2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop Report

ESA-EOPG-EOPGMQ-RP-2025-4

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop

17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

Table of contents

Report authors

Contributing co-chairs:

- Level 1 sessions: *Gerd-Jan van Zadelhoff, Hiroaki Horie, Luca Baldini, Minrui Wang, Oliver Reitebuch, Pavlos Kollias, Woosub Roh*
- Aerosol sessions: *David Donovan, Tomoaki Nishizawa, Ulla Wandinger, Yoshitaka Jin*
- Cloud & Precipitation sessions: *Alessandro Battaglia, Hajime Okamoto, Luca Baldini, Nobuhiro Takahashi*
- Aerosol, Cloud & Precipitation sessions: *Holger Baars, Kaori Sato, Shannon Mason, Takashi Nakajima*
- Synergy and radiation session: *Kentaroh Suzuki, Nicolas Clerbaux, Shannon Mason, Takashi Nakajima*
- Model, Science and Validation Application session: *Masaki Satoh, Robin Hogan*

Other contributors in alphabetical order:

- *Almudena Velázquez Blázquez*
- *Anja Hünerbein*
- *Eleni Marinou*
- *Holger Baars*
- *Jason Cole*
- *Nils Madenach*
- *Rene Preusker*
- *Rob Koopman*
- *Stephanie Rusli*
- *Takuji Kubota*
- *Toshiyuki Tanaka*
- *Vasileos Tzallas*

Introduction: EarthCARE mission

The Earth Cloud Aerosol and Radiation Explorer (EarthCARE) satellite mission, launched on 28 May 2024, is designed to advance our understanding of the role that clouds and aerosols play in reflecting incident solar radiation back out to space and trapping infrared radiation emitted from Earth's surface.

Developed within ESA's Earth Observation FutureEO programme, EarthCARE is the largest and most complex satellite in the series of Earth Explorer missions.

EarthCARE is a joint venture between ESA and JAXA, the Japan Aerospace Exploration Agency. JAXA provides the cloud profiling radar instrument. Both agencies have developed dedicated data products which have been subject to validation.

Introduction: EarthCARE In-Orbit Workshops

Validation workshops coincide with public data releases

Data Product Level	Release to ECVT	Public Release
Level-1	3 Months after launch	6 Months after Launch **14 Jan 2025**
Level-2a and two-sensor Level-2b	6 Months after launch	9 Months after Launch **17 Mar 2025**
Three and Four-sensor Level-2b	9 Months after launch	18 Months after Launch

1st ESA-JAXA EarthCARE In-Orbit Validation Workshop (online), 14-17 Jan 2025

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop (ESRIN), 17-20 Mar 2025

2025 ESA-JAXA EarthCARE In-Orbit Science and Validation Workshop, 1-5 Dec 2025

Workshop websites (presentation slides and workshop report are available for download):

https://www.earthcare-validation-2025-1.org/

https://www.earthcare-validation-2025-2.org/

Introduction: EarthCARE In-Orbit Workshops

1st workshop

The objectives of this workshop are as follows

- Discuss findings from initial validation activities related to Level 1 and early L2 products
- Formulate recommendations for product improvements
- Inform the broader scientific community of the quality of the publicly-released Level 1 dataset

Workshop report is available on the workshop website

2nd workshop

The objectives of this workshop are as follows

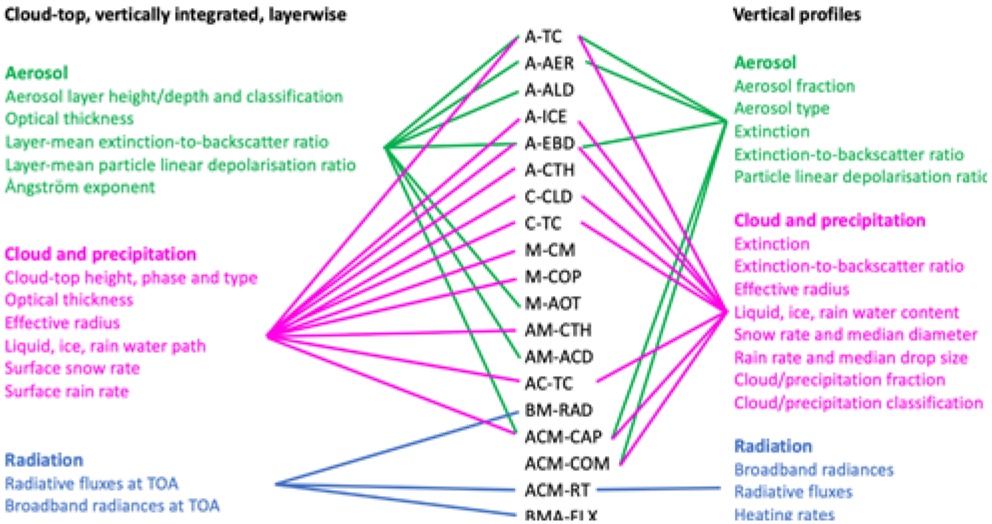
- Discuss findings from initial validation activities related to Level 2a and 2-sensor Level 2b products
- Review further findings on Level 1 product validation
- Formulate recommendations for product improvements
- Inform the broader scientific community of the quality of the publicly released Level 2a and 2-sensor Level 2b dataset

Introduction: 2nd workshop in numbers

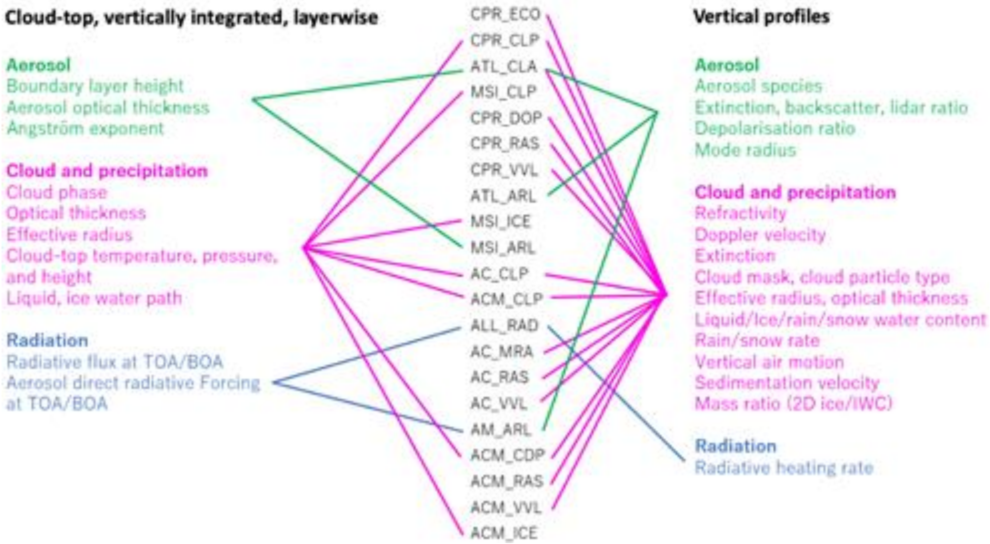
8	oral (topical) sessions	83	oral contributions (including summary presentations)
168	on-site participants	40	poster presentations
123	online participants	5	demonstrations of tools

Large number of EarthCARE products have been intercompared with a diverse and significant correlative data set (including 73 underflights).

Overview of ESA L2 products



Overview of JAXA L2 products



Information exchanges between algorithm developers and validation teams prior to this workshop has resulted in high quality of analyses.

Posters presented at the 2nd Workshop (1/4)

PDF file of the posters (when made available by the author) can be found on
https://www.earthcare-validation-2025-2.org/poster-list-demos

Poster number	Title	Author
1	An overview of of the European activities for the EarthCARE validation in the framework of ACTRIS/ATMO-ACCESS (EVID05)	Holger Baars
2	MSI and BBR geolocation and coregistration performance assessment: an update	Edward Baudrez
3	Comparison of ATLID/EarthCARE, IceSat-2 ATLAS andCALIPSO/CALIOP molecular and clouds measurements.	Marius Dahuron
4	Assessing EarthCARE Ability to Detect Polar Stratospheric Clouds Over Antarctica: Insights from Ground-Based Lidar Observations at Concordia Station	Alessandro Bracci
6	Evaluation of CPR products using mirror image profiles	Nobuhiro Takahashi
7	Some findings from CPR Level 1 products	Nobuhiro Takahashi
8	Dominant Ice cloud microphysical processes in cirrus clouds captured by ground doppler radar observations	Tatsuya Seiki
9	Surface Echo Detection in ATLID Observations: A Foundation for Cloud Profile Classification	Aiten Alava Baldazo
10	Validation of EarthCARE CPR Level 2 precipitation products in the central Mediterranean (EVID11)	Sabina Angeloni
11	Progress in COSP Lidar Simulator Development using ALADIN dataset and Prospective Applications for ATLID	Marie-Laure Roussel

