cloud ice/water phase.

We assume the CALIPSO mission will end before the launch of EarthCARE. Therefore, comparisons of CALIOP data with that from ATLID will be done statistically. A meaningful mean climatology can be derived from the 11-year CALIOP data record, along with characterizations of interannual variability which can be used to estimate uncertainties due to lack of temporal matching between the CALIOP and ATLID datasets. This

intercomparison will involve an evaluation of the ATLID depolarization calibration and consideration of differences in sensitivity. Wavelength differences between CALIOP and ATLID should pose minimal difficulties as cloud scattering and attenuation is largely independent of wavelength. CALIPSO Level 1, Level 2, and Level 3 data products are already freely available to the public. We will present our intercomparison results to the EarthCARE team in the form of presentations and a written report, and also publish the results in a scientific paper. We look to NASA for funding. A future announcement of opportunity to support EarthCARE validation activities is expected, to be released closer to the time of EarthCARE launch.

27. EVID31 (AOID 39821)

Title	EarthCARE Cal/Val Ottawa (ECALOT) & Arctic Polar Night Experiment (PONEX)
PI Name	Zhipeng Qu
PI institution	Environment and Climate Change Canada
Project summary: This project consists of two sub-orbital campaigns. The EarthCARE Cal/Val Ottawa (ECALOT) campaign aims at assessing EarthCARE's Level 1 and Level 2 products through and suborbital campaign with Ottawa as homebase (Sep. - Nov. 2026). The coordinated data will be obtained from surface-base instruments deployed at Ottawa airport (45°19'34.3"N 75°39'52.1"W; 114 m ASL) and the National Research Council (NRC) of Canada's Convair-580 aircraft. The campaign is scheduled to commence in mid-September 2024 and will conclude at the end of November 2024. The primary goal is to furnish observational datasets concerning aerosol, cloud, precipitation, and radiative properties. These datasets are intended for direct or indirect comparison with EarthCARE Level 2 physical retrievals, and to acquire Level 1 type datasets for direct comparison with associated L1 products. The Arctic Polar Night Experiment (PONEX) campaign aims at assessing EarthCARE's cloud property retrieval algorithms for persistent ice-phase clouds in the Canadian Arctic region during Polar night (Jan 2026). The basis of this proposal is to assess the potential performance of EarthCARE's ice cloud, and aerosol, retrieval algorithms for polar night conditions using coordinated data obtained from surface-base instruments near Inuvik (NT) airport (68°18′14″N 133°28′59″W; 68 m ASL) and the National Research Council (NRC) of Canada's Convair-580 aircraft. Both platforms are equipped with a suite of active and passive remote sensing instruments that closely mimic those that will fly on the EarthCARE satellite. Most importantly, the Convair-580 has a 94 GHz Dopplerized cloud radar, a 355 nm backscattering lidar, and passive narrowband radiometers. Data will be collected continuously from surface-based instruments at Inuvik, along with NRC aircraft flights for both low-Arctic conditions and polar night during Jan 2026. The low-Arctic flights will coordinate with the Inuvik site. This campaign will collaborate with the Canadian project High-altitude Aerosols, Water vapour and Clouds (HAWC) mission (pre-launch phase).	

28. EVID32 (AOID 39873)

Title	EarthCARE Calibration and Validation Using an Airborne HSRL
PI Name	Chris Hostetler
PI institution	NASA Langley Research Center

Project summary:

We propose to participate in EarthCARE calibration and validation program using data from NASA's Airborne High Spectral Resolution Lidar(HSRL-2) instrument. The HSRL-2 instrument developed and operated by NASA Langley Research Center (LaRC) implements the HSRL technique at 355 nm and 532 nm and the backscatter technique at 1064 nm. It is also polarization sensitive at all three wavelengths. HSRL-2 has flown on numerous deployments from a variety of aircraft and the data have been used extensively for science as well as CALIPSO calibration/validation assessments. Because HSRL-2 provides accurate aerosol and cloud products at both 355, 532, and 1064 nm, the measurements also provide a bridge between the ATLID 355-nm and CALIOP 532/1064-nm data records. This bridge may prove to be important for statistical calibration/validation comparisons between ATLID and CALIOP as well as a means to connect the two data records for trend studies.

Under the assumption that NASA provides the necessary funding and also that the schedules for NASA aircraft, the HSRL-2 instrument, and our team members allow, we will contribute in one to three ways. First, we will participate in planning activities of the EarthCARE Cal/Val Team and share our experience from conducting CALIOP validation flights. Second, we will provide HSRL-2 data from aircraft flights along the EarthCARE ground track. These data will provide the measurements necessary to assess ATLID calibration and the accuracy and precision of several ATLID and ATLID-MSI Level-2 products. Third, we will execute calibration and validation assessments and produce reports/journal articles on the results, as we have done for the CALIOP lidar on the CALIPSO satellite.

Update: May 2024

Current airborne opportunities for EarthCARE validation.

1. PACE-PAX campaign (will also target underflights of the EarthCARE satellite.)
   Project Lead, team members: Kirk Knobelpiesse, GSFC
   Dates: Sept 2024
   Location: West coast of United States
   Website Links: https://espo.nasa.gov/pace-pax/,
   https://pace.oceansciences.org/docs/PACE_Validation_Plan_14July2020.pdf

2. ARCSIX campaign (flights of opportunity)
   Project Lead, team members: Sebastian Schmidt, Lauren Zamora, Ewan Crosbie
   Dates: June 2024, August 2024
   Location: Pituffik (Thule) Greenland
   Website Links: https://espo.nasa.gov/arcsix/

ARCSIX will collect many parameters that are of interest for EarthCARE validation, including aerosol, cloud, and radiation remote sensing. For example, there will be data from several lidars, including the High Altitude Lidar Observatory (HALO) which has two wavelengths (532nm HSRL, and 1064nm standard backscatter). There will also be several radiometers, a precipitation radar, and a large suite of other in situ and remote sensing cloud

and aerosol data. ARCSIX will be based out of Ptuffik, Greenland. The high latitude location means that there will be substantial overlap between ARCSIX sampling locations and EarthCARE overpasses. Moreover, we already expect to sample thin, low-level clouds, aerosol layers, multi-layer clouds, and possibly clouds that are snowing, all of which are of special interest to EarthCARE validation.

29. EVID33 (AOID 51515)

Title	Validation of Atlid lidar data with ground-based lidars in Northern Sweden
PI Name	Peter Völger
PI institution	Swedish Instute of Space Physics
Project summary: The proposed project aims at validation of Atlid backscatter lidar measuremants of cirrus clouds and Polar Stratospheric Clouds. The work will be mainly done at the Swedish Institute of Space Physics (IRF) in Kiruna, Sweden. Some lidar measurements will be done at Esrange, 30km east of Kiruna, in collaboration with the Department of Meteorology of Stockholm University. ATLID level 2a products A-EBD and A-CTH will be validated with lidar measurements at IRF in Kiruna, Northern Sweden. Scarcity of data at high latitudes makes our lidar observations valuable for ATLID products in these regions. Validation will be done for one year of satellite operation, and, as a result, errors of ATLID products will be evaluated. For certain cases (e.g. high likelihood for occurrence of mountain lee waves) the comparison will be done in more detail using a second lidar situated at Esrange.	

30. EVID34 (AOID 51949)

Title	WEGN4CARE - Validation of EarthCARE cloud and precipitation products by the WegenerNet 3D Open-Air Laboratory for Climate Change Research in southeastern Austria
PI Name	Gottfried Kirchengast
PI institution	University of Graz - Wegener Center
Project summary: Cal/Val of EarthCARE L2a and L2b products will be provided using data from the WegenerNet Feldbach Region high-resolution 3D Open-Air Laboratory for Climate Change Research in southeastern Austria (in short WEGN hereafter; website: wegcenter.uni-graz.at/wegenernet). The WEGN is a pioneering weather and climate observation facility comprising 155 meteorological ground stations measuring temperature, humidity, precipitation, and other parameters, in a tightly spaced grid within a core area of 22 km x 16 km centered near the city of Feldbach (46.93°N, 15.90°E). With its stations every about two square-km (area of	

about 300 square-km in total), and each station with 5-min time sampling, the network provides regular measurements since January 2007. Currently, the station network is being expanded by three major new components (start of operations of all components in the field completed in spring 2021):

1) a radiometer pair consisting of two azimuth- and elevation-steerable radiometers: (a) a microwave atmospheric-profiling radiometer with built-in auxiliary IR radiometer for vertical profiling of temperature, humidity, and cloud liquid water in the troposphere above the WegenerNet area, also capable of estimating cloud base altitudes, vertically integrated water vapor (IWV), and slant IWV along line-of-sight paths towards GNSS satellites (from the GPS and Galileo systems); and (b) a complementary IR cloud structure radiometer at similar spatiotemporal sampling for further refining gridded cloud-base altitude calculations and enabling multi-layer cloud-field reconstruction over the WegenerNet area, providing 3D cloud-field (multi-layered cloud fraction) estimates.

2) a polarimetric X-band Doppler weather radar for studying precipitation parameters in the troposphere above the ground network, such as rain rate, hydrometeor classification, Doppler velocity, and approximate drop size and number; it can provide 3D volume data (at about 1 km x 1 km horizontal and 500 m vertical resolution and 2.5 min time sampling) for moderate to strong precipitation, where the 94 GHz CPR signal suffers from strong(er) attenuation;

3) a water-vapor-mapping high-resolution GNSS station network named GNSS-StarNet, comprising six ground stations and spatially forming two star-shaped subnets across the WegenerNet area (one with ~10 km interstation distance and one embedded with ~5 km interstation distance), for providing slant IWV, vertical IWV, and precipitable water, among other parameters, at 2.5 min to 15 min time sampling. This GNSS-StarNet is operated jointly with GFZ Potsdam (Prof. Jens Wickert Team) and one of them is collocated with the radiometer and set as GRUAN reference quality station; also the other five ones are high-quality IWV stations.

This expansion upgrades the WEGN from a 2D high-density ground network operated since more than 13 years to a 3D weather and climate research facility and was completed in April 2021 with the commencement of the cloud structure radiometer operations. Therefore, the data from the WegenerNet 3D Open-Air Laboratory will be fully available for the cal/val of EarthCARE products.

Main methods: use of WEGN radiometers, weather radar, GNSS, and ground station data for statistical analysis and intercomparison (ample of heritage and experience available) with EarthCARE C-TC and ACM-CAP data.

Deliverables: Cal/Val results products as to be agreed with ESA and whole cal/val team.

Funding: Funding for WEGN is provided by the Austrian Ministry for Science and Research, the University of Graz, the state of Styria (which also included European Union regional development funds), and the City of Graz; additional funding is provided by the Austrian Science Fund (FWF) until 2022 and planned successor programmes (in particular the Austrian Space Applications ASAP Programme Call in 2022).

Principle Investigator (PI) and Co-Investigators (Co-Is): WEGN leader Gottfried Kirchengast acts as PI (see contact details under "Metadata" above) and is joined in the lead of this AO

project by the senior WEGN team members Ulrich Foelsche, Jürgen Fuchsberger and Andreas Kvas acting as Co-Is (see contacts at the WEGN website under wegcenter.uni-graz.at/wegenernet/team).

31. EVID35 (AOID 60799)

Title	Validate Cloud Profiling Radar on EarthCARE against Aircraft Observations of Cirriform Cloud
PI Name	Vaughan Phillips
PI institution	INES, Lund University

Project summary:
I am currently applying to the Swedish National Space Board (SNSB, Rymdstyrelsen) for a research grant to support a PhD student for a 4 year project. The SNSB project (entitled "The Land-Ocean Contrast of Convection and Anvil Cirrus: EarthCARE Satellite Observations and Cloud Modeling ") will address the mechanisms for the land-ocean contrast in the intensity and microphysical properties of deep convective storms.

A component of this SNSB project will be to collaborate with ESA comparing the 95 GHz Doppler 'Cloud-Profiling Radar (CPR)' on the EarthCARE satellite with coincident aircraft observations of cirriform cloud in two storm cases. This comparison will be done in the final year of the PhD project. The 95 GHz frequency is prone to strong attenuation in precipitating convection. Hence, the CPR is only expected to monitor layer-cloud, such as cirriform cloud produced by convective outflow.

As described by Illingworth et al. (2015), the CPR in conjunction with both the lidar and Multi-Spectral Imager (MSI) on the satellite will measure vertical profiles of aerosol conditions in the environment and the microphysical properties of cloud and precipitation. In the cirriform cloud, the concentrations and mean sizes of crystals and snow will be sensed. Ascent of air is then inferred from the measured precipitation velocity.

My proposed collaboration with ESA is not intended to provide any additional satellite-derived products or new retrieval algorithms. All EarthCARE measurement products will be made available anyway by ESA scientists who will apply the two existing algorithms (e.g. CAPTIVATE) described by Illingworth et al. (2015). Rather, I intend to collaborate with ESA to evaluate the accuracy of these measurements by the satellite of cloud properties and ascent.

The EarthCARE retrieval of in-cloud vertical air velocity is important to validate somehow with an assessment of accuracy. EarthCARE algorithms applied to the lidar, radar and MSI measurements will infer the air velocity from the precipitation (Doppler) velocity by estimating the reflectivity-weighted average of the fall-speeds of ice particles. This involves making assumptions about the hydrometeor shapes, sizes and bulk densities, and their

particle size distributions. Yet since ice particles are diverse in morphology and sizeeven in a given cloudy volume much error may be introduced by these assumptions. Aircraft data of ascent are not accurate enough for direct validation in cirriform cloud. Consequently, I will use aircraft measurements of ice morphology and ice size distributions to derive a reflectivity-weighted fallspeed. That will be compared directly with the satellite-derived fall-speed from EarthCARE. All microphysical products from the EarthCARE algorithm for inferring reflectivity-weighted fallspeed can also be directly compared with aircraft measurements. Finally, the aircraft measurements of convective ascent (> 1 m/s) are accurate and will validate my high-resolution simulation of the storm, which will in turn provide statistics of simulated vertical air velocity in the cirriform cloud for comparison with EarthCARE. Thus, a joint modeling/aircraftbased approach will allow the EarthCARE Doppler-derived ascent to be validated. A benefit for ESA from the PhD project will be preliminary proof-of-concept validation of the Doppler-radar retrieval of in-cloud cirriform ascent for the EarthCARE satellite. When I have identified which quantities are most in error and the type of cloud conditions where a bias is likely, then recommendations will be made to ESA about how to improve the retrieval method.

32. EVID36 (AOID 70173)

Title	Aerosol product Validation and Evaluation for EarthCARE (AVE-ECARE)
PI Name	Larisa Sogacheva
PI institution	Finnish Meteorological Institute
Project summary: Objectives This proposal focuses on assessment of the validation and evaluation of EarthCARE ATLID and MSI aerosol products using AERONET ground based observations and other similar aerosol products retrieved from satellites (e.g., MODIS for column AOD, MISR and Calipso for aerosol vertical profile). Validation of aerosol products will be performed to (i) increase the level of confidence the users will have in these products, and (ii) to better identify areas where the products are limited and where they can be improved. Methods The proposed work is aimed at the validation and evaluation of EarthCARE aerosol products with the main focus on the AOD validation. As a reference dataset, AOD measured at AERONET stations will be unitized. Satellite/AERONET match-ups will be created. The following collocation criteria for match-ups will be considered : AERONET data in time window ±30 min around satellite overpass, satellite data in 25km radius around AERONET stations will be collected and utilized. In case satellite AOD is provided at other than AERONET wavelengths, AERONET AOD will be extrapolated to satellite wavelengths using AERONET Angstrom exponent. If number of collocations is sufficient, validation will be performed over seasons to reveal annual variability and over regions specified by surface type and prevailing aerosol type. Test will be performed to evaluate if AOD product satisfies GCOS	

requirements. Special attention will be paid on the analysis of extreme anomalies. Profiles of particle extinction and backscatter and additional profile information can be evaluated with corresponding CALIPSO products.

