



ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop

13 – 17 November 2023 | ESA-ESRIN, Frascati (Rome), Italy

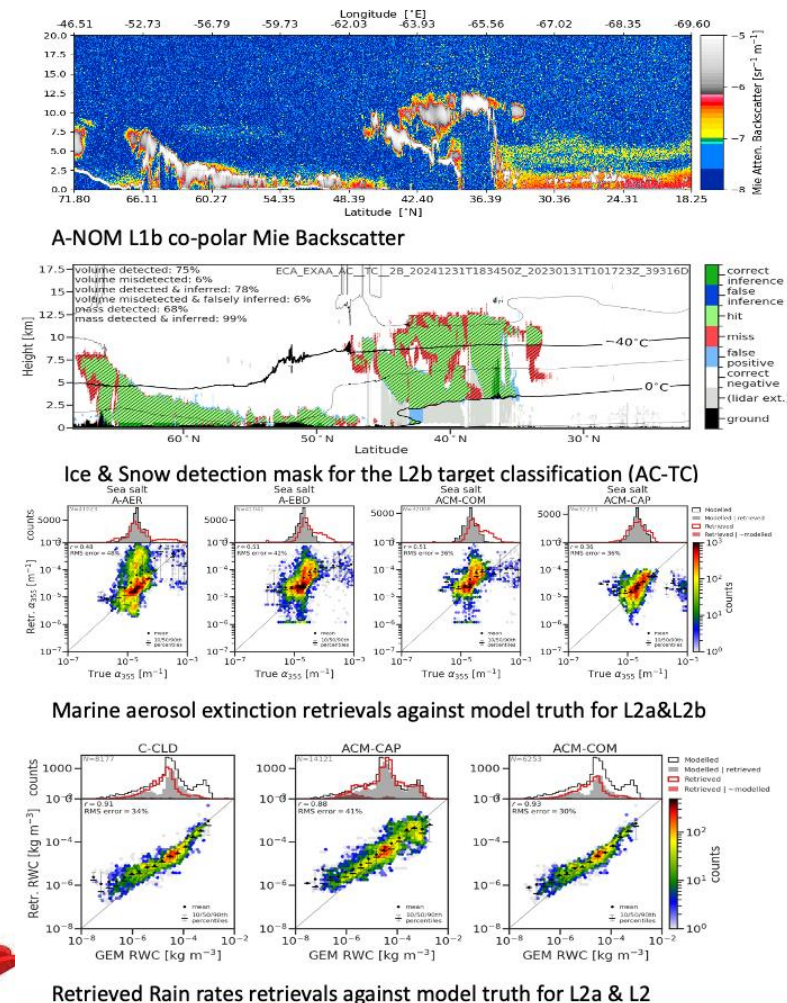
EarthCARE ESA product overview

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G.J. Van Zadelhoff (KNMI/CARDINAL), et al.*

Content



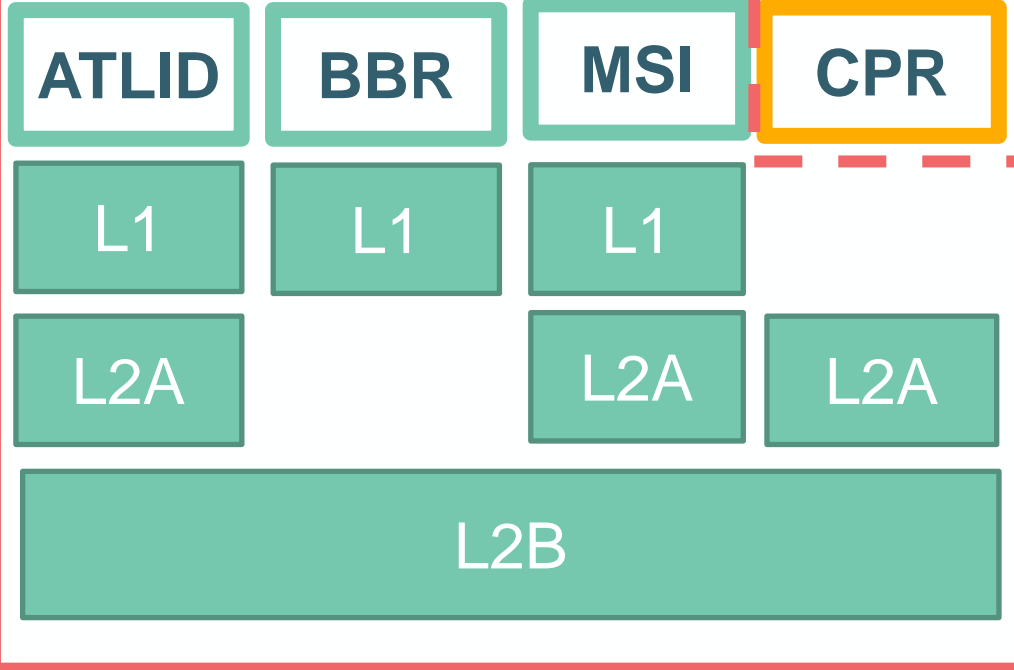
1. Processing Chain Overview
2. L1 and Auxiliary Processors developed by *GMV, Airbus (sat/payload industry) and S&T*
3. L2 Processors developed by the CARDINAL consortium (*KNMI, TROPOS, McGill, University of Torino, Free University of Berlin, Royal Meteorological Institute Belgium, GMV, ECMWF, LATMOS Environment and Climate Change Canada, LMD/IPSL,..*)



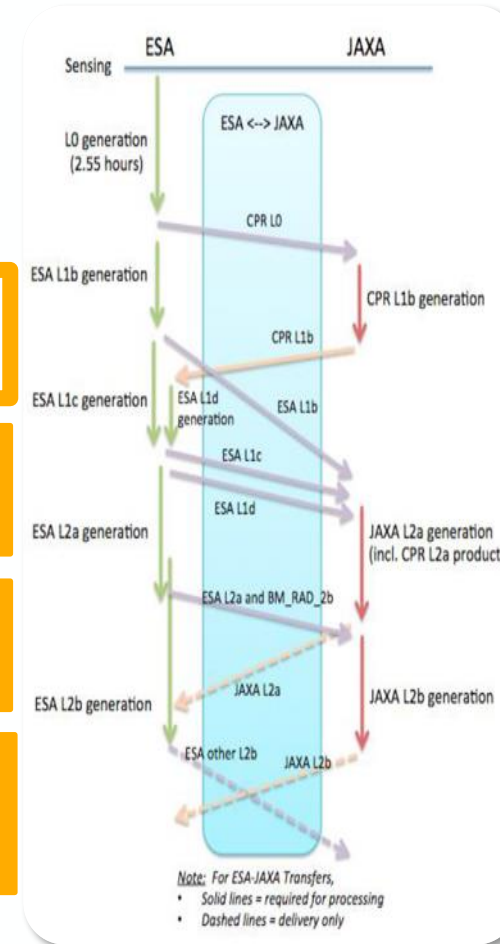
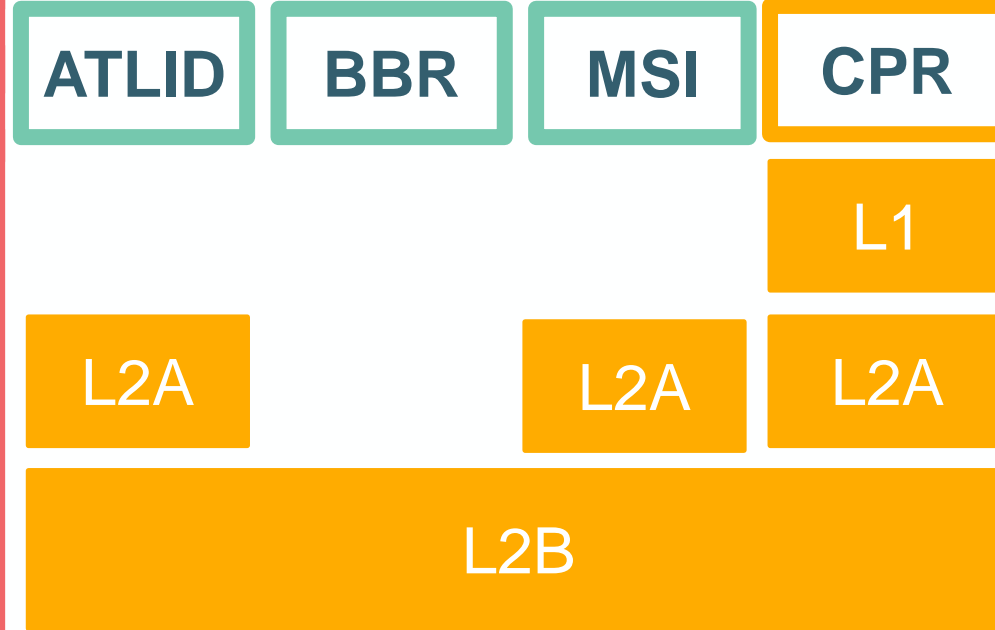
EarthCARE data products are generated by ESA and JAXA