Posters presented at the 2nd Workshop (2/4)

Poster number	Title	Author
12	Assessments of EarthCARE L2a CPR Echo product using ground-based W-band cloud radar observations	Yuichiro Hagihara
13	Low-level cloud observed by the EarthCARE Cloud Profiling Radar, validated against data from Jülich and NyÅlesund (EVID03)	Lukas Pfitzenmaier
14	Validation of EarthCARE cloud and precipitation products by the WegenerNet 3D Weather Research Facility (WEGN4CARE) - Initial results	Esmail Ghaemi
15	Preliminary Ground Validation of CPR Radar Reflectivity and Doppler Velocity Products at the Mario Zucchelli Antarctic Site Using the K2W Methodology with 24 GHz Doppler Radar and Disdrometer	Alessandro Bracci
17	Observation of an Arctic cirrus by groundbased lidar and balloonborne imager during an EarthCARE overpass	Peter Voelger
18	Studying the cloud layer detection from EarthCARE CPR to improve MSI cloud properties	Gregor Walter
19	Validation of EarthCARE aerosol products using data recorded in Northern-Norway (EVID 18)	Martin Flügge
20	ATLID and MSI Level 2 products validation with ground-based measurements at Lampedusa and Rome Italian observatories (EVID 11)	Daniela Meloni
21	Validation of EarthCARE Level 2 Aerosol and Cloud Products Using Ground-Based Observations from E-PROFILE and AERONET Networks (EVID 41)	Onel Rodríguez Navarro

Posters presented at the 2nd Workshop (3/4)

Poster number	Title	Author
22	Effects of multiple scattering in cirrus clouds in ACTRIS-SCC retrievals for the validation of ATLID L2 optical products (EVID14)	Diego Alves Gouveia
23	First Intercomparison of EarthCARE's ATLID Level 1 and Level 2 Aerosol Products with Ground-Based Lidar Observations in Thessaloniki, Greece	Georgia Peletidou
24	The relevance of a GAW regional station for correlative lidar measurements supporting ATLID product validation	Doina Nicolae
25	Synergistic exploitation of aerosol products using polar-orbiting and geostationary passive satellites in conjunction with the EarthCARE mission	Konstantinos Michailidis
27	First validation results of ATLID L2 product using a high-power ground-based lidar in Finland	Maria Filioglou
28	Exploring aerosol composition and optical thickness: Validation of EarthCARE ATLID AOD with CAMS forecast	Xuemei Wang
29	Level 2a M-AOT product evolution and verification	Nicole Docter
30	Validation of ATLID Level 2A Products Using Potenza Ground-Based Measurements (EVID05)	Christina-Anna Papanikolaou
31	Evaluation of the EarthCARE aerosol classification scheme using ACTRIS/EARLINET automated aerosol typing methods	Kalliopi Artemis Voudouri
32	LITES lidar in the UK: Intercomparisons with ATLID level-2A products	Avinash Yadav

Posters presented at the 2nd Workshop (4/4)

Poster number	Title	Author
33	Validation of the EarthCARE ATLID and MSI ESA aerosol products using ground-based lidar and sunphotometry measurements in East Asia	Tomoaki Nishizawa
34	Evaluation of EarthCARE aerosol backscatter profiles with ceilometers (EVID-36)	Larisa Sogacheva
35	Product quality monitoring and evolution of the EarthCARE's A-LAY processor	Athena Augusta Floutsi
36	Product quality monitoring and evolution of the EarthCARE's AM-COL processor	Athena Augusta Floutsi
37	Validation of EarthCARE MSI thermal-infrared radiation measurements – First comparisons to airborne spectral imaging during PERCUSION (EVID03)	Sophie Rosenburg
38	Validation of BBR TOA broadband irradiance by high altitude airborne solar and thermal-infrared radiometer measurements	André Ehrlich
39	EarthCARE BBR Validation Results within the BRAVO project	Christine Aebi
41	DISC visualization tools for ATLID L1 and L2 product validation	Andreas Karipis
42	The McGill EarthCARE Imagery Portal	Bernat Puigdomènech Treserras
43	Comparison of MSI radiances and brightness temperatures with MSI-Tool based simulations for dust, ice and liquid clouds	Nils Madenach

Tool demonstrations at the 2nd Workshop

Atmosphere Virtual Lab (AVL) – Sander Niemeijer
ESA Atmospheric Validation Data Centre (EVDC) – Jarek Dobrzanski
EarthCARE DISC (Data, Innovation, and Science Cluster) tools – Eleni Marinou
MAAP: Multi-Mission Algorithm and Analysis Platform – Saskia Brose
DIVA platform – Alexandru Dandocsi

BBR Level 1 summary and recommendations

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop

17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

BBR L1 presentations

EarthCARE BroadBand Radiometer (BBR) Level 1 Performance - Nicolas Clerbaux

- The Chopper drum has been running mostly at 75% of CDM speed (along track res. ~1113 m)
- Assessment domain used is 5x21 JSG pixels (nadir ~8x19 and aft /fore ~5x19 pixels)
- Calibration is performed each 88 sec between cold ~260K and warm ~302 K Black Body
- B-SGN noise ~0.8 W/m2/sr but reduced during domain's integration.
- There is a visible detector-to-detector variability (mostly in the aft and nadir views)
- Update of B factors has been proposed to solve this and will result in lower SW radiances and fluxes. Laser gain correction factor C will also be updated to new value ~1
- Testing on the impact of L1 changes in BM-RAD and BMA-FLX will start soon.
- Since Jan/Feb several L1 data have been missing due to a threshold reached with the Calibration Target Mechanism (CTM) encoder. Update on the CCDB will be done to prevent missing more data. Data will be recovered during reprocessing

BBR products evaluation with respect to CERES – Nicolas Clerbaux

- Solar products (L1 & L2) too high of ~9% brighter w.r.t CERES
- Thermal products too low of ~3% lower w.r.t CERES
- The proposed changes in L1 processing (see previous talk) will significantly improve the agreement with CERES.

BBR L1 conclusion and recommendations

Positive findings about the data quality since the 1st Workshop
Update of B factors has been proposed and will result in better values in the SW.

Aspects identified for improvement since the 1st Workshop and proposed way forward
Since Jan/Feb several L1 data have been missing due to a threshold reached with the CTM encoder. Update on the CCDB will be done to prevent missing more data. Data will be recovered when reprocessing.

Products or aspects are not yet (optimally) validated
Testing on impact of the L1 changes in BM-RAD and BMA-FLX will start soon.

Which issues have been addressed since the 1st Workshop and which issues remain?
Addressed: Proposed update on B factors. Not addressed: Collocation campaigns with CERES not yet organised.

Recommendations/suggestions for future L1 validation activities (e.g. validation needs, gaps) and for mission planning
Suitability of L1 for reduced CDM speed, i.e., 60% (lifetime consideration) -> 24 h campaign suggested.

MSI Level 1 summary and recommendations

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop

17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

MSI L1 presentations

EarthCARE MSI L1 performance and vicarious calibration – Rene Preusker

Reported the results of MSI L1c radiometric verification after baseline AF update. Various methods of vicarious calibration for MSI L1c are also mentioned.

- Still MSI VNS bands are systematically too high compared to SEVIRI and FCI (~10%).
- Although the ‘solar irradiance measurement’ is only 5-6% off, the reflectance is 3% too high in VIS and 10% higher at 1.6µm.
- The diffuser (ground) characterization cannot be trusted, and calibration is necessary particularly for VNS band.

Cross-satellite validation of MSI L1 data using collocated SEVIRI and FCI observations – Sebastian Bley

- VNS bands too bright in contrast to SEVIRI (17 % for VIS)
- VNS bands too bright in contrast to FCI (10 % for VIS)
- Excellent agreement for TIR bands (both vs SEVIRI and vs FCI).
- Uncertainties in L1 data will directly affect L2 products

MSI L1 conclusion and recommendations

Positive findings about the data quality since the 1st Workshop

Excellent agreement for TIR bands (both vs SEVIRI and vs FCI).

Aspects identified for improvement since the 1st Workshop and proposed way forward

- MSI VNS bands are still systematically too high compared to SEVIRI and FCI (~10%). Although the ‘solar irradiance measurement’ is only 5-6% off, the reflectance is 3% too high in VIS and 10% higher at 1.6µm.
- The solar calibrations via diffuser: measurements and temporal variations are not understood, and calibration particularly for VNS bands are needed (vicarious calibration).

Products or aspects are not yet (optimally) validated

VNS bands (because of the calibration issues)

Which issues have been addressed since the 1st Workshop and which issues remain?

MSI solar irradiance issue - way forward: MSI theoretical spectral solar irradiances will be used in the operational environment and for the re-processing, instead of measured, diffuser based solar irradiances.