Validation activity will follow AOD validation protocol developed in the frame of ESA LAW project, focused on validation and evaluation of Sentinel 3A and 3B SY_2_AOD product and best practice from the AATSR/SLSTR AOD validation of CCI projects. Validation methodology will be adapted to EarthCARE ATLID and MSI aerosol products, considering the specifications of those products. To better understand validation results, iterations with data providers (product developers) are important. We expect that validation results may help reveal conditions when an improvement in the retrieval algorithm is needed. Recommendations base on the validation results will be provided to data providers (product developers).

Deliverables

Evaluation reports with recommendations to data providers (product developers)

Funding
AVE-ECARE is a contribution to the EarthCARE validation programme. The work proposed in AVE-ECARE is based on the best practice obtained in ESA Aerosol_cci and LAW projects on validation end evaluation of ATSR/SLSTR AOD products funded by ESA. Therefore, routines for column AOD validation were largely funded. However, additional efforts on applying early developed validation routines to EarthCARE aerosol products are needed. Validation and evaluation of vertically resolved aerosol products needs special funding. Separate AO proposals for validation and evaluation of EarthCARE aerosol products will be submitted to ESA and the national agencies.

33. EVID37 (AOID 85993)

Title	Calibration and Validation of EarthCARE Retrieved Products Using Measurements from the UK Facility for Airborne Atmospheric Measurements (FAAM)
PI Name	Thorwald Stein
PI institution	University of Reading

Project summary:
EarthCARE (Earth cloud, aerosol and radiation explorer; Illingworth et al. 2015) is a joint ESA-JAXA satellite due for launch in September 2023. It carries four instruments: a cloud profiling radar (CPR), an atmospheric lidar (ATLID), a multi- spectral imager (MSI) and a broadband radiometer (BBR). The Doppler capability of the CPR and the high-spectral-resolution lidar (HSRL) capability of ATLID offer the potential for significantly more accurate retrievals than possible from the earlier CloudSat and CALIPSO satellites, and the co-located BBR measurements will enable the retrieved radiative properties of clouds and aerosols to be evaluated in-flight by comparing the BBR measurements to fluxes computed from radiative transfer calculations on the retrieved profiles. Around 25 operational level-2 algorithms have been developed, covering single-instrument and synergistic retrievals of clouds, aerosols, precipitation and radiation. The unprecedented detail offered by these

retrievals should provide a tighter-than-ever constraint on the representation of fundamental processes in weather and climate models, but in order for this promise to be realised, a crucial part of the mission will be the first 12 months during which the products will be carefully evaluated and adjusted both based on their internal consistency and via the use of independent observations. Here we propose a series of under-flights of EarthCARE by the UK's FAAM aircraft, within a year of launch, to provide an invaluable dataset of in-situ microphysical measurements for evaluating the EarthCARE retrievals in a range of contrasting meteorological conditions. The FAAM aircraft is a world leader in terms of atmospheric in-situ measurement capabilities. The comparison with the first versions of the official ESA products will be used to refine and improve the algorithms underpinning them. Moreover, measurements of upwelling and downwelling solar and thermal fluxes at the aircraft location will provide an important additional point of evaluation, complementing the top-of-atmosphere radiation constraint provided by the BBR. The objectives are, therefore, to: 1. Obtain aircraft measurements of clouds and radiation for 10 sorties collocated within 20 minutes of the EarthCARE track. 2. Evaluate and refine official ESA EarthCARE retrieval products. This project is conditional upon obtaining funding.

34. EVID38

Title	Norwegian initiative for EarthCARE Validation of Aerosol uncertainties and Radiation products in the Arctic (NEVAR)
PI Name	Kerstin Stebel
PI institution	The climate and environmental research institute NILU, Norway
Project summary: The "Norwegian initiative for EarthCARE Validation of Aerosol uncertainties and Radiation products in the Arctic" (NEVAR) project aims at supporting the geophysical validation of the EarthCARE data products. It is split in two phases. 1. Preparatory support activities during phase-I proposed here, which do not depend on the actual launch data. 2. EarthCARE validation activities building phase-II of NEVAR will be kicked-off nine months before launch. More specific, the main goals and objectives of the NEVAR proposal are: • O1. To inventory instrumental and institutional capabilities in Arctic countries, and to engage these in the validation of EarthCARE. • O2. To contribute to the formulation of best practice validation protocols for aerosol and cloud profiles. • O3. To perform a global assessment of aerosol and uncertainty products from EarthCARE.	

- O4. To evaluate radiation products for selected location in the Arctic.

Phase 1 Tasks are:

Task 1: Inventory of correlative instrumentation and institutional capabilities in the Arctic

In the Arctic, only a few atmospheric observatories are permanently installed. These observatories have well established monitoring programs and most of them belongs to larger infrastructure programs and projects such as AMAP, TCCON and AERONET. The infrastructures have their own web pages and data repositories, including well described stations and programme overviews. Through EU and ESA projects as well as national projects within the Arctic countries, there is an increased activity in exploring the capacity and value of drone and UAV is-situ data. In addition, there are data and measurements from non-ESA campaigns that might be relevant for EarthCARE Cal/Val. A common overview of all instalments and projects, including data quality, relevant for EarthCARE Cal/Val is currently missing. This task will compile an overview of research projects, datasets and research infrastructure instruments from all Arctic Areas that are relevant to the validation of the 44 data products of EarthCARE. The report will identify, and give further recommendations of data availability gaps, data quality gaps, uncertainty, access gaps or bottlenecks.

Task 2: Contribution to best practice protocol for validation of aerosol and cloud profiles

This task responds to the need for agreement on common validation practices and approaches for the field of Aerosol and Cloud / Precipitation profiling. In collaboration with international experts and through literature research and community consultation, this task will contribute to the EarthCARE validation best practice protocol for aerosol and cloud profiles. This will be done with particular focus on NILU's domains of expertise: transport modelling, data formats, aerosols and aerosol uncertainty validation. It will be a part of a collaborative effort of experts.

Phase 2 Tasks are:

Task 3: Preparation for Global Evaluation of Aerosol uncertainties

This task will prepare for evaluation of the EarthCARE aerosol uncertainty products. The methodology for this was initially developed in the ESA Aerosol_CCI project for the evaluation of Level 2 AOD pixel-level uncertainties from various satellite retrievals (e.g., ADV, SU, ORAC) from e.g., ATSR/AATSR (Popp et al., 2016; Kinne et al., 2017). For a recent review and a generalized framework for the evaluation of pixel-level uncertainty estimates in satellite aerosol remote sensing, see Sayer et al. (2020). In general, not limited to AOD, the transfer of the methodology to other geophysical parameters can be challenging/non-applicable, e.g., if the uncertainties of the reference data are significantly smaller than the uncertainties of the satellite data. We will assemble a catalogue with uncertainty information of the EarthCARE Level 2A/B cloud and aerosol products and prepare for the evaluation (Task 6) of EarthCARE aerosol uncertainties, using simulated data.

Task 4: Preparation for Evaluation of Radiation Products

This task will prepare for evaluation of the EarthCARE radiation products by building an interface between the EarthCARE Data Products and the 3D MYSTIC radiative transfer model (RTM, Mayer, 2009; Emde et al., 2011) run within the libRadtran environment (Mayer and Kylling, 2005; Emde et al., 2016). Test runs will be made both for 1D and 3D geometries using simulated EarthCARE data, and the results will be compared with existing simulated EarthCARE radiation products.

Task 5: Engagement of the Arctic community

Task 5 will be based on the outcome of Task 1 and engage with the Arctic community in order to keep the information in D1 (inventory and recommendation report) and D2 (country reports) up to date during Phase 2 of the project. We will continue to organise meeting the working groups defined in Task 1 and engage with these and based on their input update recommendations for attracting data and explore new technologies to be developed. The engagement shall foster new engagement in the EarthCARE Cal/Val in the Arctic science community.

Task 6: Evaluation of Aerosol uncertainties

This task will use the software and tools developed in Task 3 to validate EarthCARE Level 2 aerosol data and to evaluate their uncertainties. In a first instance this will be done for multi-wavelength AOD, and implications for the Ångström exponent will be discussed. Depending on the outcome of D-4, the uncertainty evaluation will be extended to other suitable geophysical datasets (if applicable) and/or additional work will be performed on regional assessments on aerosols in the Arctic region.

Task 7: Evaluation of Radiation Products

Task 7 will use the software from Task 4 together with combined EarthCARE ATLID, CPR and MSI data products to simulate BBR data products. The simulated BBR data will be evaluated against the EarthCARE BBR data. Horizontal cloud variability and how that affects the uncertainty and variability in the BBR data will be evaluated by comparing 1D and 3D RTM results. The evaluation will be done for selected locations in the Arctic where relevant surface data are available to give further constraints and for locations with large seasonal changes in surface albedo (snow/not snow).

35. EVID39 (AOID 91949)

Title	Cyprus Observations for EarthCARE vALidation (CORAL)
PI Name	Rodanthi-Elisavet Mamouri
PI institution	ERATOSTHENES Centre of Excellence, Cyprus

Project summary:

Cyprus offers a unique environment and setup for aerosol and clouds observation, and studies related to their interactions. In this regard, state-of-the-art facilities have been developed on the island for research on aerosol-cloud-radiation interactions. It is the most isolated, the most eastern and southern station for remote sensing observations, compared with other similar European infrastructures.

The CORAL project aims to validate the EarthCARE cloud and aerosol products. The validation will be performed using the Cyprus Atmospheric Remote Sensing Observatory (CARO), a National facility by the ERATOSTHENES Centre of Excellence in Limassol. CARO consists of a station for aerosol remote sensing (multiwavelength Raman lidar with depolarization capabilities at 355 and 532 nm) and clouds remote sensing (35GHz cloud-radar, ceilometer, microwave radiometer and ancillary sensors) , providing unbiased profiles of particle extinction, optical depth, backscatter, extinction-to-backscatter ratio and linear and circular depolarization ratios for clouds and aerosol. Furthermore CARO is complemented by a solar network across the island, comprising 5 stations established by the ERATOSTHENES CoE. The CORAL project also leverages observations fromthe Cyprus Atmospheric Observatory (CAO): polarization lidar in Nicosia, as well as ceilometers and sunphotometers at three stations (Nicosia, Agia Marina Xyliatou, and Troodos). These observations will be complemented with high-altitude in-situ aerosol observations with optical particle counters, impactors and backscattersonde. The latter observations will exploit the drones of the Unmanned Systems Research Laboratory (USRL). Both CAO and USRL are operated by the Cyprus Institute (CyI).

Due to its position, Cyprus is affected by strong dust events that occur mostly in spring, when airmasses originating from the Middle East or North Africa carry fine dust particles. These events are often associated with the formation Mediterranean cyclones, or “medicanes”, due to the interaction between the dusty air masses and warm sea surface temperatures. Often referred as a hotspot for climate change, Eastern Mediterranean has recently witnessed a notable increase in both the frequency and magnitude of wildfires, especially originating from Greece and Turkey. The emissions from these wildfires that can be detected by the advanced aerosolmonitoring infrastructure in Cyprus, given that the wildfire plumes are passing above the observationstations. This capability is crucial for assessing the environmental impact and dispersion of dust and smoke particulate matter and aerosols resulting from these events.

36. EVID40 (AOID 92137)

Title	Combining EarthCARE and ARM facility measurements for validation and research applications
PI Name	James Mather
PI institution	Pacific Northwest National Laboratory, USA

Project summary:

The United States Department of Energy Atmospheric Radiation Measurement (ARM) user facility operates a network of six extensively instrumented ground-based atmospheric observatories in diverse meteorological regimes (www.arm.gov). ARM operates long-term, fixed-location observatories in Oklahoma and Alaska in the United States and on Graciosa Island in the Azores. Two mobile facilities are deployed for a year at a time on a proposal-driven basis. An extended-term mobile facility is being deployed in the southeast United States in a forested region in northwest Alabama. Each ARM observatory includes a vertically pointing 35 GHz radar, lidars, and a variety of other sensors for providing measurements of aerosols, clouds, precipitation and the surface energy budget.

Two upcoming ARM activities that may be of particular interest to EarthCare are the aforementioned mobile facility deployment to the southeast United States and a mobile facility deployment to Cape Grim, Tasmania, AU. The deployment to the southeast United States will include a scanning C-band radar, lidar extinction at three wavelengths (355nm, 532nm, and 1064nm) several supplemental sites providing surface fluxes and basic aerosol properties, and a 40m tower that will extend above the surrounding forest canopy. This deployment will begin in January 2024 and is slated to operate for at least five years. The Cape Grim site will operate from approximately April 2024 – September 2025. All ARM sites have the potential to host guest instruments and all ARM data are fully available.cARM is collaborating with the NASA Atmosphere Observing System (AOS) sub-orbital science team with the object of providing measurements to support ground validation and collaborative science. The object of this project is to form a similar collaboration between ARM and EarthCare. Through this project, ARM will keep the EarthCare science team informed on current and emerging ARM measurement capabilities and will explore the possibility of custom data products that would be of particular benefit to EarthCare and NASA/AOS. In addition, it is anticipated that EarthCare measurements will have significant value to ARM. For example, EarthCare radar measurements will provide a reference that can be applied across ARM sites. ARM has similarly used CloudSat radar measurements in the past.

37. EVID41 (AOID 92320)

Title	Assessment of EarthCARE Aerosol and Cloud Products through Ground-Based Measurements from the E-PROFILE and AERONET Networks (AEROCLOUD)
PI Name	Francisco Navas Guzmán
PI institution	University of Granada, Spain

Project summary:

The AEROCLOUD project focuses on the evaluation of the EarthCARE Cal/Val activities of aerosol-vertical profiles and cloud measurements using the densest network of ceilometers in Europe: E-PROFILE network. E-PROFILE is part of the EUMETNET composite Observing System, managing the European networks of radar wind profiles (RWP) and automatic lidars and ceilometers (ALC) for monitoring of vertical profiles of wind and aerosols. This EarthCARE Cal/Val activity will have an international impact with the vertical aerosol measurements from the E-PROFILE network, which covers more than 400 stations from 22 European countries. This system will provide near-real-time vertically-resolved and columnar aerosol properties in a continental scale. The higher-level products to be deliver in relationship to the atmospheric aerosol profiling will allow for testing the complex assumptions made in satellite retrieval algorithms.

The methodology employed in the study includes the use of the E-PROFILE network, which comprises over 432 ceilometers for attenuated aerosol backscatter across Europe, as well as collocated measurements from the ground-based networks of AERONET and E-PROFILE to be used as input data for the GRASP code. This integration of sun-photometer and ceilometer data via the GRASP algorithm enables the inclusion of novel, vertically-resolved optical and microphysical aerosol properties for this validation. The study also includes the use of radiative transfer models (RTMs) to account for the radiative effects of aerosol measured by ceilometers. To further enhance understanding, intensive field campaigns will be conducted within the AGORA (Global Observatory of the Atmosphere of Andalusia) in Southern Spain, and at the aerological station of MeteoSwiss in Payerne, Switzerland. These campaigns aim to gather in-situ measurements of aerosols and cloud properties, complemented by remote sensing data.