Covered in this Presentation



Next Presentation:



- **Four EarthCARE instruments** are used in synergy
- Complex processing chain: **24 processors, 47 data products**
- Transforming raw instrument data into geophysical data products
- To support the **mission objective of assessing broadband radiances/fluxes based on BBR** measurements

VS

radiances/fluxes derived from ATLID/CPR/MSI measurements of cloud/aerosol parameters via radiative transfer models

CPR Level 1b (JAXA)
Radar reflectivity and Doppler velocity profiles

ATLID Level 1b (ESA)
Attenuated backscatter in

- Rayleigh channel
- Co-polar Mie channel
- Cross-polar Mie channel

MSI Level 1b/c (ESA)
TOA radiances for four solar channels, TOA brightness temperatures for three thermal channels

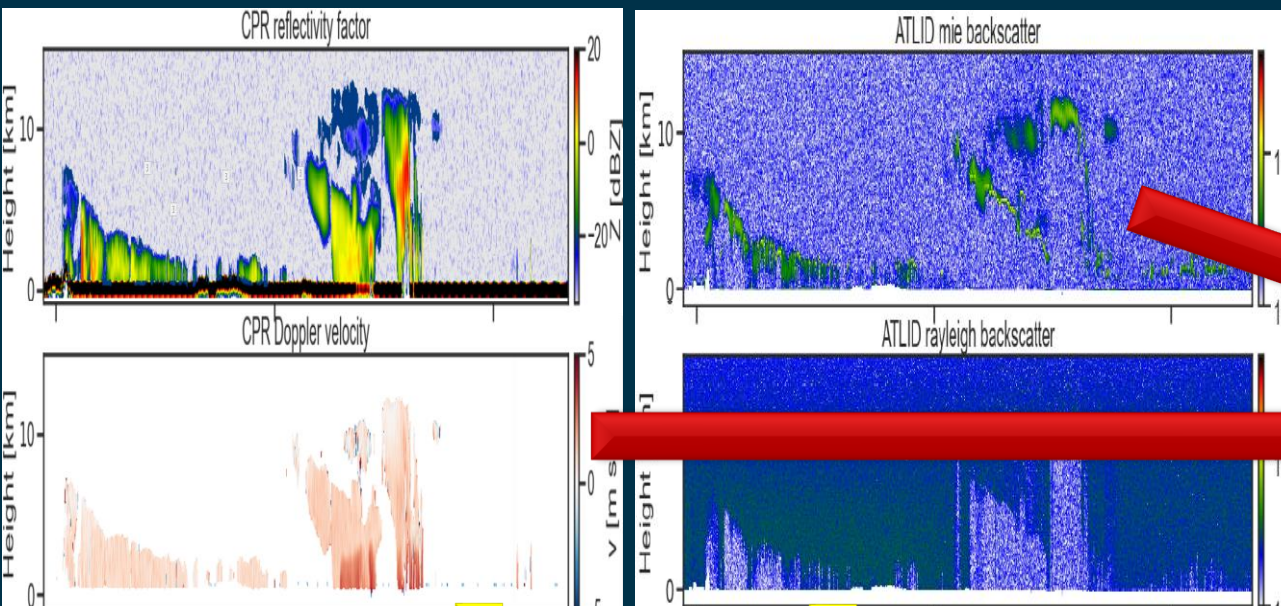
CPR Level 2a
Radar echo product, feature mask, cloud type, liquid and ice cloud properties, vertical motion, rain and snow estimates, ...

ATLID Level 2a
Feature mask and target classification, extinction, backscatter & depol. profiles, aerosol properties, ice cloud properties, ...

MSI Level 2a
Cloud mask, cloud micro-physical parameters, cloud top height, aerosol parameters, ...

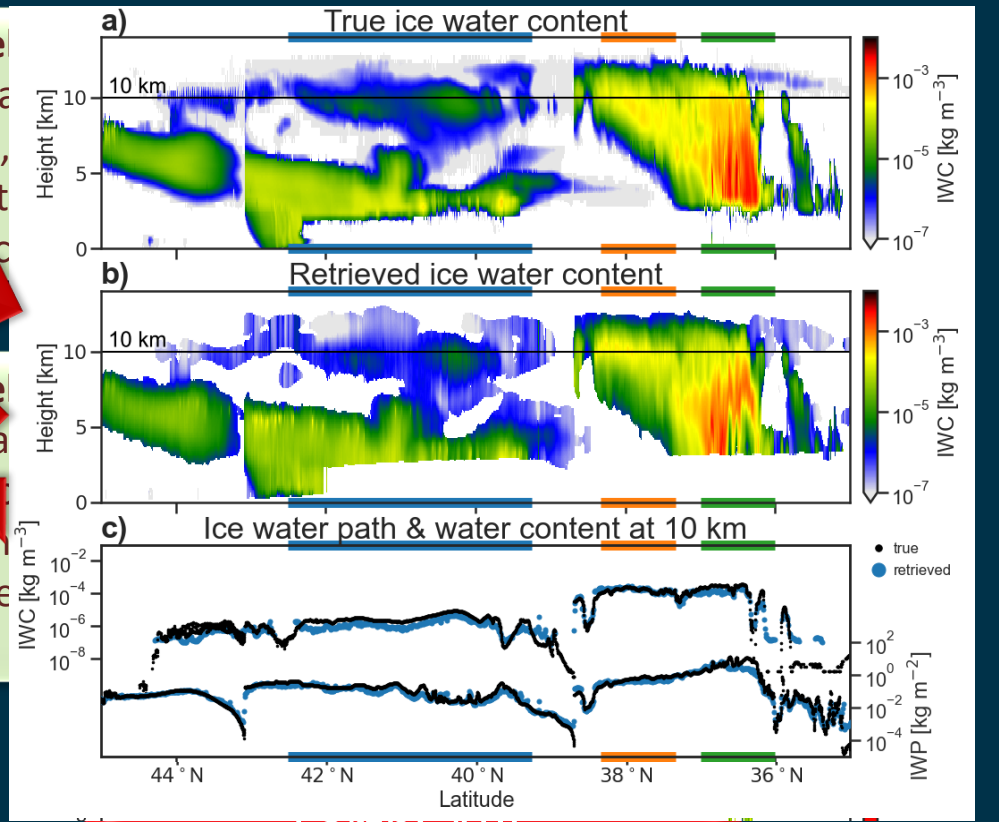
Synergistic Level 2b
1. Target classification
2. Cloud & aer. prof. at x-sec