Recommendations/suggestions for future L1 validation activities (e.g. validation needs, gaps) and for mission planning

Need of evaluation of the re-processed L1 data (baseline AG)

ATLID Level 1 summary and recommendations

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop

17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

ATLID L1 presentations

Evolution and status of the ATLID L1 processor – David Donovan

- Described all the updates which have taken place since the beginning (noise spikes, discontinuities, spurious 20km features, Hot Pixels etc..)
- Hot pixels (nasty) → regular operational dark count measurements
- Health of every pixel has to be tracked
- Depolarisation ratio was too low for baseline AC and earlier, hopefully now better results (TBD) from baseline AD onwards
- Status of L1 AE: L1 data looks to be of good quality

Near-real time monitoring of ATLID L1 data using NWP – Mark Fielding

- ECMWF Quality Control: Rapid detection of instrument issues, continuous evaluation
- There are good signs that the assimilation is working and improving cloud fields
- ATL L1b total backscatter evaluation is stable for ice clouds and very close to the Calipso measurements
- Bias in the Arctic in AE looks a lot better since AD, also the South Atlantic Anomaly seen in AC is gone

ATLID L1 presentations

Using a Daily Flow of L1 and L2 Data for Statistically Based Calibration/Validation Control of ATLID – Artem Feofilov

- L1 results, combining all baselines in time showing the evolution.
  - Baseline AD show a day/night bias, the bias is removed when moving to AE baseline
  - Mean stratospheric signals are quite stable, both daytime and nighttime ones
  - Seasonal behaviour of daytime noise is observed in all 3 channels
- L2 analysis with clusters shows stable behaviour starting from Baseline AB (using A-EBD)

Validation of ATLID L1 products using airborne measurements with the research aircraft HALO during the PERCUSION campaign: Comparison of different L1 Baseline versions – Martin Wirth

- ATLID L1 data very good performance !
- AA: showed Mie signals in Rayleigh channel & depolarisation well below HALO
  AB: improvement in cross talk correction, depolarisation improved but still smaller
  AE: Mie signals still below zero in clean atmospheric region! Depolarisation further increased in the expected range
- Sometimes still visible cross-talk from Mie to Rayleigh channel, but greatly enhanced from baseline AC on, but still not perfect in AE.
- Signals are sometimes significantly negative, or positive where they should be zero (e.g. below opaque clouds), even for baseline AE.

ATLID L1 presentations

The ATLID laser beam observed by the cosmic ray observatories Pierre Auger (Argentina) and Telescope Array (USA) – Oliver Reitebuch

- They can measure exact energy in the UV lidar beam. First measurements were for the Aeolus UV lidar beam.
- ATLID much easier to observe due to nighttime overpass every 25 days.
- Laser energy show oscillations between 31.3 and 33.0 mJ (specific for ATLID)
- Median departure geolocation < 100 m (preliminary)
- Reconstruction of laser beam and energy is on-going work
- In Baseline AC (AD was wrongly reported) there was a timeshift by 66 seconds of laser energy records; this has been corrected thanks to this work.
- ATLID can be used as calibration "star" for cosmic-ray detection astronomy!

Validation of depolarization ratio of ATLID with low, medium and highly depolarizing targets – Moritz Haarig

Reported comparison with ground-based lidars and provided a statistical comparison of baseline AC, AD and AE:

- Baseline AC:
  - Daytime depolarization ratio too low (offset bug) → fixed in baseline AD
  - Depolarization in cirrus too low → fixed in baseline AE
- However, depolarization ratio in aerosol regime (<30%) seems to be overestimated in baseline AE → needed to be checked

ATLID L1 presentations

On-orbit Validation of Space-Lidar Depolarization Profiles – David Winker

Provided insights into the depolarization calibration using the polarization gain ratio (PGR) for CALIOP

- inserting a depolarizer into the receive-optics that both channels see the same signal
- Daytime PGR using the Cirrus background method (Liu et al. 2004)
- Opaque Water Cloud (OWC) method (day/night) (Y Hu et al. 2007) – also applicable for ATLID, but it was discussed, how the methods perform with the larger Rayleigh background in the UV.

Validation of EarthCARE ATLID Level-1b Profile Products Using Airborne Lidar Observations from NASA's HSRL-2 and HALO Lidars – Chris Hostetler

Highlighted the results from the validation of ATLID using NASA´s UV HSRL-2 on the high-flying aircraft ER-2 and from the HALO-lidar instrument (on GIII) from 4 airborne campaigns starting in August 2024.

- Very impressive comparisons were shown for L1 products (Ray and Mie co-polar ATB´s), and the derived scattering ratio – even below clouds and for low values of the scattering ratio
- For the Mie cross-polar channel lower values are seen by ATLID as compared to airborne HSRL-2
- An upcoming airborne campaign is planned from Bermudas mainly focusing on night-time flights in September 2025 with the UV- HSRL-2 on the NASA Gulfstream III.

ATLID L1 conclusion and recommendations

Positive findings about the data quality since the 1st Workshop

- Status of L1 AE: L1 data looks to be of good quality and performance
  - ATL L1b total backscatter evaluation is stable for ice clouds and very close to the Calipso measurements
  - Bias in the Arctic in AE looks a lot better since AD, also the South Atlantic Anomaly seen in AC is gone
  - Baseline AD show a day/night bias, the bias is removed when moving to AE baseline
  - Mean stratospheric signals are quite stable, both daytime and nighttime ones
  - Seasonal behavior of daytime noise is observed in all 3 channels
- ATLID can be used as calibration star for astronomy!
- Daytime depolarization ratio that was too low (offset bug) in baseline AC is fixed in baseline AD
- Depolarization in cirrus that was too low in baseline AC is fixed in baseline AE
- Very impressive comparisons were shown for L1 products (Ray and Mie co-polar ATB´s), and the derived scattering ratio – even below clouds and for low values of the scattering ratio

ATLID L1 conclusion and recommendations

Aspects identified for improvement since the 1st Workshop and proposed way forward

- Hot pixels (nasty) → regular operational dark count measurements
- Health of every pixel has to be tracked! → this in the meanwhile has been implemented.
  - If corrected by DCM, then they are not flagged because already corrected in L1 data
  - if corrected by adaptive Hot Pixel algorithm (L1 post processing) -->flagged.
- Depol ratio was too low, improved with Baseline AD and AE, but need to be confirmed by validation activities —> check for validation results in next subgroup meeting and next workshops
- Signals are sometimes significantly negative (Mie signals still below zero in clean atmospheric region) or positive where they should be zero (e.g. below opaque clouds), also for baseline AE. → is under investigation, promising results have been achieved with improved updated HR-LR background factors (to be implemented for Baseline BA)
- Sometimes still visible cross-talk from Mie to Rayleigh channel, but greatly enhanced from baseline AC on, but still not perfect in AE → might be linked to the item above, but also under investigation
- In Baseline AC (wrongly reported to AD) there was a timeshift by 66 seconds in the energy normalization appled → was fixed with AD
- Depolarization ratio in aerosol regime (<30%) seems to be overestimated in baseline AE → will be further investigated
- For the Mie cross-polar channel lower values are seen by ATLID as compared to airborne HSRL-2 → is/will be investigated with the general depolarization issue

ATLID L1 conclusion and recommendations

Products or aspects are not yet (optimally) validated

It seems that most ATLID related products are well covered by the validation teams

Which issues have been addressed since the 1st Workshop and which issues remain?

- Too low depolarization ratio has been addressed and improved but needs further confirmation. Checks that the depol in low-depol regimes (i.e. depol cross-talk correction) should also be done.
- Negative/positive signals where they should be zero. Should be fixed in AD (better HR-vs-LR background factors) but verification is necessary.
- 20 km issue improved but a more fundamental fix (i.e. Fix based on non-ideal charge transfer fix) may produce better result.
- In general L1 is of good quality now (day and night) even though some issues remain

Recommendations/suggestions for future L1 validation activities (e.g. validation needs, gaps) and for mission planning

- Checking other depol calibration methods might be worthwhile when baseline BA is available,
- e.g. depolarization calibration using Opaque Water Cloud (OWC) method (day/night) (Y Hu et al. 2007) as proposed by Dave Winker or background signal from opaque cirrus as discussed by Ulla Wandinger (but needs to check how the methods perform with the larger Rayleigh signal background in the UV).