The Cal/Val activities aim to validate Level 2 products from EarthCARE instruments like ATLID, MSI, and CPR, using independent ground-based observations from E-PROFILE and AERONET. This validation spans Europe and covers aerosol parameters, cloud classification, and other EarthCARE products. The project includes deliverables like E-PROFILE data acquisition plans, reports on E-PROFILE/AERONET stations, and a long-term database for EarthCARE product validation. Funded primarily by the "AEROMOST" Excellence Project of the Regional Government of Junta de Andalucia, it contributes to the Global Earth Observing System of Systems (GEOSS) and EU's atmospheric services. AEROCLOUD aids in validating aerosol products and creating new data through remote sensing techniques and EarthCARE products.

38. EVID42 (AOID 92687)

Title	NASA Atmosphere Observing System (AOS) Suborbital Working Group (SOWG) Collaboration With EarthCARE Validation Team
PI Name	Daniel Cecil
PI institution	NASA Marshall Space Flight Center

Project summary:
The NASA Atmosphere Observing System (AOS) is currently in Phase A, with its Suborbital Working Group (SOWG) developing plans for surface-based and airborne measurements that will contribute both to the overall project's science objectives and to validation of the satellite-based products. Since EarthCARE and AOS both feature lidars and radars to profile the atmosphere, there is strong mutual interest in validation approaches, measurement strategies, and the data collected. Members of the AOS SOWG and EarthCARE Validation Team (ECVT) have already begun collaborating on documentation of best practices for aerosol, cloud, and precipitation profile validation. This proposal is intended to strengthen collaborations between the AOS SOWG and ECVT. A SOWG leadership team (including the PI and some Co-PIs) is funded by the AOS project. The SOWG includes several other members, some of whom are funded by other aspects of the AOS project and others who are not funded by AOS but participate because of its relevance to their own research interests and activities.

39. EVID44 (AOID 94603)

Title	Radiation closure experiments for the validation of EarthCARE
PI Name	Stelios Kazadzis
PI institution	Physics and Meteorological Obs. Davos, World Radiation Center

Project summary:
EarthCARE, is a new ESA atmospheric satellite mission that will be launched in May 2024. ESA supports a number of EarthCARE related Cal/Val activities, among which the ACROSS activity that aims to organize field experiments in the Mediterranean region focused on EarthCARE validation. ACROSS lacks the deployment of high-accurate photometric suites in synergy with other ground-based remote sensors. Radiation measurements on the other hand, are vital for EarthCARE, since the missions' objective is to constrain radiative fluxes calculations at the top and bottom of the atmosphere within accuracies of 10 W/m^2.

EarthCARE atmospheric products (e.g. aerosol and cloud related ones) and radiative transfer codes are used in developed (not fully evaluated) algorithms in order to retrieve solar radiation at the surface and at the top of the atmosphere (outgoing radiation). Such parameters are vital for the earth-atmosphere balance and climate research, as this incoming vs outgoing radiation is the measure of radiative effects on climate. In order to provide a detailed evaluation of the atmospheric input used and also for the proposed radiation transfer related algorithms, atmospheric (e.g. aerosols) and solar spectral radiation measurements are needed at the surface.

PMODWRC is the World solar radiation center (defined by the World Meteorological Organization (WMO) as the world reference institute for solar measurements and aerosol

optical depth) and after an initial invitation by ESA to participate in EarthCARE Cal/Val activities, it is proposed that PMODWRC in collaboration with Un. Of Zurich (UZH) will join the ACROSS activity that is central for the mission cal/val. ACROSS will be deployed in the Mediterranean. Intensive Observation Periods are foreseen for spring of 2025 and 2026 where solar radiation and aerosol instrumentation from PMODWRC and UZH will participate, and analysis of the results will help towards radiation closure experiments that include verification of EarthCARE products and also radiative transfer related algorithms.

40. EVID46 (AOID 96398)

Title	SHAVE: Southern Hemisphere and Antarctic Validation of EarthCare
PI Name	Alain Protat
PI institution	Bureau of Meteorology, Australia
Project summary: The objectives of this validation project are to produce an independent estimate of the calibration of the EarthCare cloud radar reflectivity and high-spectral resolution lidar backscatter, as well as to evaluate the Doppler velocity observations from the radar. We also plan to assess some of the EarthCare-retrieved aerosol, cloud / precipitation macrophysical and microphysical properties, and surface downwelling radiation products. This will be done using ground-based, shipborne, and possibly airborne observations collected in the Southern Hemisphere, with a focus on the Southern Ocean and Antarctica - making this project a very complementary effort to validation plans in the Northern Hemisphere and the Tropics. This project piggybacks on already funded campaigns or proposals that will soon be submitted. The validation strategy will largely revolve around (i) statistical comparisons between ground-based or shipborne observations and corresponding spaceborne observations, following earlier work done by our team members to evaluate the CloudSat calibration and cloud products from the CloudSat / CALIPSO mission (e.g., Protat et al. 2009, 2010, Liu et al. 2010, Evans et al. 2012), including investigating limitations due to the top-down viewing geometry of satellite measurements (e.g., Alexander et al. 2018, Mace et al. 2021), and (ii) direct comparisons using aircraft flights under the CPR / ATLID tracks (if available to our project) (e.g., Protat et al.2009, Mace et al. 2009).	

2.9.2 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 of the measurements. Details on ground-based and airborne campaigns, and data quality monitoring via data assimilation are addressed in a dedicated section 2.10.

Table 5: instruments, platforms, and regions addressed by projects

EVID	AOID	PI	Validation targets				Independent validation sources				Vert prof	Geographical region
			ATLID	BBR	CPR	MSI	Satellite	Surface routine	Surface Campaign	Airborne Campaign		
01	37730	Clerbaux		✓			✓					Global
03	38188	Wandinger	✓	✓	✓	✓	✓	✓	✓	✓	✓	Global
04	38623	Genthon	✓		✓	✓		✓	✓		✓	Antarctic
05	38644	Baars	✓	✓	✓	✓		✓	✓		✓	Europe + selected regions outside Europe
06	38709	Loeb		✓			✓					Global
07	38757	Landulfo	✓					✓	✓		✓	South America
08	38768	Moisseev	✓		✓			✓			✓	Finland
09	38809	Renard	✓							✓	✓	Global
10	38810	Delanoe	✓		✓				✓	✓	✓	Barbados, Arctic
11	38811	Liberti	✓		✓	✓		✓	✓		✓	Italy
12	38813	Müller	✓					✓	✓		✓	UK
14	38834	Apituley	✓	✓	✓	✓		✓	✓		✓	Netherlands
15	38836	Goloub	✓		✓			✓			✓	France (incl. La Reunion) and Dakar
16	38839	Devasthale	✓		✓		✓	✓	✓		✓	Sweden, Global (Satellite)
17	38841	Welton	✓					✓			✓	Global (highest concentration in USA)
18	38909	David	✓		✓	✓		✓		✓		Tropical Atlantic, Arctic, Tropical Pacific
19	38935	Josset	✓									Global
21	39147	Chandrasekar			✓		✓	✓	✓			Finland , USA
22	39173	Nishizawa	✓			✓		✓	✓		✓	East Asia
23	39183	Amiridis	✓	✓	✓	✓		✓	✓		✓	Greece
24	39184	Chepfer	✓									Global
26	39205	Tanelli			✓		✓			✓	✓	Global (Campaigns)
27	39211	Rodríguez-Gómez	✓					✓		✓	✓	Iberian Peninsula
28	39214	Markonis	✓		✓	✓		✓				Europe
29	39217	Scott				✓	✓					Global
30	39266	Winker	✓				✓				✓	Global
31	39821	Qu	✓		✓			✓	✓	✓	✓	Arctic/North America
32	39873	Hostetler	✓			✓				✓	✓	Global (Campaigns)
33	51515	Völger	✓					✓			✓	Sweden
34	51949	Kirchengast	✓		✓	✓		✓			✓	Austria
35	60799	Phillips			✓						✓	North America
36	70173	Sogacheva	✓			✓	✓	✓			✓	Global
37	85993	Stein	✓		✓					✓	✓	UK
38	-	Stebel	✓	✓		✓	✓	✓				Global/Arctic
39	91949	Mamouri						✓	✓	✓	✓	Cyprus
40	92137	Mather						✓	✓		✓	USA plus possible campaigns elsewhere
41	92320	Navas	✓			✓		✓	✓		✓	Europe
42	92687	Cecil	✓		✓	✓					✓	USA plus possible campaigns elsewhere
44	94603	Kazadzis		✓				✓	✓			Mediterranean
46	96398	Protat	✓	✓	✓		✓		✓	✓	✓	Southern Hemisphere (focus on Southern Ocean and Antarctica)
Total		40	31	9	19	14	10	26	18	11	30	

2.9.2.1 Ground-based instrumentation

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

Table 6: Ground-based instrumentation

Instrument			
(Multiwavelength) Raman-(polarisation) Lidar	(Profiling) Cloud radar	(Microwave)/infra red/(visible)/spectro radiometer	Optical disdrometer
Backscatter Lidar	Weather radar	(Pandora)(Precision) spectrometer	(Optical) Particle (Counter)/(Sampler)
Doppler/Wind Lidar	(micro) rain radar (profiler)	Pyrometer	Aethalometer
(multi channel) (multi-wavelength) Rayleigh Mie Raman Lidar	Precipitation radar	Pyranometers and Pyrgeometers	Nephelometer
High Spectral Resolution Lidar	Radar wind profiler	Sun photometer	Radiosonde
Micro-Pulse Lidar		Sun sky radiometer	Rain gauge
Ceilometer			

2.9.2.2 Location of ground-based instruments

The following maps show the distribution of ground instruments or stations involved in EarthCARE validation. Figure 4 displays those located in Europe (with Svalbard shown in the inset) and Figure 5 zooms out to a global coverage. Note that systems from dense networks (WegenerNet, E-PROFILE, AERONET, BSRN, and NEXRAD) are not shown, for map readability.

The colored symbols in Figures 4 and 5 represent the different types of instruments: blue for lidars, yellow for radars, red for collocated lidars and radars, and green for other types of instruments (e.g. in situ).

Figure 4: Locations of ground stations in Europe (plus Svalbard shown in the inset).

Figure 5: Locations of ground stations worldwide

2.9.2.3 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 7: Satellites used for intercomparison

Mission and/or Sensor	
AVHRR	GERB
CALIPSO (*)	GPM/DPR
CATS	MTG/FCI
CERES	PACE

CLARREO	SEVIRI
CloudSat (*)	Sentinel 3 (OLCI+SLSTR)
MODIS	VIIRS

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

2.9.3 *Mapping of ESA EarthCARE validation activities to the geophysical products*

This section is intended to provide an overview of the various validation activities in terms of their coverage of the geophysical parameters retrieved by EarthCARE. In order to also identify the instrument types used to validate each geophysical product, abbreviations are used. These abbrevations are defined in the table below:

Table 8: List of validation means/instrument codes used in the tables that follow

Code	Description
A	Airborne
G	Ground-based
S	Satellite
IS	In situ
L<nm>	e.g. "L355" for 355-nm lidar
C	ceilometer
ML	multi-wavelength lidar
R-<band>	e.g. R-W for W-band radar
Aer	Aeronet
MR	multi-wavelength radar
Pol	polarimeter
OPC	optical particle counter
DP	depolarisation channel
D	Disdrometer
RDM	Radiometer
Ram	Raman capabilities
WL	Wind lidar
SAP	Ceilometer + SPM
P	Pyranometer
LWD	Pyrgeometer
SW,LW,MW	Short Wave, Long Wave, Micro Wave (for radiometers)
Sky	Skynet
RT	Radiative Transfer Modelling
PG	Pluvio (precipitation gauge)
RG	Rain gauge
RSG	Rain snow gauge
Sp	Spectroradiometer
Spec	Spectral
Spho	Sun photometer
cbi	Could be implemented
cso	Currently screened out

Table 9: L1 products

EVID	MSI	BBR	ATLID	CPR (in support of CPR L2A validation)
01		S-RDM		
03	A,S,M	S	G(M)L , A, M	G(M)R, A
04				
05			G(M)L	G(M)R
06				
07				
08				G,R-W
09				
10	A-RDM		A-ML355DP&Ram	AR-W&Ka
11				
12			G-L355DP&Ram	
14				
15				
16				
17				
18				
19				
21				
22			G,ML	
23			G-ML355	G-R-Ka
24			S,L355, L532	
25				
26				A,MR-W
27			G,L355,L532	
28				
29	S-RDM			
30				
31			A, L355	A, R-W
32			A,ML355+	
33			G,L532	
34				
35	S	S	S	S
36				
37		A,IS		
38				
39			GML; L355,Aer; A-IS-OPC, L532+DP, L808, C, Aer	
40			GML(355, 532, 1064)	GR-Ka, GMR
41			G,C1064; G,SAP440; G,SAP675; G,SAP870;	
42				
44				
46		G, IS, P, LWD	G, A, IS, L355, L532	G, A, IS, R-W

Table 10: L2 target classification products (at cloud top, vertically integrated and layerwise)

EVID	Cloud-top height	Cloud-top phase	Aerosol layer height/depth	Aerosol layer classification	Cloud detection, Cloud aerosol discrimination
1	S-RDM				
3	GR, A, S	GR, GC, A, S	GL, A, M	G-ML-Ram-DP, cb ; A, M	GR, GL, GC, GRDM; S
4					
5	GR	GR, GC	GL	G-ML-Ram-DP, cbi	GR, GL, GC, GRDM
6	S-RDM	S-RDM	S-RDM	S-RDM	S-RDM
7	G(M)L-Ram		G(M)L-Ram	G(M)L-Ram	G(M)L-Ram
8	G,R-W				
9	IS-OPC		IS-OPC	IS-OPC	IS-OPC
10	A-ML355DP, AR-W&Ka	A-ML355DP, A-R-W&Ka, A-RDM, A-IS	A-ML355DP&Ram	A-ML355DP	A-ML355DP, AR-W&Ka, A-RDM, AIS
11	G-ML-Ram , G-C, CBI(G-R-Ka)		G-ML-Ram , G-C	G-ML-Ram	G-ML-Ram ; G-C, G-WL, CBI(G-R-Ka)
12	G-L355DP&Ram		G-L355DP&Ram		G-L355DP&Ram
14					
15					
16					
17	G,L532	G,L532, DP	G,L532		G,L532
18	A,ML,IS	A,ML,IS	ML	ML	A,ML
19					
21					
22					G,ML
23	G-ML355, G-R-Ka	G-ML355, G-R-Ka	G-ML355	G-ML355	G-ML355, G-R-Ka
24					
25					
26					
27			G,L532,L355		
28					
29	S-RDM	S-RDM	S-RDM	S-RDM	S-RDM
30	S-L532	S-L532	S-L532	S-L532	S-L532
31	A, L355, R-W, IS	A, L355, R-W, IS	A, L355; G, C, L1550	A, IS	G, C; A, IS, L355, R-W
32				A,ML355+	
33			G, L532		
34					G, RDM-MW, RDM-LW
35	A,G,S	A,G,S	A,G,S	A,G,S	A,G,S
36					
37					
38					
39	GR-Ka	GR-Ka	C, GML, GR-Ka; A-IS-OPC, L532+DP, L808, C	GML, GR-Ka	GML, GR-Ka
40	GL(532), GR-Ka	GL, GR(532), GRDM(MW)	GML, GML(355) -Ram		GL(355)-Ram
41	GC		GC		GC
42					
44					
46	G, A, IS, R-W, L355, L532	G, A, IS, R-W, L355DP, L532DP	G, A, IS, L355DP, L532DP	G, A, IS, L355DP, L532DP	G, A, IS, R-W, L355DP, L532DP