EarthCARE Data Production Model



MSI Level 1
TOA radiance
channels, temperature
normal c

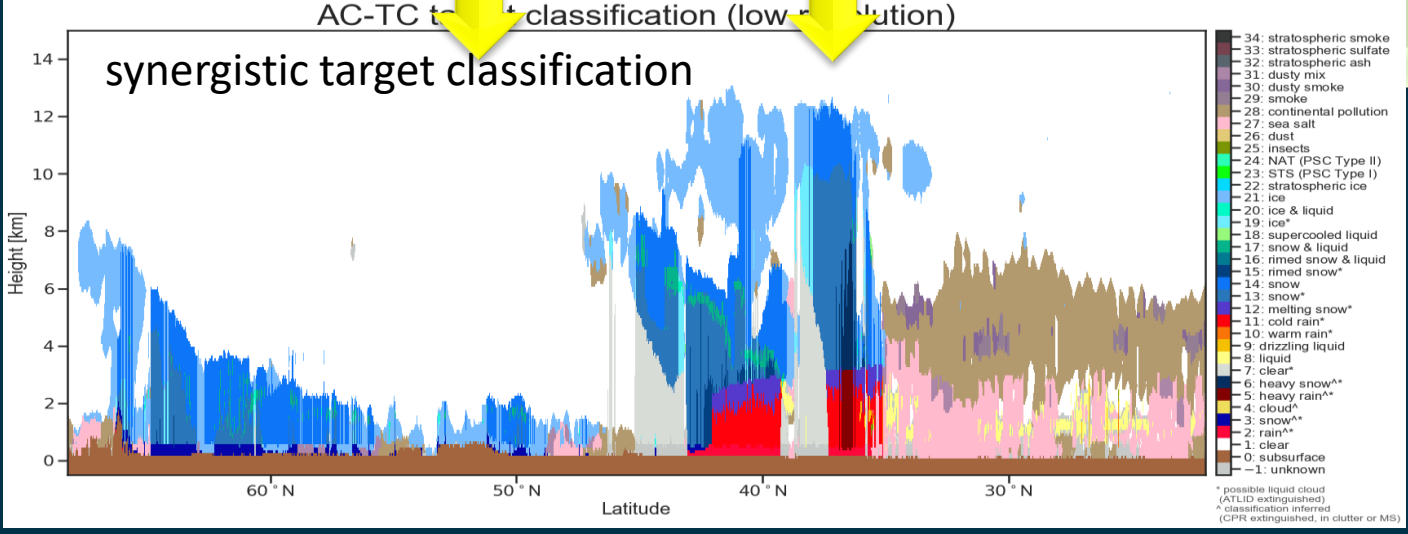
MSI Level 2
cloud radiance
physically
top height
diameter



motion, rain and snow estimates, ...

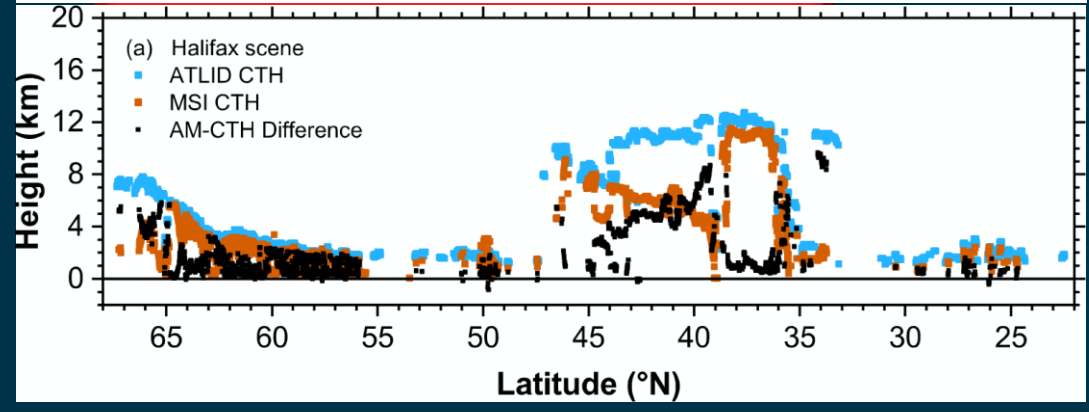
aerosol properties, ice cloud properties, ...

Synergistic Level 2b



EarthCARE

ATLID&MSI : Continuous evaluation of CTH → Evaluation GEO products



CPR Level 1b (JAXA)

Radar reflectivity and Doppler velocity profiles

ATLID Level 1b (ESA)

- Attenuated backscatter in
 - Rayleigh channel
 - Co-polar Mie channel
 - Cross-polar Mie channel

MSI Level 1b/c (ESA)

TOA radiances for four solar channels. TOA brightness

CPR Level 2a

Radar echo product, feature mask, cloud type, liquid and ice cloud properties, vertical motion, rain and snow estimates, ...

ATLID Level 2a

Feature mask and target classification, extinction, backscatter & depol. profiles, aerosol properties, ice cloud properties, ...