CPR Level 1 summary and recommendations

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop

17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

CPR L1 presentations

CPR processor & product overview – Nobuhiro Tomiyama

- Introduced CPR L1b update plan from vCa to vCb with calibration factor (-1.60dB)
- Since early December the I/Q offset is not an issue anymore
- Update plan for the antenna beam pointing correction (L+18M)
- Target accuracy check plan (L+3Y), first confirmation (L+18M)

Near-real time monitoring of CPR L1 data using NWP – Mark Fielding

- Near Real Time power calibration monitoring using the CloudSat database and the ECMWF data assimilation system
- Known issue (2nd trip echo and around 2500m height echo) are removed.
- 12 hour-mean ice cloud retrieval 4dB, 2dB, and 0.4dB difference to CPR L1b vBa, vCa, and vCb respectively

Intercomparison of spaceborne cloud radar data between CloudSat and EarthCARE with AMSR2 data – Kaya Kanemaru

- NRCS compared to CloudSat under same wind condition using AMSR - 1.70dB difference (vCa)
- Gas attenuation calculation differ from CloudSat (2B-GEOPROF) and CPR (JAXA L2 ECO)

CPR L1 presentations

Comparison of Doppler velocity measurement across CPR observation modes – Yuki Imura

- Accuracies of Doppler velocity at 3 observation modes (20km, 18km, 16km) are checked. 18km mode shows good performance
- Contamination of mirror echo at 18 km mode is only 0.34%
- The 18 km mode is recommended

CPR External Calibration by Active Radar Calibrator and CPR Level 1/Level 2 Product Validation – Hiroaki Horie

- Calibration Factor by ARC External calibration is proposed to -4.0dB (applied in vCb)
- Compare Z factor and Doppler velocity to NICT HG-SPIDER. They agree (L2 vBa equivalent)

Assessing CPR radar reflectivity and doppler products with airborne observations from the PERCUSION campaign – Florian Ewald

- HALO 35 GHz radar data converted at 94 GHz using (Pfitzenmaier et al.) are compared to CPR (4dB difference)
- Sensitivity of ~-36dBZ is confirmed
- NRCS with incidence angle data are obtained by roll flight

CPR L1 conclusion and recommendations

Positive findings about the data quality since the 1st Workshop

- The update from vCa to vCb increased the echo power level by 1.6dB, resulting in a value even closer to the radar reflectivity of CloudSat.
- The different power calibration methods (use of the ARC, use of CloudSat's sigma-0 and ice clouds climatology) agree within 0.5 dB or better regarding the power calibration of the CPR.
- Since early December, the IQ imbalance issue that affected the Doppler velocity quality at dBZ's lower than -10 is fixed. Now the Doppler is recoverable down to -20 to -25 dBZ.
- Algorithms to identify (and mitigate) mirror images due to the use of a high PRF have been developed.

Aspects identified for improvement since the 1st Workshop and proposed way forward

- Fix the error of TxRxStatusFlag after the internal calibration.
- Implementation of the antenna pointing correction in L1b (Format update TBD, JAXA, L+18M).
- Modification of the disturbance in the received power correction item

Products or aspects are not yet (optimally) validated

- Microphysical retrievals of Raindrop/particle sizes (using weather radar networks) (Level 2)
- McGill's Doppler velocity antenna pointing corrections
- CPR receiver noise and its utility for 94-GHz Tb measurements

CPR L1 conclusion and recommendations

Which issues have been addressed since the 1st Workshop and which issues remain?

- Antenna pointing - JAXA will use the five thermal sensors around the antenna to characterize the antenna mispointing. They've identified a preliminary correction, which is currently applied at L2, but the plan is to eventually migrate it to L1b. To support this, two additional variables will be included in C-NOM, allowing to reverse engineer their correction. ESA integrated the C-APC processor into the operational chain.
- Artifacts at ~2.5 km altitude – JAXA confirmed these are not related to Rx saturation. It's most likely a range-weighting function sidelobe contamination. Not sure about the way forward but must probably this will have to be addressed in the L2
- Noise floor – currently averaged every 14 profiles; likely not measured continuously, but rather at regular intervals. ESA developers suspect that the Rx temperature calibration may be interfering with the signal. JAXA will investigate further
- Radar calibration – McGill, ECMWF, and JAXA agree within 0.4 dB. The ARC surface calibration activity will continue for a few more months
- Spectrum width – improvements have been made, but abrupt transitions remain when the PRF changes
- Surface detection – still invalid under strong attenuation conditions. We are not able to fully reproduce their surface detection algorithm and s0 estimation.
- Additional information on Doppler standard deviation, high-level cloud fraction, and mirror image has been provided in order to support the preference of using the 18km mode in CPR operations. Final decision to be made.

Recommendations/suggestions for future L1 validation activities (e.g. validation needs, gaps) and for mission planning

- High latitude mixed-phase clouds
- Marine clouds

Aerosol, cloud and precipitation summary

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop

17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

Summary of talks

Best Practice Protocol for the Validation of Aerosol, Cloud, and Precipitation Profiles (ACPPV) – Eleni Marinou

- Efforts of ~100 international scientists to define best practices
- Has been reviewed and now published: https://ceos.org/publications-key-documents/ and with DOI: https://zenodo.org/records/15025627
- Use for EarthCARE validation needs still to be promoted

Overview and status of the ATLID Feature mask (A-FM) and profile processor (A-PRO) – David Donovan

- A-FM provides a feature-mask at the highest available resolution.
- A-PRO uses A-FM, A-NOM and X-MET as input and applied adaptive smoothing (output 3 different resolutions, partly based on on optimal estimation) for generating Aerosol and cloud optical properties, Target Classification, Aerosol type
- First comparisons of A-EBD and CAMS aerosol forecast shown with promising results
- Differences in the products of A-Pro by resolution and technique highlighted!

NOTE: The recommendation and key points from the talks above have been included in the Conclusion & Recommendations of the respective topics (aerosol or cloud & precipitation)

Summary of talks

Intercomparison and validation of ATLID, CPR, and synergistic target classification product – Shannon Mason

- AC-TC includes A-TC & C-TC classifications, projected onto JSG. Synergistic target classification is *mostly* a simple merging, but some interpretation still required. It's a relatively simple product, but very information-dense.
- Also Instrument Status is provided (what is seen by which instrument)
- Several validation needs have been presented

EVID17: EarthCARE Cal/Val Using the NASA Micro Pulse Lidar Network (MPLNET) – Jasper Lewis

- NASA-led Global Network of automated 532-nm elastic backscatter lidars in synergy with AERONET (L2 data only available if AERONET L2 is available), Will use CALIPSO for comparison as well
- Aim for statistical validation of ATLID L2 products, including aerosol, cloud, and PBL heights with emphasis on time-gridded diurnal products with the goal of assessing representativeness
- Report that EarthCARE horizontal resolutions (high, medium, low) can affect results

NOTE: The recommendation and key points from the talks above have been included in the Conclusion & Recommendations of the respective topics (aerosol or cloud & precipitation or synergy)

Summary of talks

Validation of EarthCARE ATLID and CPR products using Cabauw measurements: preliminary results (EVID14) – Arnoud Apituley

- Various cal/val studies for L1 and L2 products (innc. Synergistic products) using data from Cabauw ACTRIS site underlining the excellent condition of EarthCARE.
- Aim to investigate multiple scattering effects in Currus - first approaches presented

BAIVEC project - Validation of Atlid products using the in-situ aerosol and cloud measurements performed with the LOAC2 instrument under weather balloons – Jean-Baptiste Renard

- Ballon-bonre aeroso in-situ observations (10 flights) including tropospheric cloud and PSC conditions
- Report ATLID extinctions to be overestimated in the upper troposphere and in the stratosphere under cloud free conditions
- Good agreement in clouds and wrt feature detection but unrealistic extinction above 40 km.

NOTE: The recommendation and key points from the talks above have been included in the Conclusion & Recommendations of the respective topics (aerosol or cloud & precipitation)

Summary of talks

Validating from within: early Level 2 product intercomparison from CELLO-ORCESTRA – Tim Carlsen

- Airborne Aerosol/cloud in-situ measurements during Orcestra Cabo Verde (Cello)
- First validation approaches wrt ATLID targets → A-TC matches in-situ observations but discrepancy between observed
  and retrieved C-CLD:AB LWC.

Surface Validation During the EarthCARE Commissioning Cal/Val Campaign in Ottawa (ECALOT) – Zen Mariani

- Surface and airborne observations, validation of:
  - X-MET (indicate good agreement for q, T, and winds),
  - Cloud base height and hydrometeor classification (Excellent agreement in cloud base height & precip type found for several cases
- Aim to investigate additional variables, like A-EBD etc

NOTE: The recommendation and key points from the talks above have been included in the Conclusion & Recommendations of the respective topics (aerosol or cloud & precipitation)

Summary of talks

Validation of EarthCARE's ATLID L2a cloud and aerosol products using co-located independent airborne lidar profile data observed during the PERCUSION field campaign – Konstantin Krüger

- DLR HALO aircraft with EarthCARE payload during PERCUSION
- Focus on
  - A-TC:High agreement between A-TC (liquid+ice) cloud, overestimation of high-altitude clouds (because too thick, too horizontally wide-spread), but sometimes aerosol pixels at cloud edges.
  - A-CTH: Accuracy requirements (300 m) are met for the majority (66 %) of the data, Indication of an overestimation of cloud tops heights

Comparison between EarthCARE and ATR42 measurements and products during the MAESTRO field campaign – Nathan Feuillard

- EarthCARE payload onboard SAFIRE aircraft around Cabo Verde and Toulouse, France
- Consistent comparisons (same orders of magnitude) of particle backscatter coefficient, particle extinction and lidar ratio
- Consistency comparisons of classification but there are some discrepancies with the surface or sub-surface classification instead of warm liquid cloud.