Table 11: L2 ice cloud and snow products (cloud-top, vertically integrated and layerwise)

EVID	Optical thickness	Effective radius	Water path	Surface snow rate
1				
3	GR, GC, GRDM; A; S	GR, GC, GRDM, cbi; A; S	GR, GC, GRDM; A; S	GR, GD
4	G , C			IS, RSG, G, R-K
5	GR, GC, GRDM	GR, GC, GRDM, cbi	GR, GC, GRDM	GR, GD
6	S-RDM	S-RDM	S-RDM	
7				
8		G, R-C/W	G, R-C/W; MW-RDM	G, R-C/W, PG, D
9	IS-OPC	IS-OPC		
10	A-ML355DP; AR-W&Ka, A-RDM, A-IS	A-ML355DP; AR-W&Ka, A-RDM, A-IS	AR-W&Ka, A-RDM	AR-W&Ka
11		CBI(G-R-Ka)		G-RK, G-RC, G-D CBI(G-R-Ka)
12				
14				
15				
16	GR-W, S-RDM	S-RDM	GR-W, S-RDM	
17	G,L532			
18	A,ML,RDM	A,IS	A,IS	
19				
21				
22				
23	G-R-Ka	G-R-Ka, GC	G-R-Ka, G-RDM (MW)	
24				
25				
26				
27				
28				
29				
30				
31		A, IS	A, R-W/X/Ka, IS	G, IS
32				
33	G, L532			
34				
35	A,G,S	A,G,S	A,G,S	GR, GD
36				
37				
38				
39	C, GR-Ka, RDM	C, GR-Ka, RDM	C, GR-Ka, RDM	C, GR-Ka, RDM
40	GRDM			GD
41				
42				
44				
46	G, A, IS, R-W, R-K L355DP, L532DP	G, A, IS, R-W, R-K, L355DP, L532DP	G, A, IS, R-W, R-K, L355DP, L532DP	G, A, IS, R-W, R-K, L355DP, L532DP

Table 12: L2 liquid cloud and rain products (cloud-top, vertically integrated and layerwise)

EVID	Cloud optical thickness	Cloud effective radius	Liquid water path	Surface rain rate	Rain water path
1					
3	S	GR, GC, GRDM, cbi; S	GR, GC, GRDM ; A ; S	GR, GD	GR, GC, GRDM, GD, cbi
4				IS, RSG, G, R-K	
5	GR, GC, GRDM, cbi	GR, GC, GRDM, cbi	GR, GC, GRDM	GR, GD	GR, GC, GRDM, GD, cbi
6	S-RDM	S-RDM	S-RDM		
7					
8		G, R-C/W, MW-RDM, C	G, MW-RDM	G, R-C/W, PG, D	G, R-C/W, PG, D
9	IS-OPC	IS-OPC			
10	A-ML355DP&Ram, AR-W&Ka, A-RDM	A-ML355DP&Ram ; AR-W&Ka, A-RDM, A-IS	A-ML355DP&Ram ; AR-W&Ka, A-RDM	AR-W&Ka	AR-W&Ka
11		CBI(G-R-Ka)		G-RK, G-RC, G-D	R-C, R-K
12					
14					
15					
16	GR-W. S-RDM	S-RDM	GR-W. S-RDM		
17					
18		A,IS	A,IS		
19					
21					
22					
23	cbi	G-R-Ka	G-R-Ka, G-RDM(MW)	G-R-Ka, G-D	cbi
24					
25					
26					
27	G-VIS/NIR spectrometer		G-RMD(MW)		
28				RG	
29					
30					
31	A, IS	A, IS	A, R-W/X/Ka, IS	G, IS	A, R-X/Ka, IS
32					
33					
34			G, RDM-MW	G, IS	G, R-X, RDM-MW
35			G,S	G,S	
36					
37					
38					
39	C, GR-Ka, RDM	C, GR-Ka, RDM	C, GR-Ka, RDM	D	C, R-Ka, RDM
40	GRDM	GR, GRDM (SW, MW)	GRDM	GR-C, GD	
41					
42					
44	GRDM	GR, GRDM (SW, MW)	GRDM		
46	G, A, IS, R-W, R-K, L355DP, L532DP	G, A, IS, R-W, R-K, L355DP, L532DP	G, A, IS, R-W, R-K, L355DP, L532DP, RDM	G, IS	

Table 13: L2 aerosol products (cloud-top, vertically integrated and layerwise)

EVID	Aerosol optical thickness	Ångström exponent
1		
3	: G-L-Ram; G-ML-Ram-DP ; A ; S ; M	total: G-ML-Ram;G-ML-Ram-DP,: ; A; S
4		
5	total: G-L-Ram; G-ML-Ram-DP	total: G-ML-Ram,G-ML-Ram-DP
6	S-RDM	S-RDM
7	G(M)L-Ram, Aer	G(M)L-Ram, Aer
8		
9	IS-OPC	
10	A-ML355DP&Ram	A-ML355DP&Ram
11	G-Aer, G-Sky,	G,Aer, G-Sky
12		
14		
15		
16		
17		
18	ML,RDM	RDM
19		
21		
22	G,RDM	G,RDM
23	G-Aer, G-ML355	G-Aer, G-ML355
24		
25		
26		
27	G-L532,L355	G-L532,L355
28		
29		
30		
31		
32	A,ML355+	A,ML355+
33	G, L532	
34		
35	A,G,S	
36		
37		
38	Aer	Aer
39	Aer, GML; Aer	Aer, GML; Aer
40	Aer, GRDM	GRDM
41	Aer, GSAP	Aer, GSAP
42		
44	Spec	Spec
46	G, L355DP, L532DP	

Table 14: L2 target classification products (profiles at nadir)

EVID	Cloud/precipitation fraction	Cloud/precipitation phase	Aerosol fraction	Aerosol species
1				
3	GR, GC, GRDM ; A	GR, GC, GRDM ; A	A	G-ML-Ram-DP, cbi ; A; M
4				
5	GR, GC, GRDM	GR, GC, GRDM	G-ML-Ram-DP, cbi	G-ML-Ram-DP, cbi
6			S-RDM	S-RDM
7				
8	G, R-C/W, MW-RDM, C	G, R-C/W, MW-RDM, C		
9			IS-OPC	IS-OPC
10	A-ML355DP&Ram,; AR-W&Ka, A-RDM, A-IS	A-ML355DP&Ram, ; AR-W&Ka, A-RDM, A-IS	A-ML355DP&Ram, AR-W&Ka, A-RDM, A-IS	A-ML355DP&Ram, AR-W&Ka, A-IS
11	G-RK, G-RC	G-RK, G-RC		
12				
14				
15				
16				
17	G,L532, DP	G,L532, DP		
18	A,ML	A,IS	ML	ML
19				
21				
22				
23	G-R-Ka, G-ML355	G-R-Ka, G-ML355	IS	G-ML355
24				
25				
26				
27				G-L532,L355 IS
28				
29				
30				
31	A, IS (sampling at different altitudes, same below for A, IS)	A, IS		A, IS
32				A,ML355+
33				
34		G, RDM-MW		
35	A,G,S	A,G,S		A,G,S
36				
37	A,IS	A,IS	A,IS	A,IS
38				
39		C, R-Ka, RDM		GML
40	GL(355)-Ram, GR-Ka, GRDM(MW)	GL(355)-Ram, GR-Ka, GRDM(MW)		
41	GC			
42				
44				
46	G, A, IS, R-W, R-K, L355DP, L532DP	G, A, IS, R-W, R-K, L355DP, L532DP		

Table 15: L2 ice cloud and snow products (profiles at nadir)

EV ID	Extinction	Effective radius	Water content	Snow rate	Snow median diameter	Extinction-to-backscatter ratio
1						
3	cso, G-ML-Ram-DP, GR, GC, GRDM, GD, cbi ; A ; S	GR, GC, GRDM, GD, cbi ; A ; S	GR, GC, GRDM ; A ; S	GR, GC, GRDM, GD, cbi ; S	GR, GC, GRDM, GD, cbi ; S	cso, G-ML-Ram-DP, GR, GC, GRDM, GD, cbi;A
4	G, C			IS, RSG, G, R-K		
5	cso, G-ML-Ram-DP, GR, GC, GRDM, GD, cbi	GR, GC, GRDM, GD, cbi	GR, GC, GRDM	GR, GC, GRDM, GD, cbi	GR, GC, GRDM, GD, cbi	cso, G-ML-Ram-DP, GR, GC, GRDM, GD, cbi
6	S-RDM	S-RDM	S-RDM			S-RDM
7						
8		G, R-C/W, MW-RDM, C, PG, D	G, R-C/W, MW-RDM, PG, D	G, R-C/W, PG, D	G, R-C/W, MW-RDM, PG, D	
9	IS-OPC	IS-OPC				
10	A-ML355DP&Ram, AR-W&Ka, A-RDM, A-IS	A-ML355DP&Ram, AR-W&Ka, A-RDM, A-IS	A-ML355DP&Ram, AR-W&Ka, A-RDM, A-IS	AR-W&Ka	AR-W&Ka ; A-IS	A-ML355DP&Ram, A-IS
11	CBI(G-R-Ka) ; G-ML-Ram	CBI(G-R-Ka)		G-RC, G-RK	G-RC, G-RK	G-ML-Ram
12						
14						
15		To bo				
16						
17	G,L532					
18		A,IS	A,IS		A,IS	ML
19						
21						
22	G,ML					G,ML
23	G-ML355	G-R-Ka	G-R-Ka			G-ML355
24						
25						
26				A,MR-W	A,MR-W	
27	G-L					G-L
28						
29						
30						
31		A, IS	A, IS		A, IS	
32						
33	G, L532					
34				G, R-X, IS		
35		A,S	A,S	A,S	A,S	
36						
37		A,IS	A,IS			
38						
39		C, R-Ka, RDM	C, R-Ka, RDM	D	D	
40	GL(355)-Ram					GL(355)-Ram
41						
42						
44						
46	G, R-W, R-K, L355DP, L532DP	G, R-W, R-K, L355DP, L532DP	G, R-W, R-K, L355DP, L532DP	G, R-W, R-K, L355DP, L532DP	G, R-W, R-K, L355DP, L532DP	

Table 16: L2 liquid cloud and rain products (profiles at nadir)

EV ID	Extinction	Effective radius	Water content	Rain rate	Rain water content	Median drop size
1						
3	G-ML-Ram-DP, GR, GC, GRDM, GD, cbi	G-ML-Ram-DP, GR, GC, GRDM, GD, cbi	GR, GC, GRDM	GR, GC, GRDM, GD, cbi	GR, GC, GRDM, GD, cbi	GR, GC, GRDM, GD, cbi
4				IS, RSG, G, R-K		
5	G-ML-Ram-DP, GR, GC, GRDM, GD, cbi	G-ML-Ram-DP, GR, GC, GRDM, GD, cbi	GR, GC, GRDM	GR, GC, GRDM, GD, cbi	GR, GC, GRDM, GD, cbi	GR, GC, GRDM, GD, cbi
6	S-RDM	S-RDM	S-RDM			
7						
8	G, R-C/W, MW-RDM, C	G, R-C/W, MW-RDM, C	G, R-C/W, MW-RDM, C	G, R-C/W, PG, D	G, R-C/W, PG, D	G, R-C/W, PG, D
9	IS-OPC	IS-OPC				
10	A-ML355DP&Ram, AR-W&Ka, A-RDM, A-IS	A-ML355DP&Ram, AR-W&Ka, A-RDM, A-IS	A-ML355DP&Ram, AR-W&Ka, A-RDM, A-IS	AR-W&Ka	AR-W&Ka	AR-W&Ka
11	CBI(G-R-Ka)	CBI(G-R-Ka)		G-RC, G-RK CBI(G-R-Ka)	G-RC, G-RK CBI(G-R-Ka)	G-RC, G-RK CBI(G-R-Ka)
12						
14						
15						
16						
17						
18		A,IS	A,IS		A,IS	A,IS
19						
21						
22						
23	G-ML355	G-R-Ka	G-R-Ka	G-R-Ka		G-D
24						
25						
26	A,MR-W	A,MR-W	A,MR-W	A,MR-W	A,MR-W	A,MR-W
27	G-L					
28						
29						
30						
31		A, IS	A, IS, R-W/X/Ka	A, IS, R-X/Ka	A, IS, R-X/Ka	A, IS
32						
33						
34			G, RDM-MW	G, R-X	G, R-X, RDM-MW	G, R-X, RDM-MW
35		A,S	A,S	A,S	A,S	
36						
37		A,IS	A,IS			
38						
39		C, R-Ka, RDM	C, R-Ka, RDM	D, C, R-Ka, RDM		D, C, R-Ka, RDM
40	GL(355)-Ram					
41						
42						
44						
46	G, A, IS, R-W, R-K, L355DP, L532DP	G, A, IS, R-W, R-K, L355DP, L532DP	G, A, IS, R-W, R-K, L355DP, L532DP	G, IS	G, IS	G, IS

Table 17: L2 aerosol products (profiles at nadir)

EVID	Aerosol extinction	Extinction-to- backscatter ratio	Particle linear depolarization ratio
1			
3	G(M)L-Raman ; G-ML-Ram-DP; A ; M	G(M)L-Raman;G-ML-Ram-DP,; A	G(M)L-DP;G-ML-Ram-DP, ; A
4			
5	G(M)L-Raman ; G-ML-Ram-DP,	G(M)L-Raman ; G-ML-Ram-DP	G(M)L-DP ; G-ML-Ram-DP
6	S-RDM	S-RDM	S-RDM
7	G(M)L-Ram, Aer	G(M)L-Ram	G(M)L-Ram
8			
9	IS-OPC		
10	A-ML355DP&Ram	A-ML355DP&Ram	A-ML355DP&Ram
11	G-ML-Ram - C, G-L355-Ram	G-ML-Ram, G-L355-Ram	G-ML-Ram, G-L355-Ram
12	G-L355DP&Ram	G-L355DP&Ram	G-L355DP&Ram
14			
15			
16			
17	G,L532		G,L532, DP
18	ML	ML	ML
19			
21			
22	G,ML	G,ML	G,ML
23	G-ML355	G-ML355	G-ML355d
24			
25			
26			
27	G-L532,L355	G-L532,L355	G-L532,L355
28			
29			
30			
31			A, L355
32	A,ML355+	A,ML355+	A,ML355+
33	G, L532		G, L532
34			
35			
36			
37	A,IS	A,IS	A,IS
38			
39	GML	GML	GML; GL532, DP
40	GML, GL(355)-Ram	GML, GL(355)-Ram	GML, GL(355)-Ram
41	GSAP440 ; GSAP675 ; GSAP870 ; GSAP1020 ; GSAP1064 ; GC1064	GSAP440 ; GSAP675 ; GSAP870 ; GSAP1020 ; GSAP1064	
42			
44	AOD-Spec		
46	G, L355DP, L532DP		G, L355DP, L532DP

Table 18: L2 radiation products

EVID	BBR-SW and LW unfiltered radiances	Solar top-of-atmosphere flux	SW and LW fluxes at surface	Terrestrial top-of-atmosphere flux
1	S-RDM, G-RDM+	S-RDM, G-RDM+		S-RDM, G-RDM+
3	A ; S	A ; S	G	A
4				
5				
6	S-RDM	S-RDM	S-RDM	S-RDM
7		G		G
8				
9				
10	RDM		RDM	
11			G -SW, LW RDM	
12				
14				
15				
16				
17				
18				
19				
21				
22				
23			G-RDM (SW, LW)	
24				
25				
26				
27			G-RDM	
28				
29				
30				
31			G, P	
32				
33				
34				
35		S		S
36				
37				
38		RT		RT
39	S	S, G, ML, R-Ka	S, G, P, LWD; RDM	S
40			G-RDM (SW, LW)	
41				
42				
44		S,G,Spho	SW-Spec ; LW-Spec ; G RDM (SW,LW)	
46			G, IS, P, LWD	

2.10 Validation Campaigns for ESA products

Due to the narrow sampling volume, combined with the small correlation length of the target features (especially for cloud-related parameters), and the need for in-situ measurements of microphysical properties, airborne campaigns are of pivotal importance for EarthCARE validation. A succession of airborne campaigns is planned all through the in-orbit life time of EarthCARE. Among these are several dedicated campaigns, solely organised for the validation of EarthCARE, and collaborative campaigns of opportunity where EarthCARE objectives are served an addition to other objectives, for example preparations for other missions or scientific process studies. The complexity of mutiple funding sources and multiple objectives means that convergence on the number and duration of EarthCARE underflights is not complete for many of these campaigns. Also the list of campaigns is expected to grow as further collaborations materialise. Any updates with respect to this plan will be communicated through http://earthcare-val.esa.int.