Synergistic Level 2b

1. Target classification
2. Cloud & aer. prof. at x-sec

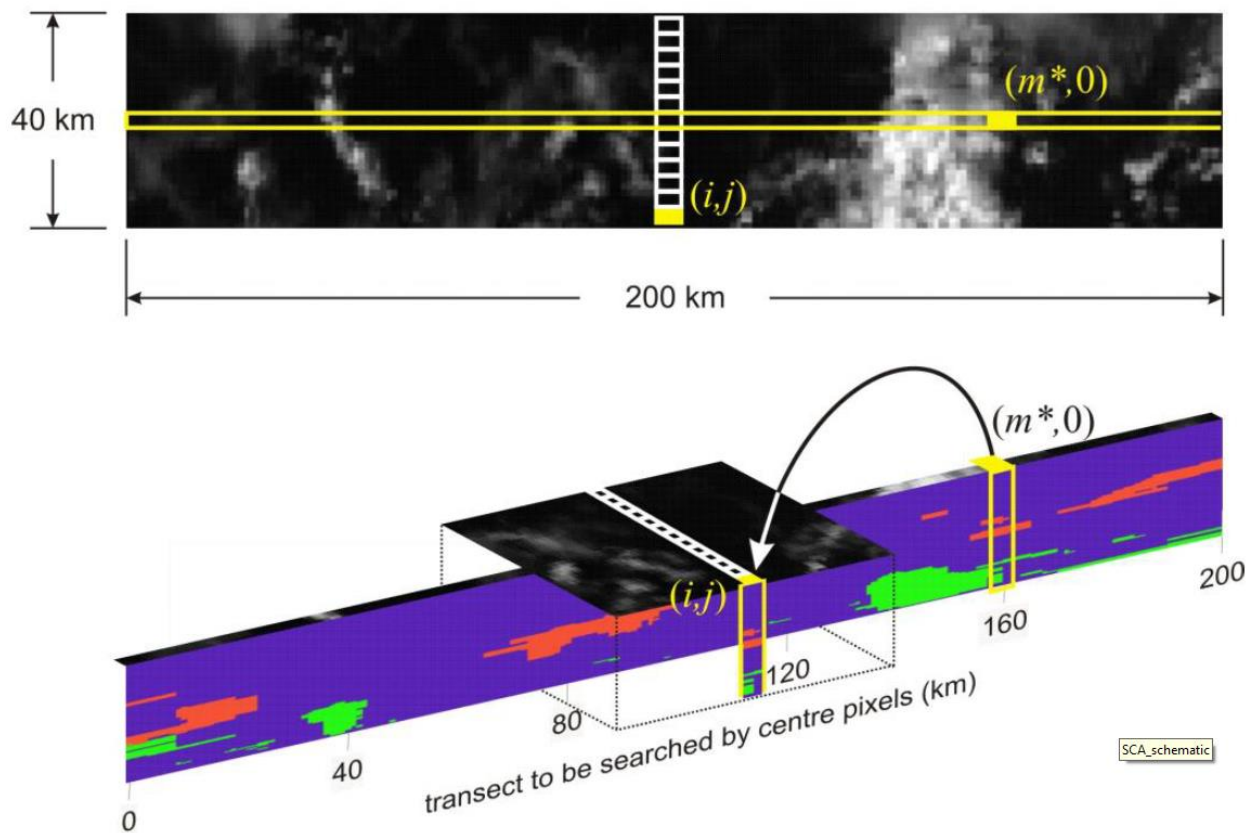
3D Scenes Construction

Expand syn. retrievals across-track using MSI; $\approx 40\text{km}$ wide

Radiative Transfer Products

calculated radiances, fluxes, heating rate profiles

Schematic of construction algorithm

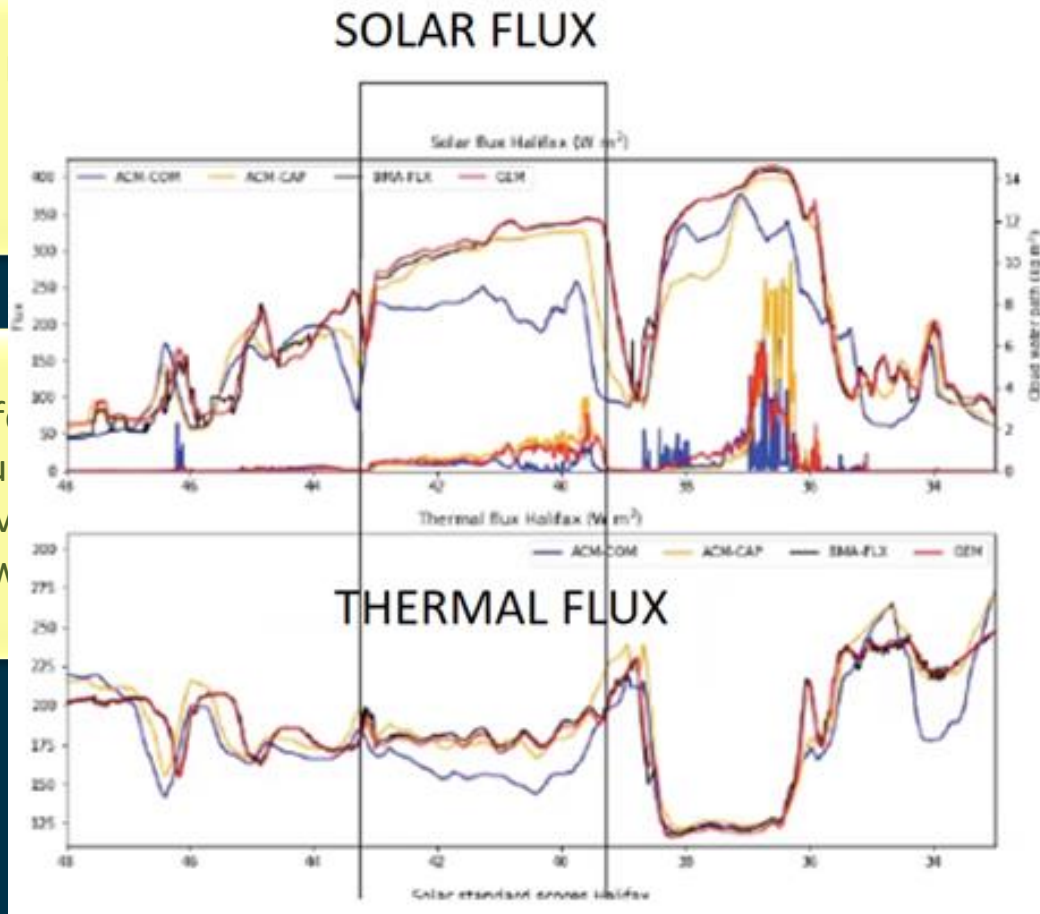


acknowledgements: Environment and Climate Change Canada

CPR Level 1b (JAXA)
Radar reflectivity and velocity profiles



CPR Level 2a
Radar echo product, flag mask, cloud type, liquid ice cloud properties, vertical motion, rain and snow estimates, ...



BBR Level 1b/c (ESA)
Fluxes for four solar channels, TOA brightness temperatures for three channels



BBR Level 2a
Flag mask, cloud micro-parameters, cloud optical depth, aerosol optical depths, ...

BBR Level 1b (ESA)
Filtered TOA short-wave and total-wave radiances



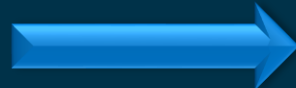
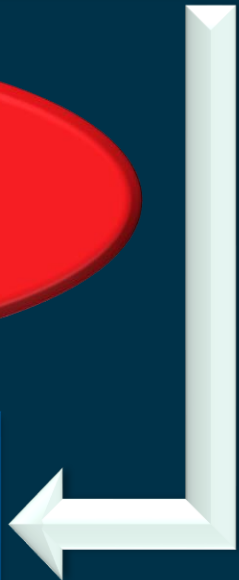
BBR Level 2a
Unfiltered top-of-atmosphere radiances, short-wave and long-wave fluxes
BBR Level 2b: enhanced products using MSI



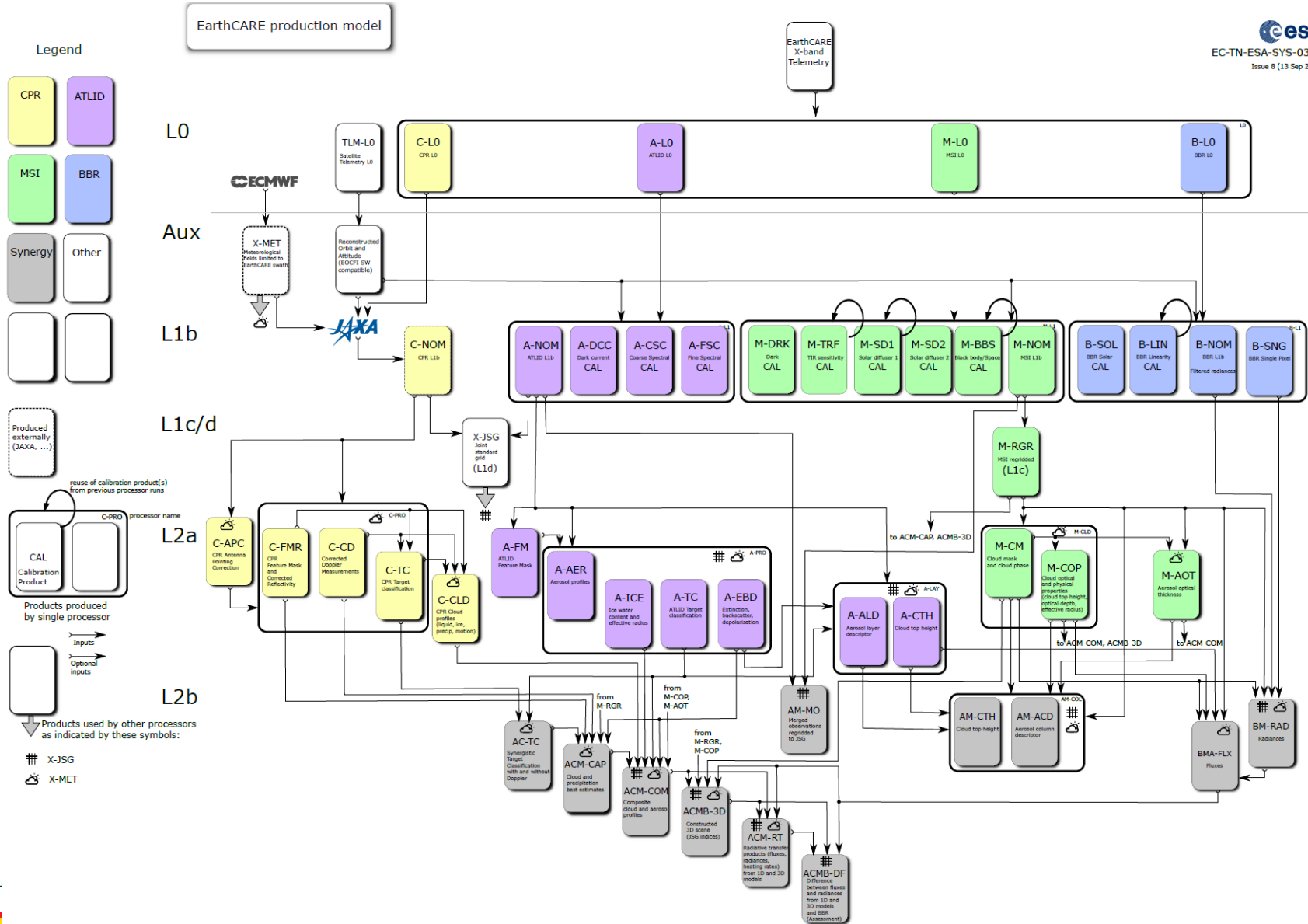
3D Scenes Construction
Expand syn. retrievals across-track using MSI; $\approx 40\text{km}$ wide

Radiative Transfer Products
calculated radiances, fluxes, heating rate profiles

Assessment
Comparison of calculated fluxes and radiances to BBR observations



EarthCARE production model (ESA)