NOTE: The recommendation and key points from the talks above have been included in the Conclusion & Recommendations of the respective topics (aerosol or cloud&precipitation)

Aerosol summary and recommendations

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop

17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

Aerosol presentations

Overview of L2 aerosol products produced by ESA and JAXA – Tomoaki Nishizawa

- JAXA ←→ ESA Aerosol algorithm and product overview
- Good concise overview of available JAXA and ESA aerosol products.
- Differences and similarities between approaches were covered

Comparison of ATLID aerosol products produced by ESA and JAXA – Ulla Wandinger

- Emphasized the different scales and techniques for all the aerosol products
- Discussion about different averaging approaches is needed.
- Generally good agreement of JAXA/ESA and ground-based lidar products
- Having both JAXA and ESA algorithms/products allows for consistency checks and increases the confidence in both sets of products

Evaluation of JAXA ATLID L2a products using AD-Net lidars – Yoshitaka Jin

- Good results for JAXA aerosol lidar products
- PBL height retrievals look plausible.
- Cloud case: Reasonable agreement. Good depol agreement.
- More results expected when dust season is in full swing

Aerosol presentations

Evaluation of the ATLID integrated surface returns for calibration and retrieval of an independent column-integrated aerosol – Diko Hemminga

- Use of Sea Surface return for AOD estimation.
- Good initial results ! CAMS comparison presented.
- If AOD is assumed could be used as 10-meter wind retrieval.

Monitoring and assimilating EarthCARE ATLID aerosol products in ECMWF's IFS-COMPO – Will McLean

- ECMWF Aerosol monitoring and Assimilation preparation studies. Eventually both (L2) backscatter and extinction will be used. Near-real time monitoring of L2 aerosol product will begin.
- Work based on earlier ALADIN work
- Work is still in early days but promising.

Assessment of ATLID stratospheric performance using ground-based lidars and satellite limb aerosol profiling – Sergey Khaykin

- Stratospheric work: nice comparison of Ruang results.
- Dedicated Stratospheric processing (by LATMOS) based directly on Level 1 gives good results for ATLID.
- Very good NDACC lidar vs ATLID
- ESA L2A product comparisons not very good
- ATLID ESA processing is focused on Troposphere. Dedicated stratospheric processing makes sense.
- GSAW ATLID Viewer looks nice

Aerosol presentations

Validation of EarthCARE products under ACROSS Mediterranean activities (EVID23) – Eleni Marinou

- L1 lidar tool comparisons: Good and less-good but generally good results.
- L2 comparisons: very good layer detection, depolarisation in AD better than in AE and AC ?
- Improvements in classification are needed. Improvements with baselines are visible. Layering improvements are needed?

EarthCARE Aerosol products intercomparison with CARO Polly Lidar in Limassol, Cyprus – Rodanthi Elisavet Mamouri

- Fair cirrus S even though 25 km difference.
- 04365D: Nice Dust case…S and Depolarisation good but A-TC is not perfect. Maybe a good case for tuning of depol-S space -vs- type ?
- Look at back trajectories….to aid in comparisons ! Tools…a recommendation ?

Validation of EarthCARE L2a products using ground-based lidar measurements at Cabo Verde, in the framework of the German Initiative for the Validation of EarthCARE (GIVE) – Henriette Gebauer

- Mindelo: Issues with S and depol when dust layer above (cloudy) marine BL
- Layering going wrong when water clouds are around?
- Lower resolution slightly better agreement with Polly than higher resolution for aerosols

Aerosol presentations

Airborne lidar measurements: PERCUSION's contribution to validate EarthCARE ATLID L2 optical properties – Silke Gross

- WALES: 13 Aug 24, 01193E (dust/mixture case)
- Again: layering issues when water clouds are around ?
- Conclusion: Aerosols when BL clouds are around needs attention.
- Problem with depolarisation going from HR to Med and LR ?

Validation of EarthCARE Aerosol Products Using Ground-Based Lidar and UAV Observations in Cyprus and Greece – Franco Marenco

- Cyprus: Sea Salt under clouds...should be filtered or set to unknown…consequence of low SNR depolarisation ?
- Decent consistency between In-situ and with A-TC aerosol types.
- Need simple to use A-TC confidence flag.
- Spatial variability in aerosols should be investigated.

Aerosol presentations

EMORAL lidar ATLID L2 data validation effort: contribution to EVID47 – Iwona Stachlewska (presented by Afwan Hafiz):

- EMORAL lidar used at different locations close to EC track
- Scattered results, compare SCC with in-house SW
- A comparison of target classifications was attempted (generally agreed, some discrepancy).
- ATLID extinction in fog was much stronger than EMORAL lidar

Validation of EarthCARE ATLID aerosol products using EARLINET measurements: preliminary results – Ping Wang

- Statistical approach with data from different stations
- Explicit about quality control procedures as well as other selection criteria
- To be clarified if the best TC has been used

First Insights into ATLID Level 2A Data: Comparisons with ACTRIS/EARLINET observations as part of EVID05 – Christina-Anna Papanikolaou

- Often excellent agreement, but sometimes not… Why ?
- Calculation of errors in percentage for very small values of measurement may cause misleading

Aerosol presentations

An Initial Assessment of EarthCARE ATLID and MSI ESA L2a Uncertainties (NEVAR, EVID38) – Kerstin Stebel

- Detailed assessment of reported uncertainties: important to look at
- MSI focused
- M-AOT is not doing so bad (vs AERONET)!
- Even ATL_ALD vs AERONET is not bad

Progress of CAL/VAL activities for EarthCARE aerosol products at SPU Lidar Station, Brazil – Eduardo Landulfo

- Sao Paulo: Good layered aerosol case.
- Station is in the middle of the South Atlantic Anomaly…to be checked if they are more radiation-spike affected.
- Comparing A-ALD and Aerosol AOD for different sites (different surface conditions).

Aerosol Conclusion and Recommendations

Positive findings about the data quality

- Generally good agreement with JAXA/ESA products and ground-based lidar
  - PBL height retrievals look plausible.
  - Good depol agreement.
- ESA ATLID L2 products
  - Decent consistency between In-situ and with A-TC aerosol types
  - Aerosol level 2 intercomparisons: Often excellent agreement often. But sometimes not! → reasons to be investigated
  - very good layer detection
- Stratospheric performance: independent processing based directly on L1 gives good results for ATLID: great comparisons with NDACC
- Evaluation of the ATLID integrated surface returns for column-integrated aerosol gives good initial results, also with respect to CAMS
- Near-real time monitoring of L2 aerosol product @ ECMWF will begin soon.
- ATLID and MSI ESA L2a: AOT is not doing so bad (vs AERONET)

Aerosol Conclusion and Recommendations

Aspects identified for improvement and proposed way forward

- EarthCARE agency L2 products not good in Stratosphere (as expected as by product, the user's own dedicated stratospheric processing based on ATLID L1 gives very good results)
- ATLID extinction in fog was much stronger than EMORAL lidar
- Layer and target identification
  - Issues with lidar ratio and depolarisation when dust layer above (cloudy) marine Boundary Layer, e.g. Cabo Verde
  - Layering going wrong when water clouds are around (and general)
  - Deviations in A-TC in dust case
  - Sea Salt under clouds...should be filtered or set to unknown…consequence of low SNR depolarisation? (Cyprus)
  - differences in target categorization depending on different resolution
- Different resolutions in A-EBD:
  - Problem with: depolarisation going from HR to Medium and LR ?
  - EarthCARE horizontal resolutions (high, medium, low) can affect results
- Documentation:
  - Dependency of these different products needs to be documented in an accessible way
  - Averaging strategy (layer based even in high-res products) need to highlighted

Aerosol Conclusion and Recommendations

Products or aspects are not yet (optimally) validated

Validation needs identified by ESA/DISC:

- ATLID vs ground-based comparisons presented ranged from very good to “not-so-good”. It is currently unclear under what circumstances the comparisons are not good.
  → Please try to identify contributing factors (circumstances (e.g. when low broken clouds are present?).
- Feature mask and Target classification validation is desired
- Check layer identification as lidar ratio, depolarisation and R_{eff} are layer-based even though vertical resolution of extinction in A-EBD is 100 m and 1 km
- Otherwise, the ATLID products seems to be well covered

Aerosol Conclusion and Recommendations

Recommendations/suggestions for future L1 validation activities (e.g. validation needs, gaps) and for mission planning

Recommendations towards ESA/DISC:

- Change medium resolution of A-EBD to 10 km. →This has been implemented and will appear with baseline BA. It is then aligned with resolution in equivalent Japanese ATLID products.
- Organise discussion on how to validate the target classification (e.g., supercooled water from CPR, supercooled drizzle and rain classification, classification in PBL, simplification of classification) and investigating impacts on higher level products
- L2 outreach is needed !
  - Make clear guide for use of A-AER and A-EBD
  - When averaging depolarization ratio and lidar ratios for comparison with ground-based lidar, backscatter or extinction (backscatter is better?) weighted averaging is needed (but L2a backscatter or extinction sometimes includes extreme values?) → DISC to identify the reasoning for extreme values → and then clear recommendation how to average desired
  - Different resolution for A-EBD and A-AER product: Dependency of these different products is not clear to some users → guidance to documentation?