The section 2.10.1 provides the list of airborne campaigns, including both dedicated and collaborative initiatives, contributing to EarthCARE validation. Shipborne and ground-based campaigns complement the airborne validation activities and are described in 2.10.2 and 2.10.3 respectively

Note that several campaigns combine aircraft and surface-borne instruments (on land and at sea) for scientific and validation synergies. This is the case for ORCESTRA, PACE PAX, ECALOT, GoSOUTH, among others. ORCESTRA is the umbrella name for the combination of several campaigns that are partially collocated, most of which have EarthCARE validation objectives, often complementing scientific objectives. The ORCESTRA components with EarthCARE validation objectives are individually addressed in the table (Table 20) namely PERCUSION, MAESTRO, CELLO, and BOW-TIE.

2.10.1 Airborne campaigns

The EarthCARE mission advisory group has provided a listing of target scenarios for airborne campaigns, which is shown in Table 19. The purpose of the table is to list a set of meteorological scenes that present specific challenges from the point of view of EarthCARE retrieval algorithms. While the list is not exhaustive, it will hopefully be useful in planning EarthCARE Cal/Val activities to ensure that the meteorological conditions sampled in all campaigns involving in-situ aircraft observations span at least those listed in this document. It should not be used to judge that a campaign focusing on conditions not specifically mentioned below is of less value than one that is. There are of course many previous science-focused campaigns targeting these conditions, but the unique set of instrument aboard EarthCARE, and the specific challenges for a spaceborne platform (such as radar multiple scattering and additional noise), necessitate underflights of the satellite specifically for the purpose of evaluating retrievals. Moreover, we expect situations where the radiative closure exhibits a bias, and in-situ observations are the only way to identify the cause.

The list was formulated in the specific context of a proposal for a flight campaign in which in-situ sampling would evaluate EarthCARE's synergy retrievals. However, the retrieval challenges identified are general enough to be relevant to single-instrument retrievals as well.

Table 19: Target scenarios for airborne campaigns

Conditions	Key retrieval challenge
Mixed aerosol types, especially over land	Aerosol type and optical properties are estimated primarily from ATLID, with information on aerosol absorption coming from the backscatter-to-extinction ratio and asphericity from the depolarization ratio (see Fig. 8 of Illingworth et al. 2015), but with a prior constraint on possible types and mixtures. How well suited are the predefined types to the real world, and how accurate are the retrieved properties in contrasting aerosol conditions, scenes containing layers of different aerosol types, and in the presence of noise such as from solar contamination?
Cumulus and marine aerosol	Drizzle-free and sometimes optically thin cumulus are widespread over the ocean and so are radiatively important, but retrieving their properties is challenging because they are often smaller than the instrument sample volume and barely detectable by the radar. It is also a challenge to cleanly mask them out when performing retrievals of marine aerosols, which tend to be optically thinner than over land so require horizontal averaging of the lidar signal to overcome instrument noise.
Marine stratocumulus	A key synergy challenge: CPR will often be dominated by drizzle drops, ATLID detects cloud top but is rapidly attenuated, while solar radiances provide an optical depth constraint and the radar ocean-surface return provides a path-attenuation constraint on integrated liquid water. Can the retrievals infer the location of cloud base and information on the vertical profile of liquid water content?
Large-scale rain	The CPR reflectivity signal in rain can be tricky to interpret as it is affected by melting-layer and rain attenuation, so a key constraint is path-integrated attenuation (PIA) from the ocean return (Mason et al. 2017). However, there are frequently liquid clouds embedded in the rain that also contribute to PIA and for which an assumption needs to be made. In this context, how accurate are retrieved rain rates? (Note that rain from deep convection presents severe additional difficulties, outlined in the final item of this list.)
Snow, including snow above the melting layer	The snow region in nimbostratus (temperature between –15 and 0°C) frequently contains embedded supercooled liquid clouds that cause riming and lead to significantly denser ice particles. Since these fall faster than low-density ice aggregates, we can use the CPR Doppler velocity to estimate snow density (Mason et al.

	2018), but how accurate are these retrievals, and can we also get a handle on the water path of the supercooled liquid?
Altocumulus and cold-air outbreaks	The simplest mixed-phase cloud consists of a layer of supercooled liquid seen by ATLID, within and beneath which ice crystals are falling and dominate the CPR return. The need to retrieve four variables simultaneously (water content and effective radius of ice and liquid) means there is more reliance on a-priori assumptions and so evaluation of retrievals is needed.
Cirrus	The synergy of radar and lidar provides a powerful constraint on particle size as demonstrated by CloudSat and CALIPSO, but how can we make retrievals fully consistent with the extra Doppler and HSRL information, as well as MSI radiances in the solar and thermal infrared? Do the retrieval assumptions and priors need to be relaxed or changed?
Complex multi-layer scenes	It is common for multiple cloud layers to be present in a profile (the simplest being cirrus over stratocumulus), in which case as well as evaluating the microphysical retrievals in each layer, we need to determine whether the optical depth information from solar radiance measurements (and indeed PIA) has been correctly partitioned between the upper and lower layers; this can in principle be inferred from aircraft radiation measurements taken between the two layers.
Deep convection	In this situation the radar attenuation is so strong that PIA cannot be estimated, and multiple scattering makes interpretation of the reflectivity profile higher in the cloud very difficult. Except for the very top of the cloud where the lidar still has sensitivity, is there anything that can be meaningfully retrieved in such situations? Given these retrieval difficulties, and indeed the challenge of sampling deep convection in-situ with aircraft, it is not clear how much focus should be given to deep convection.

Table 20 lists campaigns where underflights of EarthCARE will be performed for objectives that include EarthCARE validation.

Table 20: List of airborne campaigns

Time frame	Campaign	Area / Base	Platform	Instrumentation
Spring part: May-June 2024. Summer part: 22 July-16 Aug 2024	ARCSIX [EVID32] – Collaborative	Arctic. up to 86N, 15E to 115 W / Ptuffik, Greenland	G-III, P-3, Learjet	HALO (HSRL532, 1064) on G-III, MARLi (raman) on P3 low flyer, wind lidar, ELVIS lidar, in situ sampling (cloud and aerosol), radiometers including BBR-LW Learjet with precipitation Radar + microphysics.
June 2024 onwards (flexible, adapted to payload readiness)	BAIVEC [EVID09] – Dedicated	4 sites in France: Aire sur l'Adour (CNES balloon base) Orléans (LPC2E-CNRS) Ury (MeteoModem company) Reims (Reims University)	LOAC (Light Optical Aerosol Counter) Balloons	LOAC (Light Optical Aerosol Counter)
July-August 2024	Pre-Maestro [EVID10] – Dedicated	Toulouse	SAFIRE	• Doppler W band radar (RASTA, BASTAir) • HSRL 355 and backscatter 532&1064 (LNG) • 355 Raman (aWALI) • In-situ suite (FCDP/HVPS/UHSAS/CVI/INP/FSSP) • Radiometer (CLIMAT) • Pyrano & pyrgeometers
August-September 2024	PERCUSION [EVID03] – Collaborative -part of ORCESTRA	Cape Verde Barbados Oberpfaffenhofen transects	HALO	• HAMP 36GHz (Ka) Cloud Radar • HAMP Radiometer • WALES 532, 935, 1064 Lidar • SMART radiation and irradiation measurement system • specMACS hi-res imaging spectrometer • VELOX camera with broad and narrow band images • Dropsondes • BAHAMAS

				• BACCARDI radiometers SW + LW
10 August - 10 September 2024	MAESTRO(SAFIRE) – [EVID10] - Collaborative - part of ORCESTRA	Cape Verde (Sal)	SAFIRE-ATR42 (aircraft)	• Doppler W band radar (RASTA, BASTAir) • HSRL 355 and backscatter 532&1064 (LNG) • 355 Raman (aWALI) • In-situ suite (FCDP/HVPS/UHSAS/CVI/INP/FSSP) • Radiometer (CLIMAT) • Pyrano & pyrgeometers
August-September 2024	CELLO-ORCESTRA[EVID18] – Dedicated - part of ORCESTRA	Cape Verde	INCAS-King Air	CAPS (DMT) Hawkeye (SPEC)
September 2024	PACE-PAX [EVID32, EVID42] – Collaborative	West USA	ER-2 Twin Otter, RV Shearwater	HSRL-2
September-November 2024	ECALOT (NRC Convair) [EVID3] – Dedicated	Ottawa	NRC Convair	Airborne: • Elastic cloud lidar (355 nm, up and down) • W,X-band radar • HISRAMS • UHSAS • Nevzorov – Analog & Robust probe • Goodrich Icing Detector (x2) • DMT Cloud Droplet Probe (CDP-2) & SPEC Fast CDP (FCDP) • SPEC 2D-S (Stereo) Probe & DMT CIP-15 • Particle-I • DMT PIP & SPEC HVPS Surface: • Halo Doppler lidar or Leosphere Doppler lidar • Micro Rain Radar • Pluvio + Parsivel + FD71p + WXT520 • CNR4 Net Radiometer • Microwave Radiometer • AERI (TBD)

October 2024	WhyMSIE [EVID32, EVID42] – Collaborative	US West Coast	ER-2	To be confirmed CPL CoSMIR-H eMAS imager
November 2024	GLOVE [EVID32, EVID42] – Collaborative	US West Coast	ER-2	To be confirmed CPL eMAS imager CRS
August 2025	CELLO-ARCTIC [EVID18] – Collaborative	Norway/ Sweden	INCAS-King Air	CAPS (DMT) Hawkeye (SPEC)
September 2025	HALO South [EVID03] – Collaborative	New Zealand	HALO	• HAMP 36GHz (Ka) Cloud Radar • HAMP Radiometer • WALES 532, 935, 1064 Lidar • SMART radiation and irradiation measurement system • specMACS hi-res imaging spectrometer • VELOX camera with broad and narrow band images • Dropsondes • BAHAMAS • BACCARDI radiometers SW + LW

January 2026	PONEX [EVID31] – Collaborative	Arctic (Inuvik)	NRC Convair	Airborne:
				• Elastic cloud lidar (355 nm, upwards (zenith-viewing only)
				• FRR-2 & aerosol limb profiler ALI
				• Radars: X, W, Ka-band (up/side/down)
				• HiSRAMS (microwave sounder for temperature and water vapour)
				• In-situ suite:
				  - Aerosol mass spectrometer, aerosol size spectrometers, INP spectrometer, CCN, trace gases
				  - Cloud microphysical instrumentation (2DS, HVPS, CDP, CPI, HSI, Extinction, hot-wires, RID)

				• Aircraft data and atmospheric state probes Surface: • Halo Doppler lidar or Leosphere Doppler lidar • Micro Rain Radar • Pluvio + Parsivel + FD71p + WXT520 • CNR4 Net Radiometer • Microwave Radiometer • AERI (TBD)
July-August 2026	CELLO-Palau [EVID18] – Collaborative	Palau	INCAS-King Air	CAPS (DMT) Hawkeye (SPEC)
Tentative:				
2024	FAAM MLU flights [EVID37] – Dedicated	Cranfield, UK	FAAM	FAAM payload: Broadband Radiometers Imaging Infrared Radiometer ISMAR (International Sub-Milimetre Airborne Radiometer) Microwave Airborne Radiometer Scanning System Mini-Lidar Droplet counters Imaging probes Particle Soot Absorption Photometer Nephelometer Cloud Condensation Nuclei Counter Condensation Particle Counter
2025	CARES [EVID37] – Collaborative	Ireland	FAAM	Same as above
After mid 2025	(Piper Seneca, CNR-ISAC + OGS) [EVID11] – Collaborative	Mediteranean	Piper Seneca (OGS)	In-situ payload covering 0.01 to 50 micron: Aethalometer Nephelometer SMPS CCN counter
August-October 2025	CARINA [EVID46] – Collaborative	Melbourne, Australia	NSF NCAR HIAPER Gulfstream -V aircraft	Cloud radar (HCR) High spectral resolution lidar (HSRL) Suite of aerosol and cloud in-situ probes
2025/2026	ARISTOTLE [EVID46] – Collaborative	McMurdo Station, Antarctica	NASA P-3	Suite of aerosol, cloud and remote sensing instruments
2025/2026	Mediterranean campaign [EVID23, EVID32] – Collaborative	Mediterranean (Ponza/Italy, Cyprus, PANGEA/Greece)	Aircraft platform(s) under discussion. Skywalker UAV and	ACTRIS aerosol and cloud remote sensing facilities Microwave radiometer Disdrometer Cloudradar Raman lidar

			additional airborne measurements	Doppler lidar Radiometer Pyranometer PollyXT lidar eVe lidar Aeronet HSRL-2 *For the airborne payload see above
2026	HALO tentative backup slot in 2026 https://halo-research.de/ressources/halo-calender/. [EVID03] – Collaborative		HALO	See above
September 2026	BACCOPA - Collaborative	West Africa	SAFIRE	See above

2.10.2 Shipborne campaigns

Timeframe	Campaign	Area / Base	Platform	Instrumentation
August-September 2024	BOW-TIE [EVID03] – Collaborative-part of ORCESTRA	Barbados	FS-METEOR (ship)	• Raman lidar (1064, 532, 355 nm) • Radiosondes • Wind LiDAR • W-band cloud radar • Drones • 3D Precipitation field (PICCOLO: CSU Sea-Pol C-band scanning Rain Radar) • Ceilometer • Microwave radiometer • Disdrometer • Infrared Thermometer • Sea snakes • Onboard Weather Station • Ultra-Sonic Anemometer/Thermometer • Open-path gas analyser • Aerosol Spectrometer
February-April 2025	Denman Glacier Voyage [EVID46] – Collaborative	From Hobart, Tasmania to the Denman Glacier close to Antarctica (66.75°S)	RV Nuyina	• Cloud radar • Lidar • Micro rain radars • Microwave radiometer • Surface radiation station • Suite of in-situ aerosol, CN/CCN, INP, and aerosol precursor gas observations

May 2025	COAST-K [EVID46] – Collaborative	Coast of Tasmania and Southern Ocean	RV Investigator	Same instrumentation as for the Denman Glacier Voyage
Tentative:				
January-February 2026	ACAROA [EVID03, EVID46] – Collaborative	Christchurch, New Zealand	HALO, RV Sonne	• Ground-based radar • Doppler lidar • Micropulse lidars • Ceilometers See above for the HALO payload

2.10.3 Ground-based campaigns

Validation from ground-based systems involves many network instruments that measure routinely, but this section is dedicated to intense observation campaigns by ground-based instruments.