EarthCARE product levels



Level 0 instrument science packets with annotation headers (unprocessed data), time-ordered, duplicate packets removed

Level 1b instrument measurements in physical units, annotated with geolocation, error quantification and quality flags, on instrument spatial grid

Level 1c same as level 1b, but spatially interpolated to reference band (MSI M-RGR only)

Level 1d auxiliary data products, not containing instrument measurements: meteorological fields (X-MET) and spatial grid for synergy processing (X-JSG)

Level 2a geophysical parameters, single instrument, on instrument spatial grid

Level 2b geophysical parameters, two or more instruments (synergy), on instrument or joint spatial grid

- ATLID/BBR/MSI level 1 processors (v4.2) fully implemented
- Successfully tested in Ground Segment Verification processing runs
- Successfully chained with level 2 processors (functionally)

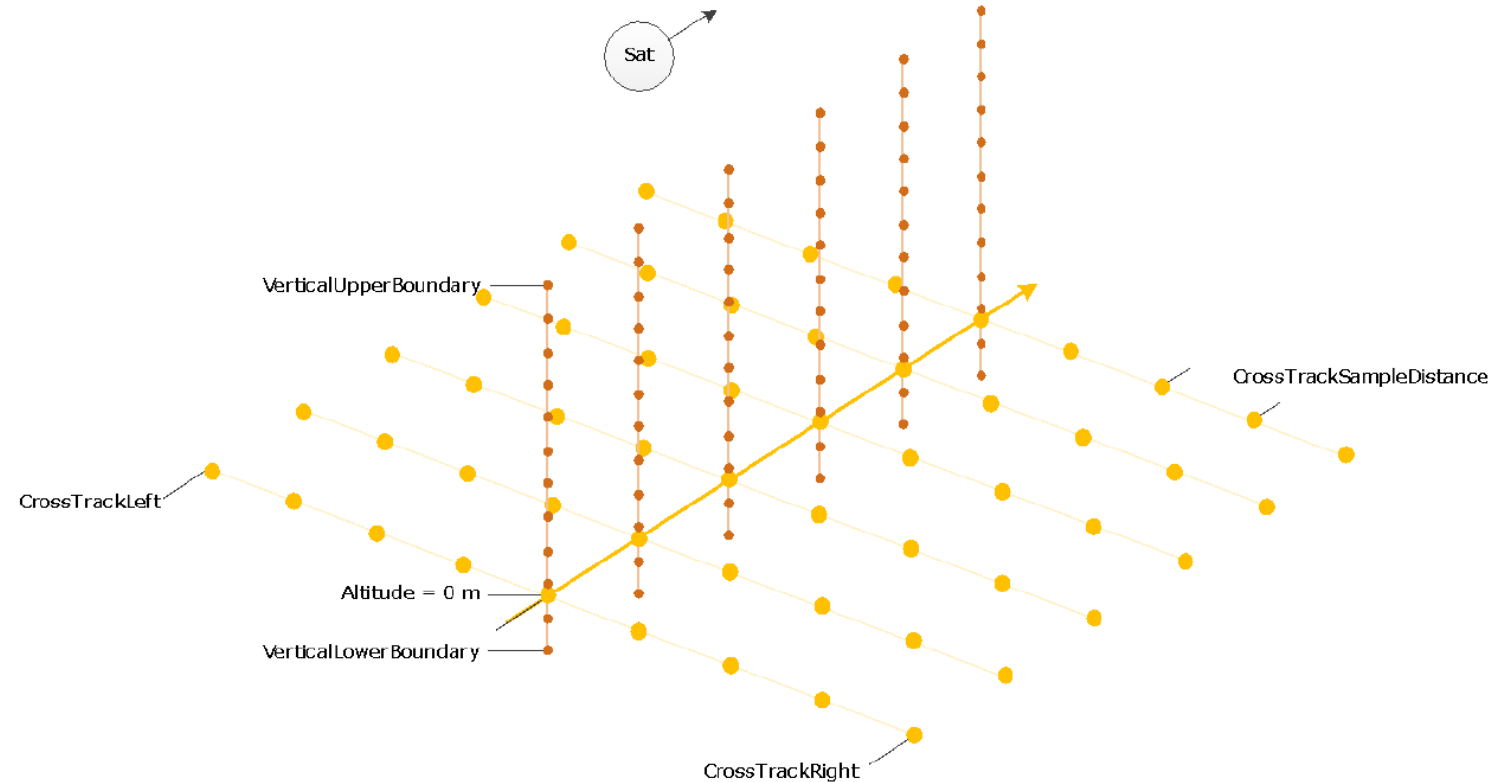
Remaining open issues for chaining with level 2 processors in a scientifically meaningful way, to be solved in Q1/2024:

- ATLID: implement new cross-talk correction algorithm, developed by KNMI within CARDINAL. Prototype implementation (in Python) available
- MSI: implement placeholder(s) for radiance/brightness temperature errors
- BBR: resolve discrepancy in filtered radiances/spectral response (ESSS or ECGP)

X-JSG: The Joint Standard Grid

- Spatial grid for use in EarthCARE synergy (L2b) processors and products
- Combination of two 2D grids (“inverted T”) to define a 3D grid:
- **Horizontal (along track, across track)** and **Vertical (along track, height)**

- Horizontal grid from CPR
- Vertical grid from ATLID
- Grid is continuous (no gaps)