Aerosol Conclusion and Recommendations

Recommendations/suggestions for future L1 validation activities (e.g. validation needs, gaps) and for mission planning

Recommendations towards validation teams:

- The 100 km criteria is used to set the collocation for the provided overpass tables→ it is not set in stone for validation analysis
- Best practice document for validation of space-borne profilers published: https://zenodo.org/records/15025627 - please use it!
  - E.g., 100km radius should not be taken as absolute. Depends on conditions (see also discussion in CEOS Validation Protocol). Some cases will need back trajectories. Also checking MSI image for gradient between station and ATLID
- There is value to in looking at and using both ESA and JAXA products
- Same L2 Baseline can be based on different Level 1 Baseline → always indicate time of processing.
- Use only data between the “frameStartCoordinates” and “frameStopCoordinates”
- Check layer identification as S, depol and R_{eff} are layer-based even though vertical resolution of extinction in A-EBD is 100 m and 1 km
- Different resolution for A-EBD and A-AER product > always indicate what was used.
  - Cloud features are not going to be smoothed in A-EBD.

Cloud and precipitation summary and recommendations

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop

17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

Cloud and precipitation presentations

Reflectivity Validation of EarthCARE CPR reflectivity using ACTRIS ground-based Cloud Radar Network – Nathan Feuillard

- Difference between CPR and ACTRIS ground-based radar reflectivity: -2±1dB (CPR - ground-based)
- L2 hydrometeor classification reduces the uncertainty on the liquid water filtering
- L2-L1 difference with 8 ACTRIS radars as baseline: 1±2 dB

Doppler velocity validation of EarthCARE cloud profiling radar using ACTRIS ground-based cloud radar network (EVID05) – Lukas Pfitzenmaier

- A tendency of doppler velocity overestimation of the ground-based observations in the L1 data, with a mean range of 0.5 ms-1, using an adapted method for statistical comparison of the doppler velocity
- Artifacts in the L1 data disturb the statistics

Operational implementation of the sub-orbital to orbital tool together with Doppler velocity unfolding across the ACTRIS cloud radar network for EarthCARE validation (EVID05) – Ewan O'Connor

- Sub-orbital to orbital tool operational for all sites
- Method for dealiasing ground-based radar measurements in testing
- Reliable attenuation correction of ground-based data will substantially increase proportion of data available for comparison

Cloud and precipitation presentations

Second-Trip Echoes Appeared in EarthCARE/CPR: Characteristics and Mitigation Performances in JAXA CPR L2a Product – Shunsuke Aoki

- Echo removal using masking was generally successful
- No significant difference in removal performance was observed between the 20km, 18 km, and 16km modes
- Investigation of the overlap between false echo and actual cloud echo in the 18km mode showed that the ration was quite small, therefore the use of the 18k mode is supported

The EarthCARE CPR L2A C-PRO data product: Post-launch updates and performance evaluation – Bernat Puigdomènech Treserras

- Higher PRF leads to increased overlap of second-trip echoes, but also to better Doppler velocity measurements
- Usage of Doppler velocity to identify potential CPR antenna mispointing
- Surface Doppler velocity observation reveal mispointing trends influenced by solar illumination cycles and thermoelastic distortions on the CPR antenna
- New antenna mispointing correction implemented in C-PRO (baseline AC)
- Publicly available McGill EarthCARE imagery portal

Cloud and precipitation presentations

Validation of the EarthCARE CPR Doppler velocity measurements using surface-based observations – Pavlos Kollias (presented by Jiseob Kim)

- The quality-controlled CPR Doppler velocities in the L2 C-PRO exhibit near-zero biases when statistically compared to surface-based observations from high latitude sites
- L2A C-PRO antenna mispointing correction is very important for establishing reliable CPR Doppler velocity measurements in stratiform cloud conditions
- Additional work is needed to understand the impact of the CPR pulse length on the reported radar reflectivities and Doppler velocities in areas with large vertical gradients (i.e. mixed-phase clouds)

Validation for EarthCARE Cloud Profiling Radar (CPR) using Ground Based and Spaced Based Observations – Minda Le (presented by V. Chandrasekar)

- Validation for CPR L2 products (reflectivity, hydroClass) from 2025 January to February with FMI radar network in Finland and NEXRAD radar network in the USA, showing promising comparisons

Cloud and precipitation presentations

Application of dual-polarization weather radar observations to the validation of EarthCARE Doppler velocity measurements in rain – Dmitri Moisseev

- Weather radar retrieved Doppled velocity is the sedimentation velocity and does not include air motion; mainly applicable to stratiform rain cases
- The analysis shows good agreement between CPR mean Doppler velocity and ground-based weather radar observations in stratiform rain cases: mean difference around 0.21m/s

An overview of JAXA cloud and precipitation products – Hajime Okamoto

- Vertical air velocity in cloud and precipitation regions tends to be larger in higher level than in lower level. Broader distribution is found in low-level than in high-level
- Frequency distribution of vertical air velocity are statistically compared to that from the wind profiler (WPR) derived data from 30-months in 14 sites inside Japan. The distribution of upward motion from EarthCARE is generally similar to that from WPR and the frequency by EarthCARE is broader than that from WPR, i.e., larger fraction of large upward velocity in EarthCARE.

Cloud and precipitation presentations

An overview of ESA cloud and precipitation products – Shannon Mason

- L2a MSI cloud & precipitation products: cloud mask (M-CM), cloud optical properties (M-COP)
- L2a ATLID cloud & precipitation products: target classification (A-TC), cloud-top height (A-CTH), ice clouds (A-ICE)
- L2a CPR cloud & precipitation products: target classification (C-TC), cloud and precipitation (C-CLD)
- L2b cloud & precipitation products: target classification (AC-TC), cloud-top height (AM-CTH), synergistic cloud and precipitation (ACM-CAP), composite cloud and precipitation (ACM-COM)

EarthCARE's Multi-Spectral imager cloud products – Anja Hünerbein

- M-CM and M-COP products together with examples of those
- Comparison of M-COP with SEVIRI data
- Known issues and disclaimers for the products

Early Phase Results and Validation of JAXA EarthCARE MSI Level 2 Cloud Products – Minrui Wang

- MSI_CLP provides high-quality results of clouds in low/middle latitude regions, especially when combined with other sensors in EarthCARE.
- Snow cover in high elevation regions and polar regions have a negative effect on the quality of MSI_CLP cloud products.
- Supervised machine learning can be used to determine cloud regions. Compared to conventional visual cloud cover determination and threshold method, it can eliminate the subjective and sensory aspects.
- The accuracy of cloud fraction was high in daytime, achieving an overall accuracy of over 85% and very high agreement with MSI's RGB composite images. In addition, the results were close to those obtained with Himawari.

Cloud and precipitation presentations

Intercomparison of Cloud Products between MSI and Himawari-9/AHI – Masataka Muto

- The results of the intercomparison between MSI and AHI showed that:
    - 3 TIR channels are well calibrated
    - Version vAf of VNS is still excessive and calibration issues remain
    - Cloud optical thickness tends to be overestimated
    - Cloud top temperature and effective radius are estimated relatively well
- Implemented a simple quality control to reduce the L1 VNS bias, over-trend of cloud optical thickness was mitigated and matched with good accuracy
- L1 VNS calibration is a key to improve L2 products

Verification of EarthCARE's cloud property retrievals and 3D scene reconstruction algorithm using in situ data from the ECALOT campaign – Zhipeng Qu

- Nimbostratus/Cirrus: Near cloud top (F05): IWC A-ICE ≈ IWC ACM-CAP ≈ in situ
- Deeper in cloud: Fall rain condition (F03): IWC ACM-CAP > IWC C-CLD ≈ in situ
- ACM-CAP showed improved LWC retrievals for F05 but encountered challenges for F03
- Stratocumulus (F04): LWC M-COP ≈ in situ > LWC ACM-CAP
- SCA performance degraded only slightly for the first 14 km away from nadir track (dist < 2.5/7.5 km for 1D/3D RT!)