2.10.3.1 ATMO-ACCESS

In the framework of the ATMO ACCESS (https://www.atmo-access.eu/) pilot activities for internal stakeholders, a project to support the validation of EarthCARE mission of the European Space agency ESA was initiated resulting in a consortium of 46 participating observatories mainly from the Aerosol, Cloud, and Trace Gas Research Infrastructure (ACTRIS) plus ACTRIS central facilities, i.e. the ACTRIS topical centres CARS (Centre for Aerosol Remote Sensing) & CCRES (Centre for Cloud Remote Sensing) and the ACTRIS data centres CLU (Cloud Remote Sensing Data Centre Unit) & ARES (Aerosol Remote Sensing Data Centre Unit).

The main goal of the initiative was to establish a near-real-time data flow to be ready at EarthCARE launch for immediate validation activities. This involves performing measurements at the National facilities and other associated stations, performing quality assurance tests which are analyzed and approved by the ACTRIS Topical Centers, and implementing a data flow in near-real time from the observatories to the centralized data processing units and from there with a preliminary but ad-hoc quality control to the ACTRIS data portal (base). From there, the ESA Validation Data Centre EVDC can “harvest“ the metadata of the performed observations for validation analysis purposes. The preparation efforts include naturally harmonization of data formats and QA/QC procedures which also pave the way for other future initiatives. Intercalibration with ground-based reference lidars of ESA and with NASA MPLNET takes place in parallel.

A rehearsal campaign using simulate overpasses of EarthCARE was performed from October to November 2023 to test the established workflow and identify potential for improvements. During the 2 months rehearsal campaign, ACTRIS aerosol and cloud remote sensing facilities next to a few associated stations performed observations according to a specific schedule defined by simulated overpasses (Figure 6) to test the newly established work and data flow. Figure 7 shows an overview of the performed observations during the rehearsal. Naturally due to the season in late autumn, Cloud Profiling (CRS) data sets are more frequent in northern, while Aerosol profiling (ARS) data sets in southern Europe. Mobile Platforms (MP) have been also deployed comprising also UAV flights. Furthermore, profiling instruments not ACTRIS-compliant (NO) were involved, too, e.g. in the frame of MPLNET. The coordinated EarthCARE Cal/Val preparation by ACTRIS facilities and stations, including the associated EARLINET and Cloudnet stations, has thus achieved 'validation readiness' already.

Figure 6: Simulated overpasses of EarthCARE during the ATMO ACCESS rehearsal campaign in October 2023, in which 46 stations participated

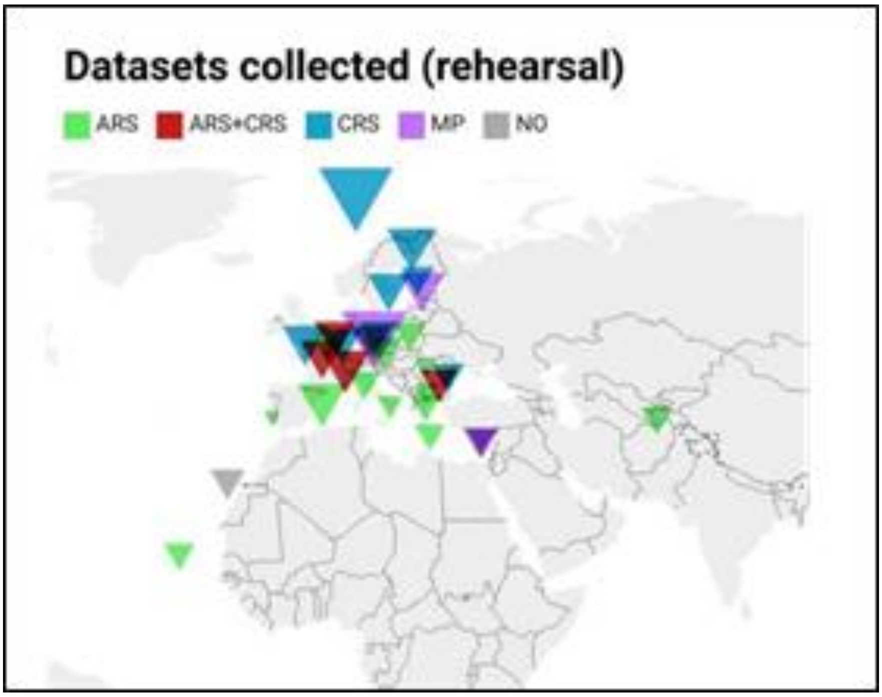

Figure 7: Data sets collected during the rehearsal campaign. Symbol size indicated the number of observations for Cloud Profiling (CRS), Aerosol profiling (ARS) stations, Mobile Platforms (MP) and not ACTRIS-compliant (NO) instruments.

Finally, real validation activities will take place shortly after the launch of EarthCARE in the Spring 2024 until the pilot activity ends in February 2025. It is expected that all of the 46 observatories will participate in this campaign. The ATMO-ACCESS network campaign is performed under the umbrella of EVID05 (ACTRIS for EarthCARE L2 product evaluation -AECARE), which includes further observatories.

2.10.3.2 EMORAL (ESA Mobile Raman Lidar)

Operated by the University of Warsaw, EMORAL is ESA's mobile Mie-Raman lidar with fluorescence, polarization and water vapor observational capabilities for Cal/Val of EarthCARE mission. EMORAL is housed in a mobile van.

The core activities planned for EarthCARE Cal/Val are to perform EMORAL observations directly under the overpass of the polar-orbiting active instrument ATLID, with initial focus on the commissioning phase.. The mobile lidar will be operated in locations under the reference orbit, including new positioning of the van for the typical duration of an overpass measurement plus ±6h margin during the commissioning phase deployment. The locations can be provided/agreed on a short notice (3-5 days prior to re-location), whereby they should be within <12h drive and <1000km from the prime location at ESTEC (Netherlands) or ESRIN (Italy) or Warsaw (Poland), thus still covering on demand practically entire Europe. The exact number of such observations will be agreed with ESA considering the required effort and logistical challenges of the final deployment location(s). Data will be delivered to ESA within one day.

2.10.3.3 CAPE k

The “Cloud and Precipitation Experiment at kennaook” at Cape Grim in Tasmania is scheduled from April 2024 to September 2025, under the lead of University of Utah with international partners. It is centered on the Global Atmospheric Watch station “kCGBAPS” and complements the baseline, long-term atmospheric instrument suite with a campaign deployment of the second ARM Mobile Facility (AMF2) which includes vertically pointing millimeter-wavelength cloud radar, lidar, and passive radiometry.
This combined instrument suite will provide correlative observations for EarthCARE cloud and precipitation product validation whilst studying the seasonal cycle of low-cloud and precipitation properties, and aerosol-cloud-precipitation interactions. For more details on the primary science objectives, and the partners, see:
https://www.arm.gov/research/campaigns/amf2024cape-k

2.10.3.4 DACAPO GoSouth

The project “Dynamics, Aerosol, Cloud, And Precipitation Observations — Model assisted vertical in-situ investigation of aerosols, and aerosol-cloud-turbulence interactions in the Southern Hemisphere marine boundary layer” by TROPOS and NIWA abbreviated as “DACAPO GoSouth” involves ground based instrumentation in New Zealand (around Invercargill) in a period (Austral Spring 2025) that includes the HALO South airborne campaign interval so that ground-air synergies can be achieved, both for the scientific campaign objectives (understanding aerosol-cloud-turbulence interactions in Southern Hemisphere marine boundary layers, and the relative influences of aerosol particle therein) and during measurements collocated with EarthCARE observations. In addition to ground-based instruments, the DACAPO Go South project will also perform soundings with balloons and UAVs. A possible shipborne element would be the atmospheric measurements from the Research Vessel "Sonne". See https://www.piccaaso.org/projects/dacapo-gosouth/ for further details.

2.10.3.5 Lindenberg 2027

This campaign is part of the Deutsche Forschungsgesellschaft Project "Cloud Structure & Climate - Closing the 3D Gap" involving TROPOS, Uni Hannover, Deutsche Wetter Dienst (German Weather Service) Offenbach KU43-SAF, Lindenberg, and the University of Cologne. The campaign takes place during the summer 2027, and the plan is to perform EarthCare correlative measurements while acquiring the most complete co-located data set of cloud and radiative properties for the scientific objectives. It makes use of the existing routinely measuring ground-based cloud radars, ceilometers, microwave radiometers (Cloudnet), a Raman Lidar, radio sounding, broadband short- and longwave radiometers (BSRN station), photometers and spectrometers (see also EVID03: GIVE). These routine ground-based radiation observations will be complemented by a dense pyranometer network (up to 100 sensors) from TROPOS and novel in-situ observational techniques from the Leibniz University Hannover to measure spectrally and temporally highly resolved radiances.

2.11 Validation networks

To maximise spatial coverage of geophysical validation using ground-based measurements, organised and coordinated network of instruments constitute an important part of validation activities. The accessibility of homogeneously formatted data using the same quality standards is another advantage that such networks provide. Several networks of ground-based instruments support EarthCARE validation activities directly via AO proposals or indirectly through the use of their data by ECVT. The following is a compilation of the networks involved in EarthCARE validation.

2.11.1 ACTRIS (Aerosol, Clouds and Trace Gases Research Infrastructure)

Participation of ACTRIS is coordinated via EVID05.

ACTRIS is the pan-European Research Infrastructure (RI) producing high-quality data and information on short-lived atmospheric constituents and on the processes leading to the variability of these constituents in natural and controlled atmospheres. ACTRIS builds on previous efforts, such as EARLINET, EUSAAR/CREATE and CLOUDNET, and thus integrates several atmospheric science communities in Europe into one coherent RI, making

ACTRIS the largest atmospheric RI in size, covering most of the atmospheric observations and experiments, and providing the broadest set of atmospheric variables in the atmospheric RI domain. For atmospheric measurements this includes in-situ and profiling observations of aerosol, clouds and trace gases. Furthermore, ACTRIS now partly supports AERONET and takes over several duties in the framework of AERONET-Europe.

With respect to profile observations relevant for EarthCARE, ACTRIS comprises most of the EARLINET and Cloudnet stations for Aerosol (Lidar and sun photometer) and Cloud (Radar, microwave radiometer, disdrometer, and Ceilometer/Lidar) Remote Sensing (ARS and CRS, respectively). In the frame of ATMO ACCESS preparation, Cal/Val activities have been carried out using a pilot TNA (Trans-National Access) study and associated stations like specific MPLNET or airborne in-situ observations have been additionally involved. For the EarthCARE validation in the framework of EVID05, all ACTRIS profiling, EARLINET, Cloudnet and participating ATMO-ACCESS pilot observatories are considered. The official webpage of ACTRIS is https://www.actris.eu.

With the intention to complement the existing EU networks, a mini-network of 94-GHz radar systems was deployed during the first phase of the FRM4RADAR project. The scope of the project was to create a foundation for Fiducial Reference Measurements (FRM) for the evaluation and validation of the EarthCARE CPR products. A tentative second phase of the project will provide collocated observations from the established 94-GHz radar network that will facilitate validation activities of the EarthCARE data.

2.11.2 LALINET (Latin America Lidar Network)

Participation of LALINET is coordinated via EVID07.

"The Latin America Lidar Network (LALINET a.k.a ALINE) is a Latin American coordinated lidar network measuring aerosol backscatter coefficient and aerosol extinction profiles for climatological studies of the aerosol distribution over Latin America, as well as other atmospheric species such as ozone and water vapor. This federative lidar network aims to establish a consistent and statistically sound database for enhancement of the understanding of the aerosol distribution over the continent and its direct and indirect influence on climate" - https://lalinet.org

2.11.3 MPLNET (Micro-Pulse Lidar Network)

Participation of MPLNET is coordinated via EVID 17.

"The NASA Micro-Pulse Lidar Network (MPLNET) is a federated network of Micro-Pulse Lidar (MPL) systems designed to measure aerosol and cloud vertical structure, and boundary layer heights. The data are collected continuously, day and night, over long time periods from sites around the world. Most MPLNET sites are co-located with sites in the NASA Aerosol Robotic Network (AERONET). MPLNET is also a contributing network to the World Meteorological Organization (WMO) Global Atmospheric Watch (GAW) Aerosol Lidar Observation Network, GALION." - https://mplnet.gsfc.nasa.gov

2.11.4 AD-Net (Asian dust and aerosol lidar observation network)

Participation of ADNet is coordinated via EVID22.

"AD-Net is a lidar network for continuous observation of vertical distributions of Asian dust and other aerosols in East Asia. AD-Net is a contributing network to the WMO GAW Program, and it forms an East Asian component of the GAW Aerosol Lidar Observation Network (GALION)." - https://www-lidar.nies.go.jp/AD-Net/

2.11.5 WegenerNet

Participation of WegenerNet is coordinated via EVID34.

"The WegenerNet provides a new multi-decadal data source for Austrian and international weather, climate, and ecosystems research. The WegenerNet climate observation network Feldbach Region comprises over 150 meteorological stations. These stations measure weather and climate in a tightly spaced grid with an unprecedented level of accuracy and detail. The measurements of several parameters are taken in 5-min intervals within the entire grid since Jan 1, 2007." – https://wegenernet.org/portal/

2.11.6 ARM (Atmospheric Radiation Measurement)

Participation of ARM is coordinated via EVID 40.

"ARM is the world's premier ground-based observations facility advancing atmospheric and climate research. The Atmospheric Radiation Measurement (ARM) user facility is a multi-laboratory, U.S. Department of Energy (DOE) scientific user facility, and a key contributor to national and international climate research efforts. ARM data are currently collected from three atmospheric observatories—Southern Great Plains, North Slope of Alaska, and Eastern North Atlantic—that represent the broad range of climate conditions around the world, as well as from the three ARM mobile facilities and ARM aerial facilities. Data from these atmospheric observatories, as well as from past research campaigns and the former Tropical Western Pacific observatory, are available at no charge through the ARM Data Center via Data Discovery." – https://arm.gov/about

2.11.7 E-PROFILE

Participation of E-PROFILE is coordinated via EVID41.

"E-PROFILE is part of the EUMETNET Composite Observing System, EUCOS, managing the European networks of radar wind profilers (RWP) and automatic lidars and ceilometers (ALC) for the monitoring of vertical profiles of wind and aerosols including volcanic ash. E-PROFILE coordinates the measurements of vertical profiles of wind from radar wind profilers (vertically pointing Doppler radars) and weather radars from a network of locations across Europe and provides the data to the end users. The main goal is to improve the overall usability of wind profiler data for operational meteorology and

to provide support and expertise to both profiler operators and end users." - https://www.eumetnet.eu/activities/observations-programme/current-activities/e-profile/

2.11.8 AERONET (Aerosol Robotic Network)

Aeronet data is used in multiple projects, e.g. EVID03, EVID11, EVID15, EVID16, EVID23, EVID17, EVID27, EVID36, EVID38, EVID39, EVID41.