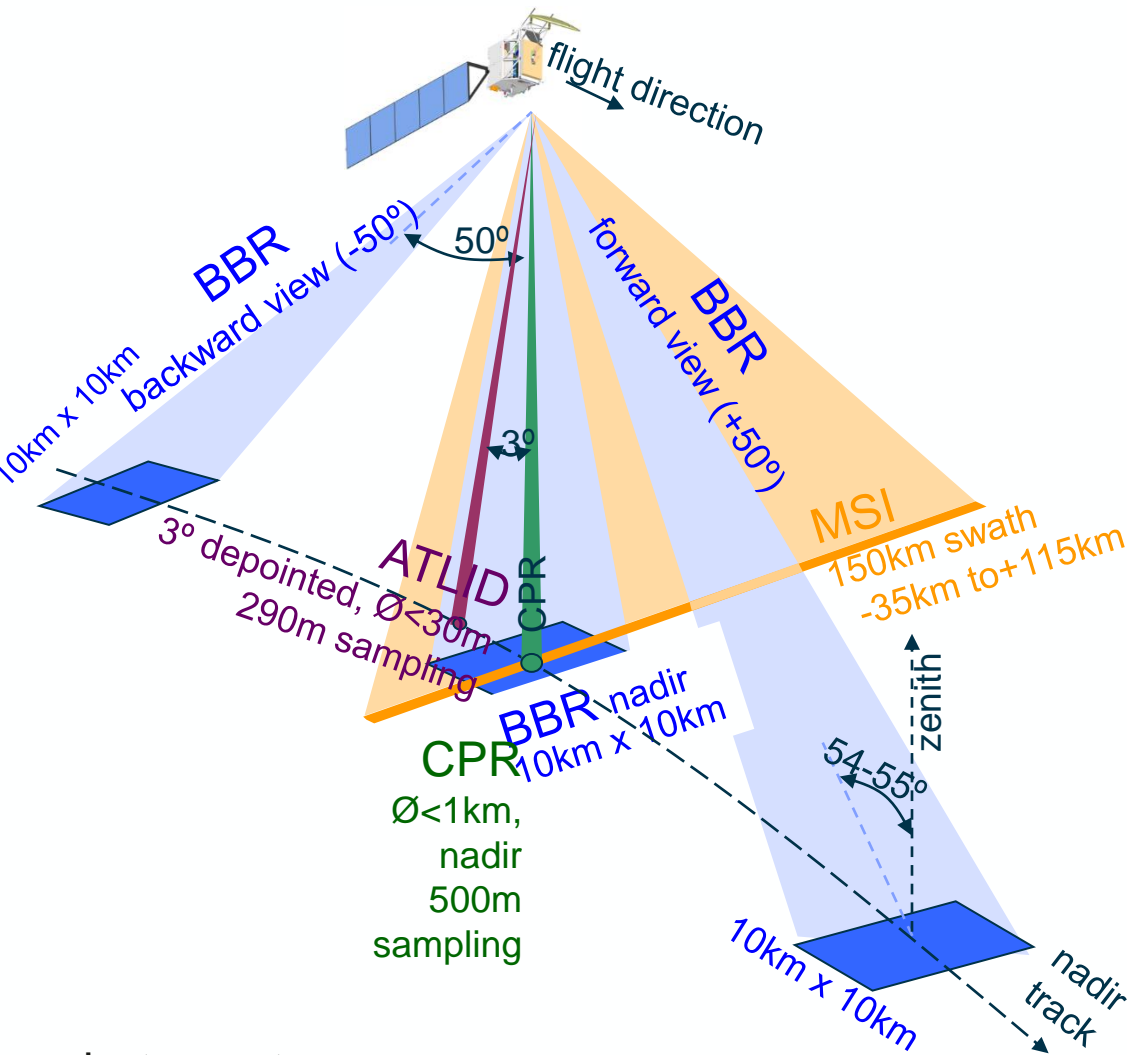


X-MET: Meteorological fields for EarthCARE swath



- Meteorological parameters from ECMWF deterministic forecast runs for the EarthCARE swath and overpass time on the original model spatial grid.
- This allows a reduction of the data volume by a factor of about 15 compared to global fields (from 750 GB/day to 54 GB/day).
- Model parameters to be extracted to X-MET have been selected based on the needs of EarthCARE level 1 and level 2 processors. The list of model parameters is configurable.
- Some parameters in X-MET are derived from a combination of model parameters.
- Used in most EarthCARE data processors

ESA will provide 25 L2-Science Products



Instruments:

CPR Radar: backscatter & Doppler

ATLID Lidar :attenuated back-scatter (molecular, particular, cross-polar channels)

MSI Imager: radiance & TB

BBR:TOA radiances and fluxes

Cloud-top, vertically integrated, layerwise

Aerosol

Aerosol layer height, classification
Optical thickness,
Layer-mean extinction-to-backscatter ratio
Layer-mean particle linear depolarization ratio
Angstrom exponent

Cloud and precipitation

Cloud-top height, phase, type
Optical thickness
Effective radius
Liquid, ice, rain water path
Surface snow rate
Surface rain rate

Radiation

Radiative fluxes at TOA
Broadband radiances at TOA

Vertical profiles

Aerosol

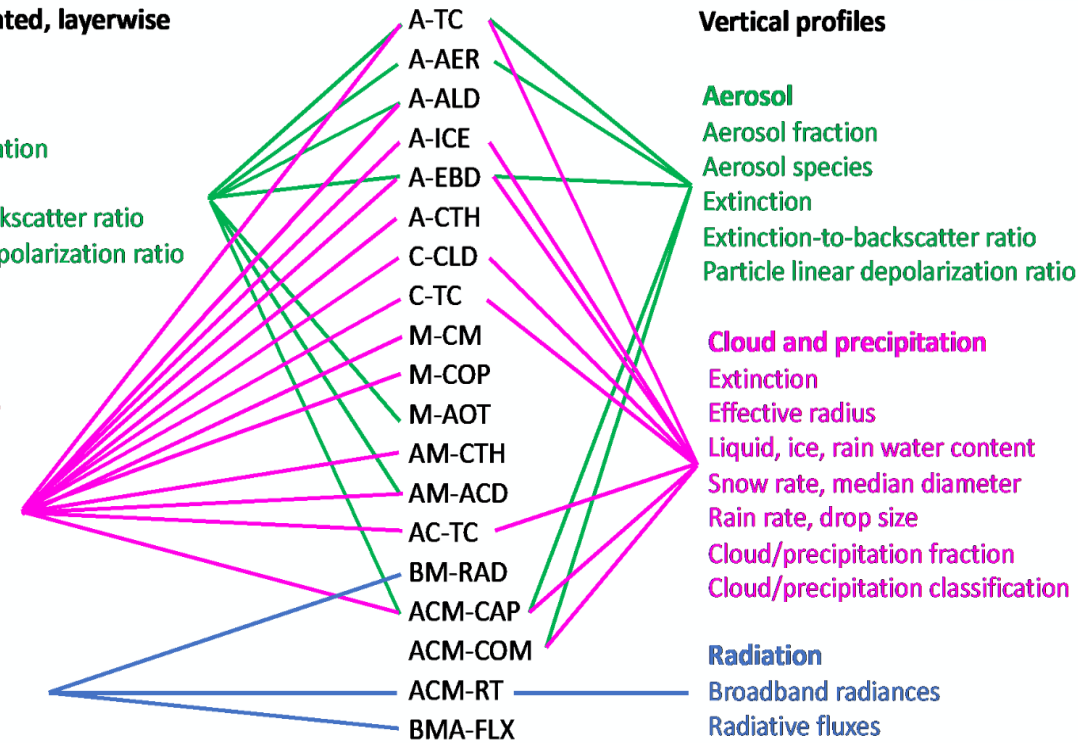
Aerosol fraction
Aerosol species
Extinction
Extinction-to-backscatter ratio
Particle linear depolarization ratio

Cloud and precipitation

Extinction
Effective radius
Liquid, ice, rain water content
Snow rate, median diameter
Rain rate, drop size
Cloud/precipitation fraction
Cloud/precipitation classification

Radiation

Broadband radiances
Radiative fluxes



EarthCARE Retrievals:

Aerosol & Cloud profiles (ice, liquid, mixed, precipitation)

Horizontal distribution of cloud and aerosol fields

→ Retrieve the 3D atmospheric state

Broad-band Solar & Thermal Radiation

→ Validate 3D atmosphere RT calc. with BBR

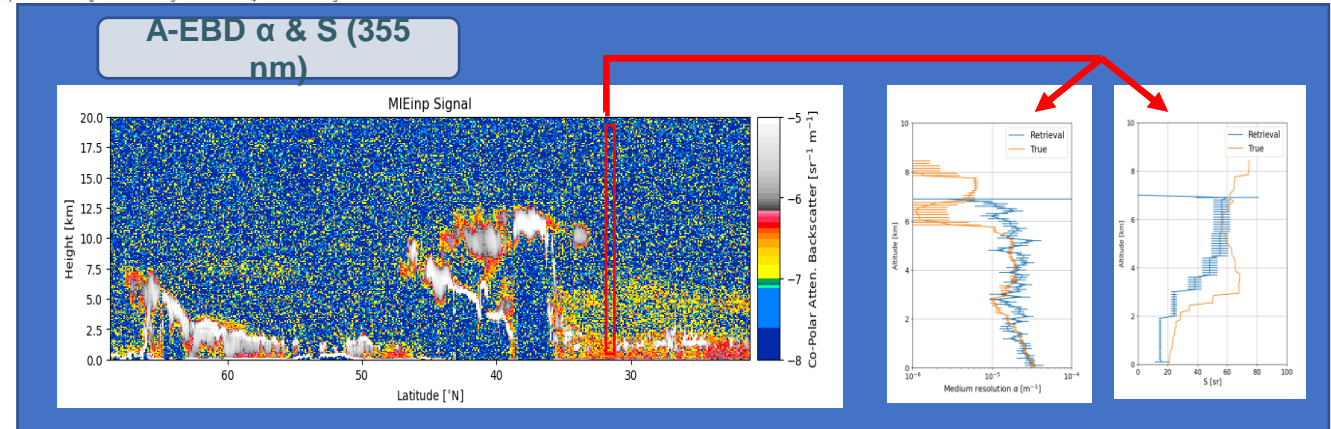
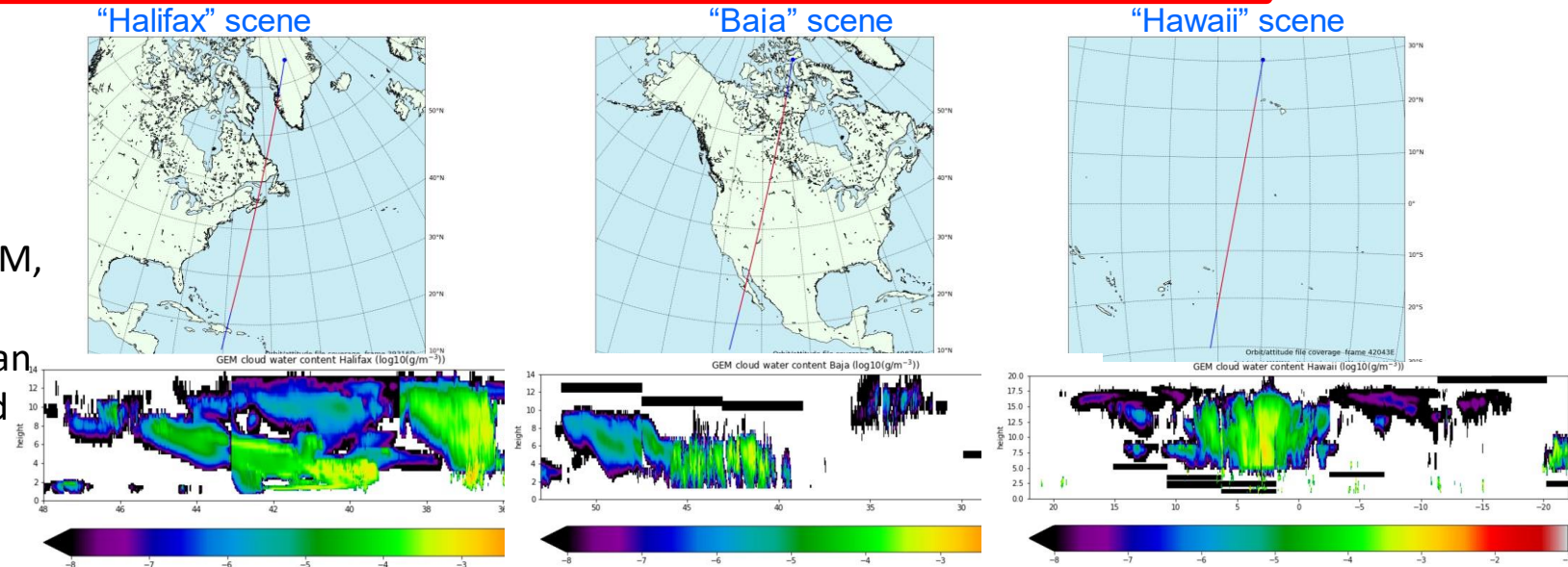
L2 Testing and Status