Cloud and precipitation presentations

The first comparisons between level-2 EarthCARE products and in-situ measurements during the VERIFY campaign over the UK – Kamil Mroz

- 9 flights performed with variable cloud regimes and close match-up
- Comparison results are still preliminary
- More comparisons are needed with other instrument/products

Using EarthCARE's radar and lidar to characterize ice-cloud size distributions and improve ACM-CAP retrievals – Robin Hogan (presented by Shannon Mason)

- ATLID extinction (only possible with high spectral resolution lidar!) finds ice clouds are three times more optically thick, at least at cloud top, than implied by analysis of aircraft data ignoring D < 100mm particles
- The prior assumption of the N0' parameter in ACM-CAP can be modified to improve retrievals, especially at night
- This could lead to improved ice effective radius assumptions in models
- The need to test the sensitivity to assumed mass-size and area-size relationships was expressed along with a request for additional campaign data to verify or disprove this finding

Cloud properties & physical parameters from MSI: Conclusion and Recommendations

Positive findings about the data quality

- Cloud properties & physical parameters retrieved from MSI look reasonable although the VNS calibration is still to be improved
- Bias confirmed by ground-based observation, comparison with GEO satellites and aircraft observations.
- Indicating that **Level-2 algorithms work as expected** so far.

Aspects identified for improvement and proposed way forward

COT is overestimated but correlation is quite good. This is confirmed with both JAXA and ESA products

Products or aspects are not yet (optimally) validated

Refer to MSI level-1-equivalent seed question

Recommendations/suggestions for future L1 validation activities (e.g. validation needs, gaps) and for mission planning

- Completion of MSI calibration
- Continuation of validation activities to see the seasonal characteristics and long-term performance.

Cloud & Precipitation from CPR-only and CPR/ATLID combined products: Conclusion and Recommendations

Positive findings about the data quality

- **Calibrations of Doppler and reflectivity are converging**: this is the condition for all cloud and precipitation retrieval to produce sensible results
- **Mirror images properly identified and flagged**
- **Outstanding co-located in situ microphysical datasets** already collected for several cloud types and conditions with different probes measuring both PSD and IWC. Data are fully available.
- **JAXA and ESA L2 products just released and show quite reasonable preliminary results** (need of course more statistics)
- **Simulator from ground based to EC-like fully developed**, also accounting for cloud and precipitation attenuation correction, vertical correlation needs attention.

Cloud & Precipitation from CPR-only and CPR/ATLID combined products: Conclusion and Recommendations

Aspects identified for improvement and proposed way forward

- Converge ASAP on **antenna mis-pointing correction and radar calibration** (affecting the whole chain) in L2. Ways forward: JAXA will use the five thermal sensors around the antenna to characterize the antenna mis-pointing. It has identified a preliminary correction, which is currently applied at L2, but the plan is to eventually migrate it into L1b processor. To support this, two additional variables will be included in C-NOM, allowing to reverse engineer their correction. ESA integrated the C-APC processor performing mis-pointing correction at level 2 into the operational chain.
- **CPR receiver noise** characterisation and its utility for 94-GHz Tb measurements (JAXA is working on it)
- **PIA** with ideas coming from mirrors to estimate attenuation profiles
- Can we better exploit **datasets merging coincident overpasses** from e.g. pmw radiometers and GPM (already produced by JAXA)?
- Validation of **separation between air motion and sedimentation velocities** (wind profiler observations, in situ aircraft, ACTRIS profiling and scanning capabilities).
- **Convective motions**. What can we do? Statistical validations, and wind profiler observations, in situ aircraft, ACTRIS profiling and scanning capabilities. Important to define Z-v_T relationship both for stratiform ice and rain
- **Strong convection and folding issues**: dual Doppler or RHI e.g. with phase array following the track scanning capabilities (no action yet on this)

Cloud & Precipitation from CPR-only and CPR/ATLID combined products: Conclusion and Recommendations

Products or aspects are not yet (optimally) validated

- Microphysical validation of ice/snow & rain is ongoing using the available campaign data. Large snowflakes have been limited in VERIFY due to the lack of a probe suited for the largest particles; more sampling of rain is needed.
- Testing ice habits and hydrometeor classification.
- Use of balloon in situ for the evaluation of both aerosol and cloud products, including the sampling of stratospheric clouds (e.g the representation of stratospheric clouds in an ACM-CAP retrieval).
- Precipitation (snow and rain), only preliminary for US, Finland, Italy, Austria, Japan, Antartica. Rain over the ocean in all regimes is not yet validated.
- Raindrop mass weighted mean diameter (Dm) validation, using e.g. collocated dataset with Dual Frequency Precipitation Radar (DPR), in situ PSDs.

Cloud & Precipitation from CPR-only and CPR/ATLID combined products: Conclusion and Recommendations

Recommendations/suggestions for future L1 validation activities (e.g. validation needs, gaps) and for mission planning

- Verification of **critical a-priori assumptions** in the L2 product retrievals need to be identified. Developers should highlight a-priori assumptions that need to be refined and microphysical quantities that are critical for their retrievals. Current work with in-situ measurements challenged product assumptions of ice PSDs and scattering assumptions.
- Representativeness of validation sites need to be better assessed (not simply based on spatio-temporal distance but also cloud regime and site location).
- More **validation for warm clouds and mixed-phase clouds**. Also try to confirm location of liquid clouds with cloud boundaries (spiral flights or coordinated remote sensing/in situ flights).
- **Extinction profiles for CPR** (coordinated flights between two aircrafts, legs at different heights, or overpasses of flights over ground-based sites)
- Fill gaps in retrieval or make Cal/Val users more aware why retrieval is not converging or not attempted (e.g. multiple scattering/no Doppler available)
- More intercomparison studies should be performed between Japanese and European and single vs synergistic products

Radiation and synergy summary and recommendations

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop

17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

Radiation and synergy presentations

Overview and early intercomparison of ESA/JAXA radiation products – Kentaroh Suzuki and Jason Cole

- Summary of ESA and JAXA three and four sensor radiation products which compute radiative quantities from retrievals
- Radiative fluxes from ESA and JAXA products show generally good agreement but with some notable differences and biases.
- These differences will serve as points of continued comparison to improve inputs from aerosol and cloud products plus improve radiative transfer modelling

L2 BM-RAD and BMA-FLX products verification – Almudena Velázquez Blázquez

- Very good agreement between the 3-views fluxes in the thermal fluxes (RMSE < 8 W m^{-2})
- Solar fluxes sensitive to input quality (MSI L1 calibration, M-CM, M-COP, …). Expected to improve with updated MSI L1 calibration.
- In general good agreement with CERES and GERB-like fluxes.
- BBR overestimates the solar radiances & fluxes and slightly underestimate the thermal ones as compared to GERB-like and CERES FLASHflux. Expected that BBR calibration update (L1 CCDB) will reduce differences.
- RMSE in the thermal fluxes comparisons with CERES < 10 W m^{-2}

Radiative Closure Verification with EarthCARE BBR Solar and Thermal Fluxes – Carla Salas Molar

- BMA-FLX product is compared with 1D and 3D fluxes from ACMB-DF (14-16 Jan 2025) for different cloud cover and surface types
- BBR solar fluxes are brighter than 3D modeled fluxes, however similar to 1D
- Spikes in the BBR solar fluxes over snow under investigation
- Very good agreement for the thermal fluxes with RMSE < 8 W m^{-2} (both 1D and 3D comparisons)

Radiation and synergy presentations

Initial Validation of JAXA's Four-Sensor Synergy Radiation Budget Product: ALL_RAD – Takashi M. Nagao

- Ongoing comparison of solar and thermal fluxes computed using ALL_RAD processor with BMA-FLX find overall low bias and high correlation
- However, the biases have geographic structure, including a systematic bias in thermal fluxes over land, and dependence on "scene" (clouds and aerosols)
- Continuing improvements to ALL_RAD processor, including consistency of optics, e.g., using the same ice particle optics as MSI retrievals
- Through ongoing feedback to Level-2 product development, expect ongoing improvement of inputs to radiative computed by ALL_RAD

Validation of EarthCARE cloud & aerosol retrievals using surface spectral infrared radiances from ECALOT campaign – Lei Liu

- Forward calculations of spectral downwelling thermal radiances using EarthCARE retrievals as inputs are compared with observations from AERI
- For two collocated EarthCARE overpasses, one with thin clouds and one with thick clouds, the compute and observed spectral radiances generally agree within uncertainties
- However, some biases are persistent and require further study to understand, including the effect of improved cloud retrievals.