"The AERONET (AErosol RObotic NETwork) program is a federation of ground-based remote sensing aerosol networks established by NASA and PHOTONS. For more than 25 years, the project has provided long-term, continuous, and readily accessible public domain database of aerosol optical, microphysical and radiative properties for aerosol research and characterization, validation of satellite retrievals, and synergism with other databases. The network imposes standardization of instruments, calibration, processing and distribution.AERONET collaboration provides globally distributed observations of spectral aerosol optical depth (AOD), inversion products, and precipitable water in diverse aerosol regimes." – https://aeronet.gsfc.nasa.gov

2.11.9 BSRN (Baseline Surface Radiation Network)

BSRN data is used in multiple projects, e.g. EVID03,EVID14, EVID31, EVID39.

"BSRN is a project of the Data and Analysis Panel from the Global Energy and Water Exchange (GEWEX) and as such is aimed at detecting important changes in the Earth's radiation field at the Earth's surface which may be related to climate changes.
In 2022 the BSRN renewed its engagement in Global Climate Observing System (GCOS) activities, and has been designated as a GCOS recognized network for global surface radiation measurements. Since 2011 the BSRN and the Network for the Detection of Atmospheric Composition Change (NDACC) established a formal agreement to become cooperative networks." - https://bsrn.awi.de

2.11.10 NEXRAD (Next Generation Weather Radar)

NEXRAD data is used by EVID21.

"The Next Generation Weather Radar (NEXRAD) system is a network of 160 high-resolution S-band Doppler weather radars jointly operated by the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the U.S. Air Force. The NEXRAD system detects precipitation and wind, and its data can be processed to map precipitation patterns and movement. NCEI provides access to archived NEXRAD Level-II data and Level-III products." -- https://www.ncei.noaa.gov/products/radar/next-generation-weather-radar

2.12 Data assimilation for quality monitoring

During the commissioning phase, ATLID attenuated backscatter and CPR radar reflectivity L1B data will be continuously monitored in near-real time against the European Centre for Medium-Range Weather Forecasts (ECMWF) model by including it in the ECMWF Integrated Forecast System (IFS). It is the intention to continue the monitoring activity during the in-orbit lifetime of EarthCARE. Every twelve hours, ECMWF atmospheric model data will be forward modelled using state-of-the-art NWP observation operators within the data assimilation system to create simulated observations for direct comparison with the latest ATLID and CPR data. Even with limited data amounts, sanity checks on calibration and qualitive checks on data quality can be made. Sudden changes in calibration or instrument quality will be readily detected through changes in the difference between observations and the model. Over time, drifts in calibration can also be detected by analysing time series of data. Indirect comparisons of model data with other sensors in the assimilation system (including cross-validation between EarthCARE instruments) will also help to diagnose potential instrument issues faster. The approach has the advantage of monitoring data for all locations along EarthCARE's orbit, so statistical significance can be achieved much faster than other validation methodologies. When L2 data is available, the monitoring will be extended to other key measurements such as Doppler Velocity and HSRL extinction.

Key outputs of this activity are

- Automated daily reports on data quality and comparisons with ECMWF model, tracking relative changes in global mean calibration, bin-by-bin changes in calibration, spatial maps of bias.
- Monthly data quality summaries.
- Automated alarms if degradation in data quality suspected.
- Assistance with investigations into possible data quality issues.

2.13 ESA Validation Support Functions

2.13.1 Validation Portal

The 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
- An interactive portal (Principal and Co-Investigators of the validation teams, algorithm teams, instrument engineers, ground and flight segment engineers) to "Information" and "Collaboration" sections (at https://ecvt.esa.int) that contain
  - o Detailed information on mission status, instrument status, processing chain status, algorithm status, ground-segment status.
  - o Once EarthCARE is in orbit: information on calibration planning, instrument maintenance and anomalies, processing changes and anomalies

- Validation programme timeline, workshop information, webinar and validation rehearsal materials
- Validation best practices, overpass information
- Interactive ("Collaboration) zone for exchanges among users, with subgroup leaders, algorithm developers, ESA Validation Data Center
- An area for each PI to provide status reports

- Discussion forum (plenary, algorithm/product-group-specific, topic specific, etc.)

The use of the Discussion forum 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 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.

2.13.2 EarthCARE data discovery and dissemination facilities

EarthCARE pre-operational data products and orbit data will be made available via the restricted data collections on the ESA Online Access Dissemination System (OADS). Download access is granted only to ECVT members who agree to the special conditions of use. All EarthCARE data can be discovered without restrictions via the catalogue services: Earth Observation Catalogue (EOCAT - https://eocat.esa.int/) and Simple Online Catalogue (SOCAT) which is accessible from each collection page inside OADS.

During the commissioning phase (6 months following the launch), download of EarthCARE pre-operational data will also be possible from a special server, i.e. commissioning server. The same conditions of use as for OADS apply as well. Access of Cal/Val users to the commissioning server is opened nominally only after data release of the last instrument (target is 90 days after launch).

2.13.3 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. In the post-launch situation, the overpass tables will be re-generated every cycle to update accordingly the UTC times of the overpass opportunities. In case the actual orbit deviates significantly from the reference orbit, a correction may be performed to the orbit scenario file, in which case the overpass tables would be re-generated.

ECVT members involved airborne campaigns are advised to use ESA orbit and overpass tools and the latest predicted orbit files for their flight planning. After the launch, the predicted orbit files will be provided daily.

2.13.4 Validation Data Centre

The EVDC (ESA atmospheric Validation Data Centre -- https://evdc.esa.int) is adapted for use by EarthCARE. This involves EarthCARE correlative data(base) management and web-based integrated tools for validation analysis/intercomparisons.

Data originating from measurement campaigns, together with data from research infrastructures and individual projects in the framework of EarthCARE validation is collected in a specific repository on EVDC. The repository is restricted to individual members of ECVT members who have signed the EarthCARE correlative data protocol, which describes the conditions for data sharing in the repository, and is formulated to protect the rights of data owners/originators. EVDC supports PIs and co-Is on the definition of metadata for their instrument types according to GEOMS (Generic Earth Observations Metadata Standard).

EVDC also hosts a set of L1 simulators and data analysis functionalities (see section 2.13.5) which will enable users to utilize the tools for data analysis and intercomparisons without local installations.

2.13.5 Inter-comparison Analysis Support Tools

There are a few software tools available for Principal Investigators and their team to 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. These tools are:

- Suborbital-orbital transformation tools for lidar (ATLID), imager (MSI), radar (CPR).

  These tools enable intercomparison between EarthCARE L1 products and correlative data measured from ground or airborne platforms by transforming the suborbital remote sensing data to what EarthCARE instruments would see. The tools/simulators have been developed in Python and are available for use by EarthCARE validation team and by the wider public. The licence of these tools is of open source type, and as such the tools can be modified to be applied to other satellite instruments. The websites that host these tools and the accompanying user guide are the following.

  - Spaceborne lidar (ATLID) simulator:

https://gitlab.com/KNMI-OSS/satellite-data-research-tools/cardinal-campaign-tools

  - Spaceborne imager (MSI) simulator: https://gitlab.com/wew_fub/msi-tool
  - Spaceborne radar (CPR) simulator: https://github.com/igmk/orbital-radar

- AVL (Atmosphere Virtual Lab):
  "The Atmosphere Virtual Lab (AVL) is a freely available Open Source software solution that can be used to analyze and visualize atmospheric earth observation dataIt is specifically designed to be used within a cloud environment, close to the data. But it can also be used on a local computer." - https://atmospherevirtuallab.org

  Support for various EarthCARE products have been added to the software, with examples and uses cases available on a dedicated webpage: https://atmospherevirtuallab.org/earthcare/

- CIS (Community Intercomparison Suite)

  "CIS is an open-source command-line tool for easy collocation, visualization, analysis, and comparison of diverse gridded and ungridded datasets used in the atmospheric sciences." - http://www.cistools.net/

  CIS (https://gmd.copernicus.org/articles/9/3093/2016/) is able to read data in various formats. Specific readers or plugins for missions such as CALIOP, CloudSat CPR, MODIS, and networks such as Aeronet are already available. EarthCARE plugin is the latest addition in the CIS Git repository; this plugin allows users to ingest ATLID and MSI L1 and L2 data:

  https://github.com/cedadev/cis

The three L1 tools and CIS functionalities are available also on the EVDC platform, where users can execute the tools without the need for local installation.

EarthCARE Scientific Validation Implementation Plan (VIP)

VOL. 3 JAXA contribution to the overall EarthCARE Validation Plan

Prepared by	**Takuji Kubota, Masataka Muto**
	EOP-PX
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3 VOLUME 3

3.1 Introduction

This document is the third volume of EarthCARE Scientific Validation Implementation Plan. This document specifies the validation implementation plan for the products of EarthCARE JAXA Product List (CPR, ATLID, MSI, CPR/ATLID synergy, CPR/ATLID/MSI synergy, 4-sensor synergy products).
The role of JAXA in EarthCARE mission is to provide users and related organizations with earth observation data sets whose quality and reliability are assured. The EarthCARE mision will construct global observation data of physical quantities related to clouds, aerosols, and radiation, including vertical velocity, and contribute to scientific research. For this purpose, JAXA develops algorithms to retrieve various geophysical quantities through validation activities.

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 roll 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: Performance 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. CPR L1b product is released officially after the proof based on NICT's validation result.

3.3.3 Level 2 products

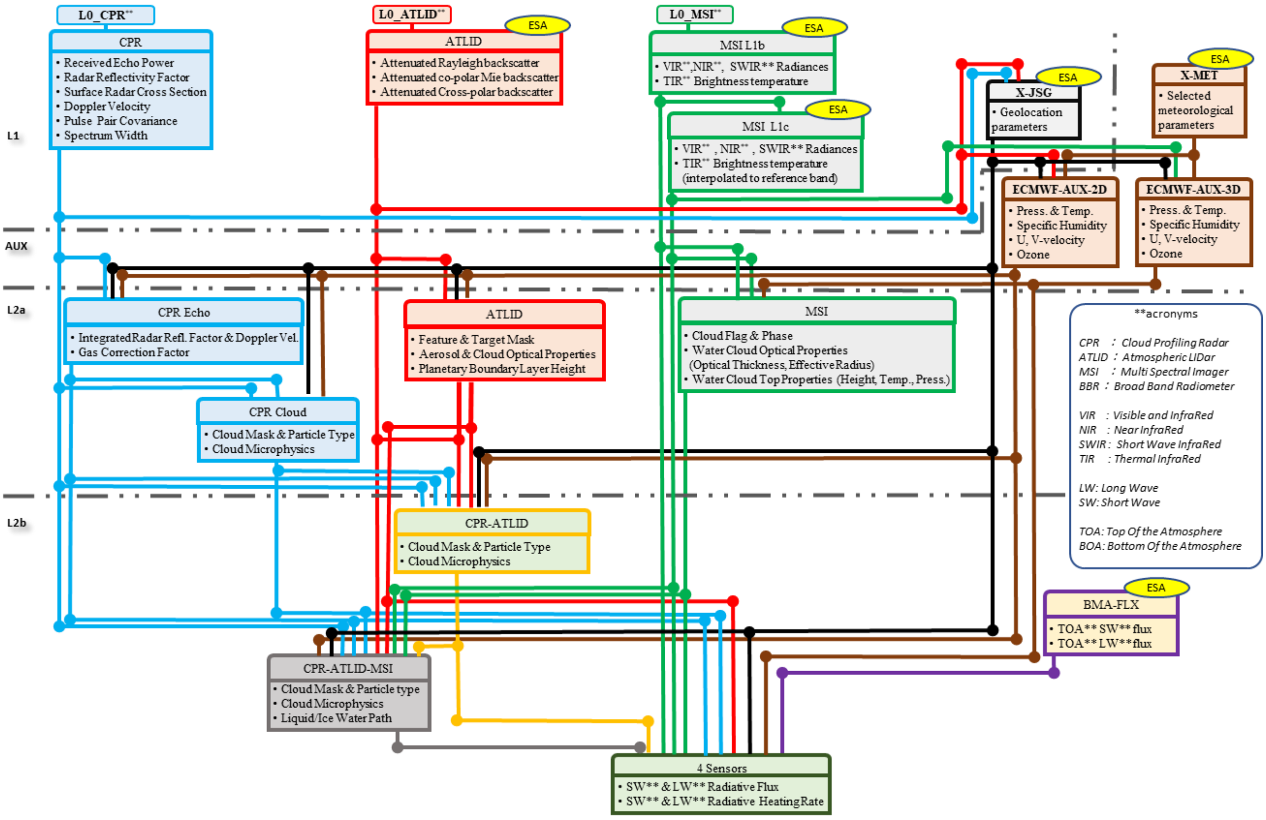
Validation is the process of evaluating the accuracy of geophysical quantities estimated from the EarthCARE/CPR, ATLID, and MSI L1 products and auxiliary products by comparing them to similar type of data obtained by independent means.
The first release of one-sensor products or two-sensor synergy products is planned to be 9 months after launch (18 months for three- or four-sensor synergy products), and it is possible that the ground observation data may not be sufficiently accumulated. Therefore, the basic policy for confirming the release accuracy is to compare with other satellite products for which more match-up data can be expected than ground observations. Since the time until release is limited, some representative parameters for each product will be set and evaluated to judge whether the product can be released or not. On the other hand, for the standard accuracy and target accuracy, which are to be judged within three years after launch, the basic policy is to compare them with ground observation data.

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:
EarthCARE products are defined as "standard Products" which includes parameters that are essential to achieve mission objectives, and "research products" which are important for scientific purposes and are supposed to become standard products when its accuracy is confirmed through validation. In this document, only the standard products are specified and research product will be mentioned in later issues.