Level 2 **Algorithm Descriptions** published in *Atmospheric Measurement Techniques Special Issue on "EarthCARE Level 2 algorithms and data products"* : https://amt.copernicus.org/articles/special_issue1156.html

Product and Algorithm testing

- **Reference scenes:** Three high-resolution scenes from the Canadian GEM model compared to output
- **Level 1** data produced by ESA processors : A-NOM, M-NOM, M-RGR, B-NOM, B-SNG
- **Level 2** products produced by European/Canadian team (based on simulated Level 1 data produced by science team until CARDINAL until 2022, and with PDGS L1 from 2023)
- **L2 Status Q3 2023:**
 - processors currently undergoing **Acceptance Review E (V11.0X)**.
 - Ground Segment Acceptance Review (GSAR) Ongoing
 - Ground Segment Verification Test Run 3 completed
 - L2 processors described in AMT special issue



ESA L2 Status Conclusions

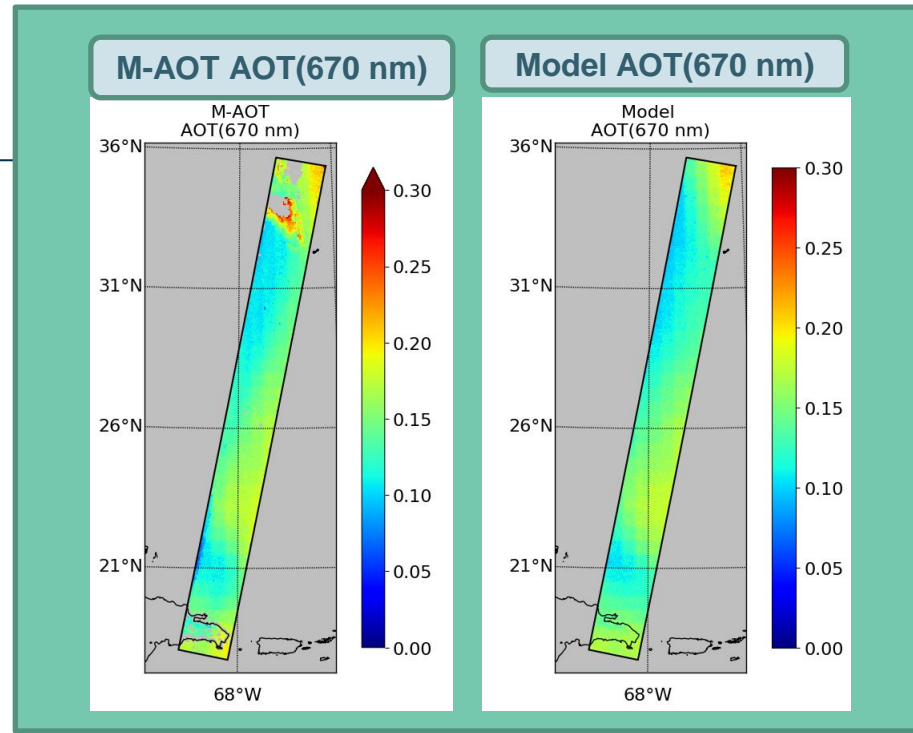


- Cloud, aerosol and radiation interaction are currently still one of the largest source of uncertainty in projections of the future climate.
- A full L2 processing chain has been developed and evaluated using modelled scenes.
- Synergy between L2 processors and L1 data streams will enable direct verification of the impact of clouds & aerosols on atmospheric heating rates and radiative fluxes.
- AMT special issue: 'EarthCARE Level 2 algorithms and data products'
- **The EarthCARE processing chain is nearly ready and will deliver unique and crucial data products, addressing uncertainties in the influence of clouds and aerosols on the incoming solar and outgoing thermal radiation**

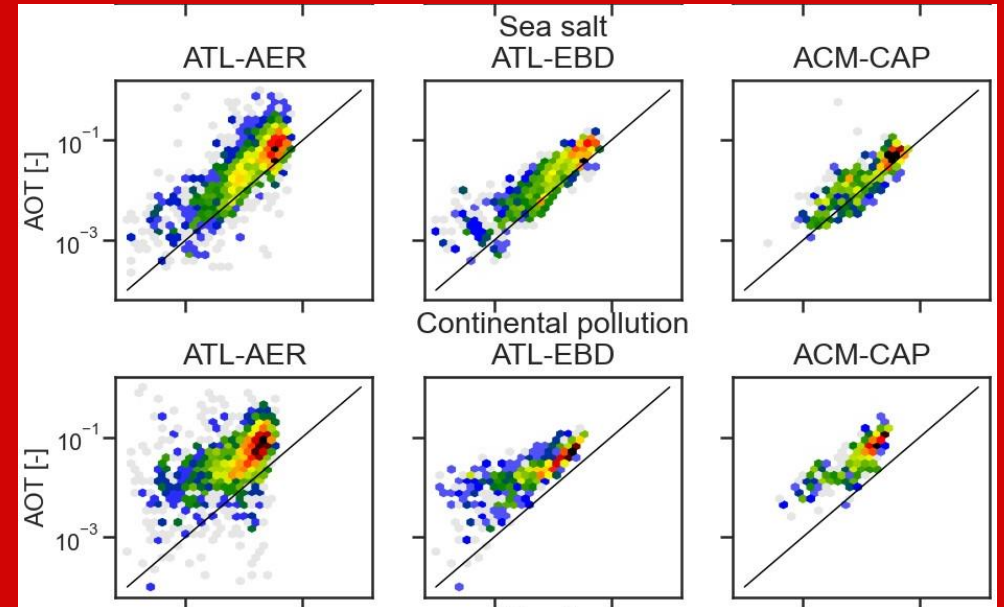
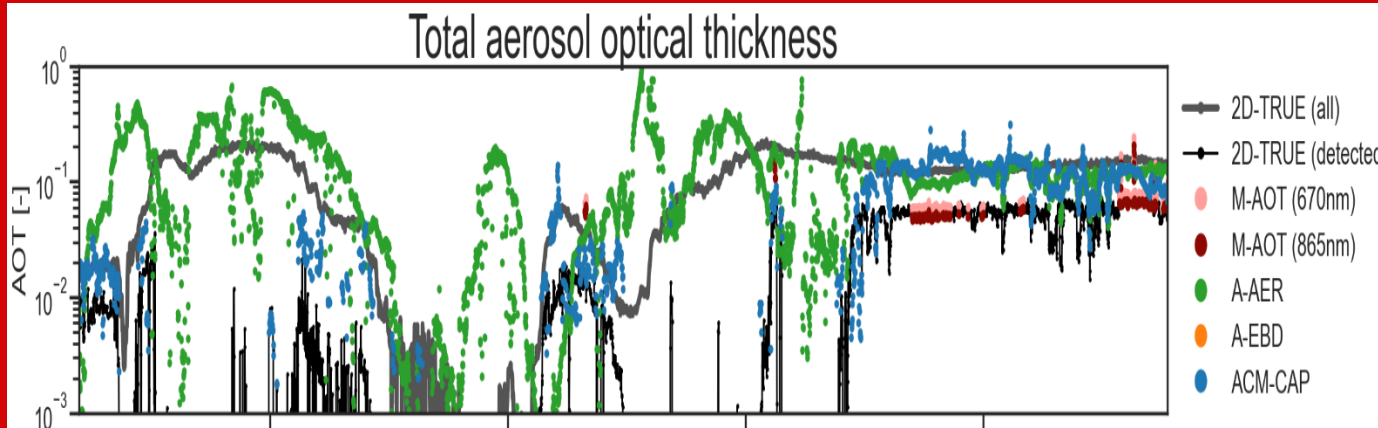
Thanks for your attention!