Radiation & synergy conclusion and recommendations

Positive findings about the data quality

- the instruments and algorithms work already sufficiently well to say that the mission objective will be met.
- **Solar : Good agreement with both 1d and 3d modelled fluxes but still needs improvement**
- Thermal : Very good agreement with RMSE < 10 W m-2 (within EarthCARE's accuracy requirement)
- still lot of work for public release of 3/4 sensor products (Dec. 2025), but have already made significant progress on radiative closure

Aspects identified for improvement and proposed way forward

- check consistency of optical properties between retrievals and RT computations (talk of Takashi). Way forward : keep meeting regularly between retrieval and flux people, document the processings on both side (ATBDs? journal papers,...), run RTM to also simulate MSI NB radiances, ...
- Similarly, the ancillary data (e.g. surface albedo, temperature, ...) should be consistent. Use X-MET as far as possible, document clearly if deviation. Valuable to validate meteorological quantities that are used by retrieval algorithms as well as the retrieval products themselves.

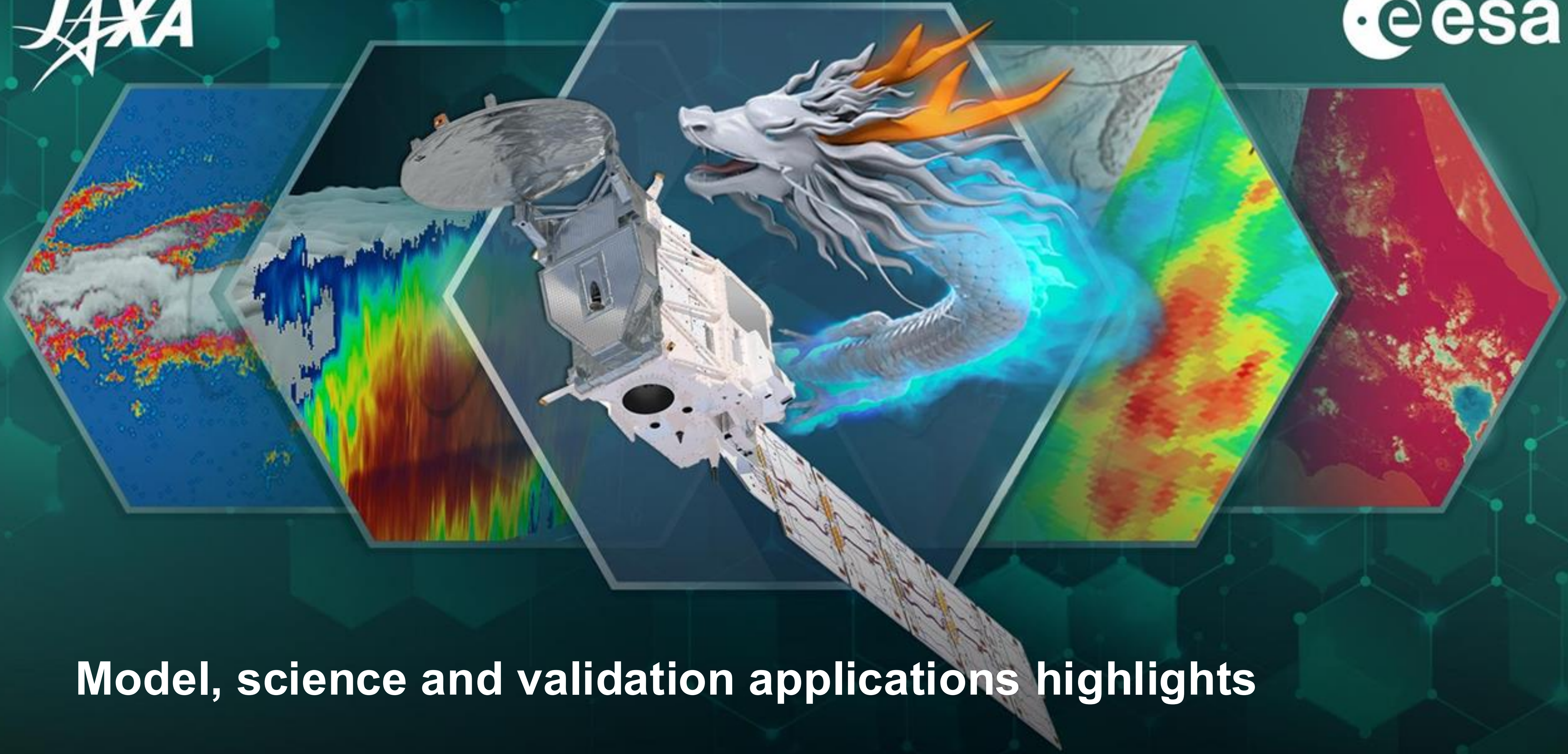
Radiation & synergy conclusion and recommendations

Products or aspects are not yet (optimally) validated

- Fluxes must be validated at surface as well. BSRN and PMOD/WRC intercomparisons foreseen
- Validation of target classifications mostly limited to ATLID or CPR; synergistic target classifications are now also available
- Need continued ground-based and aircraft validation of cloud-base height to validate assumptions in synergistic target classifications and retrievals, with strong impacts on surface radiation & radiative closure

Recommendations/suggestions for future L1 validation activities (e.g. validation needs, gaps) and for mission planning

- swapping of Japanese/European RTM and aerosol/cloud retrievals
- More intense surface validation (adding BSRN and PMOD/WRC)
- consolidate intercomparison with CERES / reduce biases
- Pursue that CERES instrument is operated in "EarthCARE" mode to get reference fluxes for BMA-FLX validation.
- Validation of cloud-base height & surface radiation in different regimes from long record of ground-based stations (e.g. CloudNet/ACTRIS)



Model, science and validation applications highlights

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop

17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

List of talks

Day 4: THURSDAY 20 MAR 2025

Model, science and validation application

Co-chairs: Robin Hogan and Masaki Satoh

CET	Min	Title	Speaker
09:15	15	EarthCARE/MSI Level-2 Algorithms: Description and Synergistic Analysis Plan with MSI and CPR	Takashi Nakajima
09:30	15	Comparisons between EarthCARE's Cloud Doppler Radar and A Global Convection-Resolving Simulation	Woosub Roh
09:45	15	Investigating convective cores and vertical updrafts using doppler velocity observations from the EarthCARE Mission	Aida Galfione
10:00	15	Advancing Climate Simulations with EarthCARE Observations: Intercomparison Frameworks and Model Improvement Initiatives	Masaki Satoh

Highlights (1)

- **Model Intercomparison and Synergy with Observations**
  - Model intercomparison projects, such as ECOMIP, are valuable for fostering synergetic activities between observational and modeling groups.
  - Evaluations should incorporate multiple satellite datasets and ground-based observations to improve model accuracy.
  - ECOMIP also aims to compare aerosol modeling approaches.
  - The **Global km-Scale Hackathon** (May 12–16, 2025) provides a unique opportunity to gain hands-on experience with global storm-resolving models.

- **High-Resolution Models for Calibration and Validation (Cal/Val)**
  - High-resolution or Large Eddy Simulation (LES) models can be utilized for Cal/Val purposes, particularly for analyzing cloud motions such as turbulent structures near cloud tops and gravity wave-induced vertical motions.
  - Models can assist in validating vertical velocity retrievals and help identify robust motion structures that EarthCARE observations might miss due to noise.

Highlights (2)

- **Improving Vertical Velocity Retrievals**
  - Vertical velocity retrievals will be refined by leveraging model-based uncertainty estimates of EarthCARE Doppler velocity measurements.
  - Since vertical velocity remains uncertain in both EarthCARE observations and numerical models, continuous improvement is necessary.

- **Cloud Microphysics and Database Development**
  - A database of terminal velocity versus radar reflectivity (Doppler velocity *Vd* vs. *dBZ*) is needed for different cloud systems and cloud particle types.
  - EarthCARE data can be instrumental in improving cloud microphysics schemes within models.
  - The dataset on cloud size and fall velocity can help refine cloud microphysics parameterizations, ensuring consistency or convergence in cloud particle size distributions within models.

Highlights (3)

- **Synergistic Use of MSI and CPR**
  - What are the potential approaches for integrating MSI and CPR data?
  - By leveraging EarthCARE's multi-sensor capabilities, CFODD analysis can be advanced using MSI and CPR, such as through instantaneous correlations between radar reflectivity and radiation.

- **Comparing Geostationary Satellite and CPR Data**
  - Geostationary satellite data provide estimates of vertical velocity at cloud tops.
  - CPR Doppler velocity should be compared with geostationary-derived vertical velocity estimates to improve observational consistency and model validation.

Epilogue

Thank you for your interest.

You are invited to submit your validation results as paper(s) to the special inter-journal issue of AMT/ACP/GMD on "Early results from EarthCARE": https://www.atmospheric-measurement-techniques.net/articles_and_preprints/scheduled_sis.html

For paper submission, use https://www.atmospheric-measurement-techniques.net/submission.html

Please join us at the 2025 ESA-JAXA EarthCARE In-Orbit Science and Validation Workshop, held from 1 to 5 December 2025 in Tokyo, Japan