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>

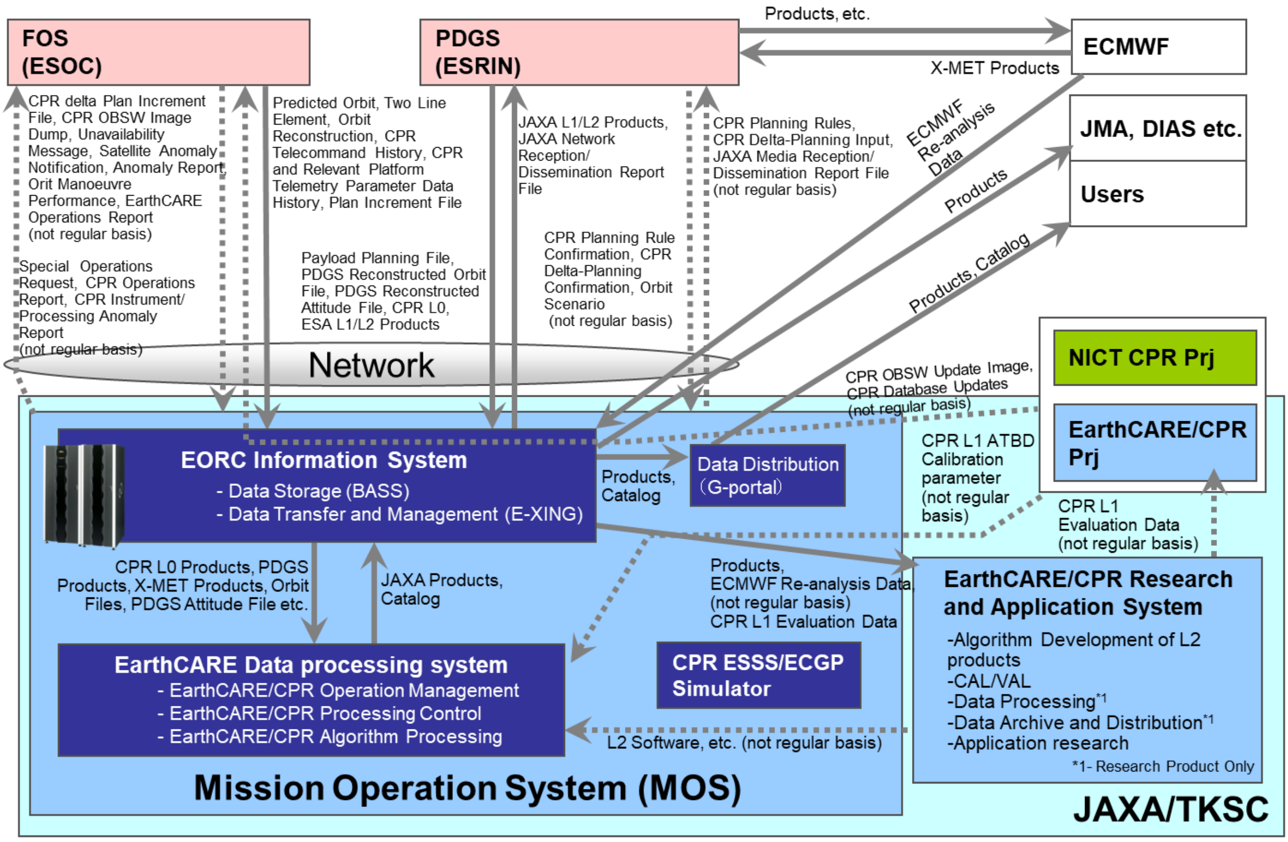
- Calibration tables related to Timing.
- Calibration tables related to Sensitivity
- Calibration tables related to Doppler Velocity
- Calibration tables related to Antenna Beam Pointing
- PRF table

<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		Spatial Resolution	
					Horizontal	Vertical	Horizontal	Vertical
CPR + ATLID	L2b	AC__CLP	CPR-ATLID Synergy Cloud Product	Cloud Mask	1km	0.1km	1km 10km	*0.5km*
				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 10km	*0.5km*
				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 MSI 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

As described in Volume 1 and 2, while each agency has distinct and complementary responsibilities, ESA and JAXA collaborate intensely on EarthCARE validation. This includes:

- 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 scientist in the validation teams.
- Coordination on validation campaigns
- Scientific exchanges between ESA and JAXA validation team members themselves.
- Workshops on validation

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

The following table show the simplified post-launch schedule of the validation.Launch	May 2024
CPR first image	June 2024
Development of L1 (v0.6) algorithm	>Aug 2024
Validation team meeting	Aug 2024
Synergy first image	Sep 2024
JMAG	Sep 2024
Development of L2 (v0.4) algorithm	>Nov 2024
L1 product release	Dec 2024
Validation workshop (L1)	Dec 2024
L2a L2b validation evaluation	Dec 2024-Feb 2025
Validation workshop (L2)	Mar 2025

3.8.1 Pre-launch activities

3.8.1.1 Validation team meeting(pre-launch)

In order to smoothly conduct validation activities after launch and complete quality confirmation before the product is released to the public, a detailed validation plan must be formulated. For this purpose, JAXA holds validation plan, preparation status, and knowledge in validation team, and to share and discuss issues related to the validation.

3.8.1.2 Validation rehearsal

Validation rehearsal refers to activities similar to the validation activities after an EarthCARE launch using the EarthCARE Research A-Train product. The EarthCARE Research A-Train products are products that applies the EarthCARE algorithm to the A-Train data. The purpose of the validation rehearsal is to provide a proof of concept of the new validation method and to quantitatively evaluate the likelihood of achieving the required accuracy for each parameter. The validation rehearsal is conducted as necessary to prepare for validation.

3.8.2 Post-launch activities

3.8.2.1 Product release

The product release process is as follows: (1) accuracy is evaluated through validation, (2) data release review is held to determine whether the data quality is good enough for public release, and (3) the standard product is released to the public through G-Portal. There are two types of release targets: one for the validation team in charge of product accuracy evaluation and the other for the general public:

Release targets for validation team

▪ L1 produtc	Launch + 3 months
▪ L2a product and L2b 2-sensor product	Launch + 6 months
▪ L2b 3-sensor and 4-sensor product	Launch + 9 months

Release targets for public

▪ L1 produtc	Launch + 6 months
▪ L2a product and L2b 2-sensor product	Launch + 9 months
▪ L2b 3-sensor and 4-sensor product	Launch + 18 months

3.8.2.2 Reports by validation PIs

The L2a product and the L2b 2-sensor synergy product will be released to the validation team by 6 months after launch, and to public by 9 months after launch. Therefore, it is necessary to conduct the validation activities intensively during approximately three months. Therefore, during the three month period between the release of the product to the validation team and the data release review, the validation PIs shall report the progress of the validation results to the JAXA validation leader once a month by email, etc. For L2b 3-sensor and 4-sensor synergy products, validation PIs shall report at appropriate frequency based on the same template for the 9 month period between release to the validation team and release to the public. The JAXA validation leader is responsible for the overall progress management of the validation activities based on the reports, etc.

3.8.2.3 Validation team meeting(post-launch)

From launch to 9 months after launch (release of some L2 products to the public), validation team meetings will be held 3 times/year to check the progress of validation activities, share knowledge and discuss issues within the validation team. After 9 months from launch, the frequency will be reduced to twice a year.

3.8.2.4 End of prime mission review (3 years after launch)

The mission accomplishment status is evaluated based on the Success Criteria at the End of Prime Mission Review planned at three years after launch. Some of the evaluation items are the achievement status of the required accuracy of the products which is based on the validation results.

3.8.3 EO-RA

JAXA/EORC is conducting Research Announcement on the Earth Observations (EO-RA), and the validation team consists mainly of EO RA PIs/CIs. The third Research Announcement on the Earth Observations (EO-RA3) is for three years from JFY2022 to JFY2024, which includes the launch period. Subsequently, EO-RA4 is expected in JFY2025 2027 and will include much of the period of routine operations.

3.8.4 Workshops

JAXA ESA Joint Science and Validation Workshop was held in November 2023 to share information and discuss validation activities with ESA and the European validation team. About six months after launch, ESA-JAXA Preliminary Validation Results Workshop is planned to be held to share and discuss the results of the L1 product validation. Another workshop for L2 product is also planned.

3.9 JAXA Validation Campaigns

3.9.1 Cooperation with institutions

3.9.1.1 German Aerospace Center (DLR)

DLR has a research aircraft, HALO (High Altitude and Long Range Research Aircraft), to conduct airborne observations. A campaign observation using HALO called PERCUSION (Persistent EarthCare underflight studies of the ITCZ and organized convection) is planned for Aug.-Sep. 2024 to validate EarthCARE products and to study deep convection in the tropical region. The HALO will be equipped with sensors similar to those of EarthCARE and will conduct observations for 9 weeks, including under-flight observations with the EarthCARE satellite. The validation cooperation between JAXA and DLR will be carried out mainly through PERCUSION.

3.9.1.2 National Oceanic and Atmospheric Administration (NOAA)

We plan to cooperate with NOAA NESDIS (National Environmental Satellite, Data, and Information Service) in validation cooperation.

3.9.1.3 Cooperation with algorithm development

Issues identified in the product validation are fed back to the algorithm development team and utilized for algorithm improvement. The products generated by the improved algorithm are again validated, and the degree of improvement is evaluated. This cycle is repeated to improve the algorithm performance and accuracy of the products.

3.9.1.4 WhymSIE

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 EarthCARE 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	EarthCARE 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.

3.10.2 Top level coverage analysis

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	3	7	2	0	0	0	

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

An airborne campaign observation using HALO (High Altitude and Long range research Aircraft) called PERCUSION (Persistent EarthCARE underflight studies of the ITCZ and organized convection) is planned for Aug.-Sep. 2024 (Refer 3.9.1.1). The HALO will be equipped with sensors similar to those of EarthCARE and will conduct observations for 9 weeks, including under-flight observations with the EarthCARE satellite. The validation cooperation between JAXA and DLR will be carried out mainly through PERCUSION.

3.10.2.3 Airborne campaign locations

The airborne campaign areas and schedules are on the table as follows.

Mission phase	Dates
Preparation, Payload Integration, EMI Testing	17 June - 8 Aug 2023
Mission Execution Part I Cape Verde	9 Aug - 5 Sep 2024
Mission Execution Part II Barbados	5 Sep - 30 Sep 2024
Mission Execution Part III Oberpfaffenhofen	4 - 19 Nov 2024
Dismounting of payload	20 - 26 Nov 2024

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.

- Validation super site at Koganei
  This is an integrated observation site for EarthCARE validation, located at the NICT headquarters in Koganei, Tokyo. Combined observations will be conducted using the High Sensitivity Cloud Radar (HG-SPIDER), Electronically Scanned Cloud Radar (ES-SPIDER), L-band Wind Profiler, 2μm Doppler LIDAR, 355nm Doppler LIDAR, 355nm Multiple Field of view Multiple Scattering Polarization Lidar (MFMSPL), 355nm High Spectral Resolution Lidar (HSRL), microwave radiometer, sky radiometer, and all sky camera The rich dat a will be used to validate CPR o ne sensor echo products, CPR one-sensor cloud products, CPR ATLID synergy cloud products, and CPR-ATLID-MSI synergy cloud products.

- Ka-band scanning radars
  The National Research Institute for Earth Science and Disaster Resilience (NIED) owns five scanning Ka-band radars in Kanto region, Japan. Since the radar can observe a radius of 30km in three dimensions, it can be expected to acquire more match-up data than up-looking radars. Validation target are radar reflectivity factor and cloud mask. We are also planning to calculate the vertical profile of cloud water content by combining the data with nearby microwave radiometer.

- WINDAS
  WINDAS (WInd profiler Network and Data Acquisition System) is a wind profiler observation network operated by the Japan Meteorological Agency, with consists of 33 wind profilers around Japan. It constantly observes wind speed at 10-minute intervals and its vertical wind data is used for validation of doppler velocity of CPR one-sensor echo product. Since the typical spatial scale of doppler velocity variations is small, having a large number of observation points across Japan is important for obtaining more match-up data.

- AD-Net
  AD-Net (the Asian Dust and aerosol lidar observation Network) is a lidar observation network managed by the National Institute for Environmental Studies, which aims to observe aerosol vertical profiles in East Asia. In addition to Mie scattering lidar and Raman lidar, it also includes HSRL and MFMSPL. AD-Net will be used to validate the cloud and aerosol parameter of ATLID one-sensor product.

- All-sky camera network
  Automatic Cloud Photograph Acquisition System (TACPAS) operated by Tokai University and several all-sky cameras used to validation GCOM-C product which is managed by GCOM-C validation team will be used for validation of MSI one-sensor cloud product, in particular cloud flag.

- SKYNET
  SKYNET is a network of sky radiometer observation sites mainly in Asia and Europe, but also in the other regions. In addition to sky radiometers, other instruments such as microwave radiometers are also installed at some stations. Data from SKYNET will be used to validate aerosol and cloud extinction coefficient in ATLID one-sensor product, optical thickness in MSI one-sensor product, and liquid water path in CPR-ATLID-MSI synergy product.

- GEBA/BSRN
  The Global Energy Balance Archive (GEBA) is a database of surface radiation flux observations and archives monthly mean values. The monthly average of BSRN is included in GEBA, but BSRN are used when instantaneous data are required. Radiation flux (shortwave/longwave) in 4-sensor synergy product and cloud phase in MSI one-sensor product will be validated with GEBA/BSRN data.

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 AMSR3/GOSAT-GW

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.

ID: 2-1	TITLE: Validation of the EarthCARE L2 products using ground-based lidar and sunphotometry measurements.
PI: Dr. Tomoaki Nishizawa (National Institute for Environmental Studies, NIES)	
Institutions involved:	
Project summary	
Geolocation summary	East Asia
Correlative Instruments	EarthCARE Level 1 Product
	CPR_NOM
AD-NET lidar systems	-

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SKYNET radiometer network	-						
SAVERNET lidar systems	-						
Correlative Instruments	EarthCARE Level 2 Product						
	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: 2-2	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					

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Agence spatiale européenne

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

ID: 3	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: 4	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				

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Agence spatiale européenne

Methods that will be applied
Expected results from the activity

ID: 5	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: 6	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	EarthCARE Level 1 Product						
Instruments	CPR_NOM						
Mie-Scattering Lidar	-						
Correlative	EarthCARE Level 2 Product						
Instruments	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

<table>
<tr><td>ID: 7</td><td colspan="7">TITLE: Datasets of in-situ and Ka-band radar observations for the validation of EarthCARE products</td></tr>
<tr><td colspan="8">PI: Dr. Ryohei Misumi (National Research Institute for Earth Science and Disaster Resilience, NIED)</td></tr>
<tr><td colspan="8">Institutions involved:</td></tr>
<tr><td>Project summary</td><td colspan="7"></td></tr>
<tr><td>Geolocation summary</td><td colspan="7">Fog monitor: Tokyo Skytree (Sumida-ku, Tokyo)
Doppler radar: Tokyo (Nishitokyo, Ota-ku), Chiba (Matsudo), Ibaraki (Tsukuba), Saitama (Hidaka)</td></tr>
<tr><td rowspan="2">Correlative
Instruments</td><td colspan="7">EarthCARE Level 1 Product</td></tr>
<tr><td colspan="7">CPR_NOM</td></tr>
<tr><td>Cloud droplet spectrometer (Fog Monitor)</td><td colspan="7">-</td></tr>
<tr><td>Ka-band scanning Doppler radar</td><td colspan="7">D</td></tr>
<tr><td rowspan="2">Correlative
Instruments</td><td colspan="7">EarthCARE Level 2 Product</td></tr>
<tr><td>CPR_ECO</td><td>CPR_CLP</td><td>ATL_CLA</td><td>MSI_CLP</td><td>AC__CLP</td><td>ACM_CLP</td><td>ALL_LAD</td></tr>
<tr><td>Cloud droplet spectrometer (Fog Monitor)</td><td>-</td><td>D</td><td>-</td><td>-</td><td>D</td><td>D</td><td>-</td></tr>
<tr><td>Ka-band scanning Doppler radar</td><td>D</td><td>D</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="8">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”)</td></tr>
<tr><td colspan="8"></td></tr>
</table>

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

There are some web tools are available for validation. These tools are:

- EarthCARE product monitor (Quick Look):
  Website for a quick look of EarthCARE product.
  https://www.eorc.jaxa.jp/EARTHCARE/Quicklook/index_j.html
- EarthCARE predicted/confirmed trajectory map:

A web tool that displays predicted and confirmed orbit maps.
https://www.eorc.jaxa.jp/EARTHCARE/auth/orbit/rs/EC_orbit_view_j.html
https://www.eorc.jaxa.jp/EARTHCARE/auth/orbit/rs/EC_orbit_search_j.html

- Verification Data Archive System:
  A web system for searching and downloading ground/aircraft observation data for verification purposes.
  (The link will be provided later)

- Validation Matchup Web:
  A web tool for automatically generating matchup data and visualizing each case.
  (The link will be provided later)