Questions?

See also Poster:
EarthCARE ESA Level 1 & 2 production model



Comparison/evaluation of L2a & L2b aerosol retrievals





Retrievals and “Closure”
Example of work in progress

Reconstructed cloud scene based on radar-only + lidar-only + imager-only cloud retrievals

(“Composite” product)
FLUX IN BLUE

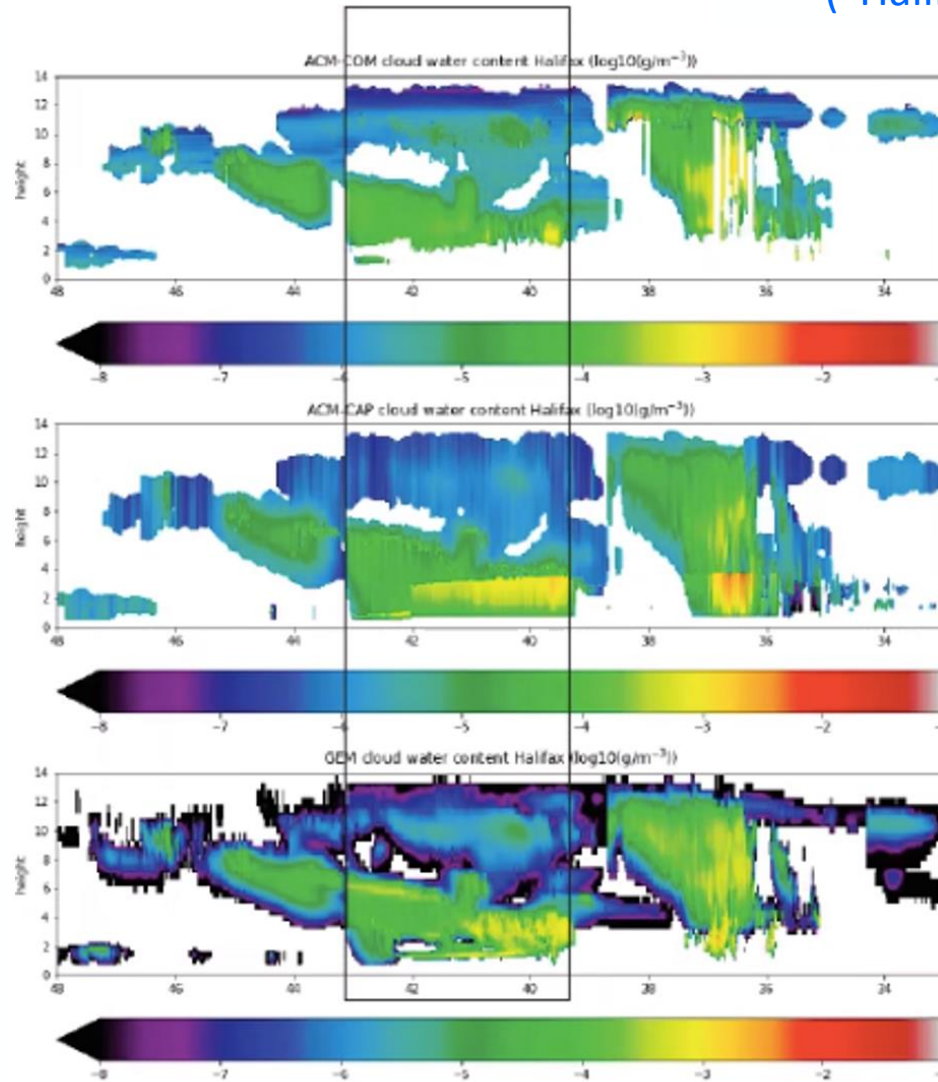
Synergistically retrieved cloud scene, CAPTIVATE algorithm (Opt. Estimation with complex state vector)

FLUX IN YELLOW

Model truth (Canadian Weather Model GEM)

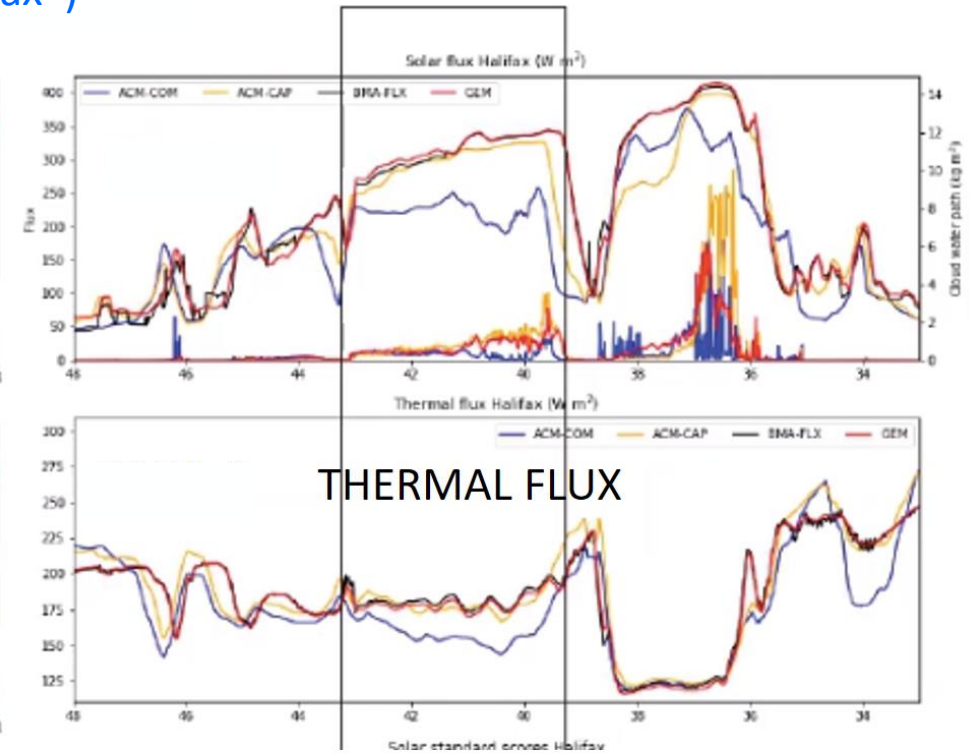
FLUX IN RED

Cloud water content



Test Scene (“Halifax”)

SOLAR FLUX



THERMAL FLUX

→ “Composite” clouds are too dull and too cold