The EarthCARE Level 2 Retrievals and Products

Gerd-Jan van Zadelhoff (KNMI)

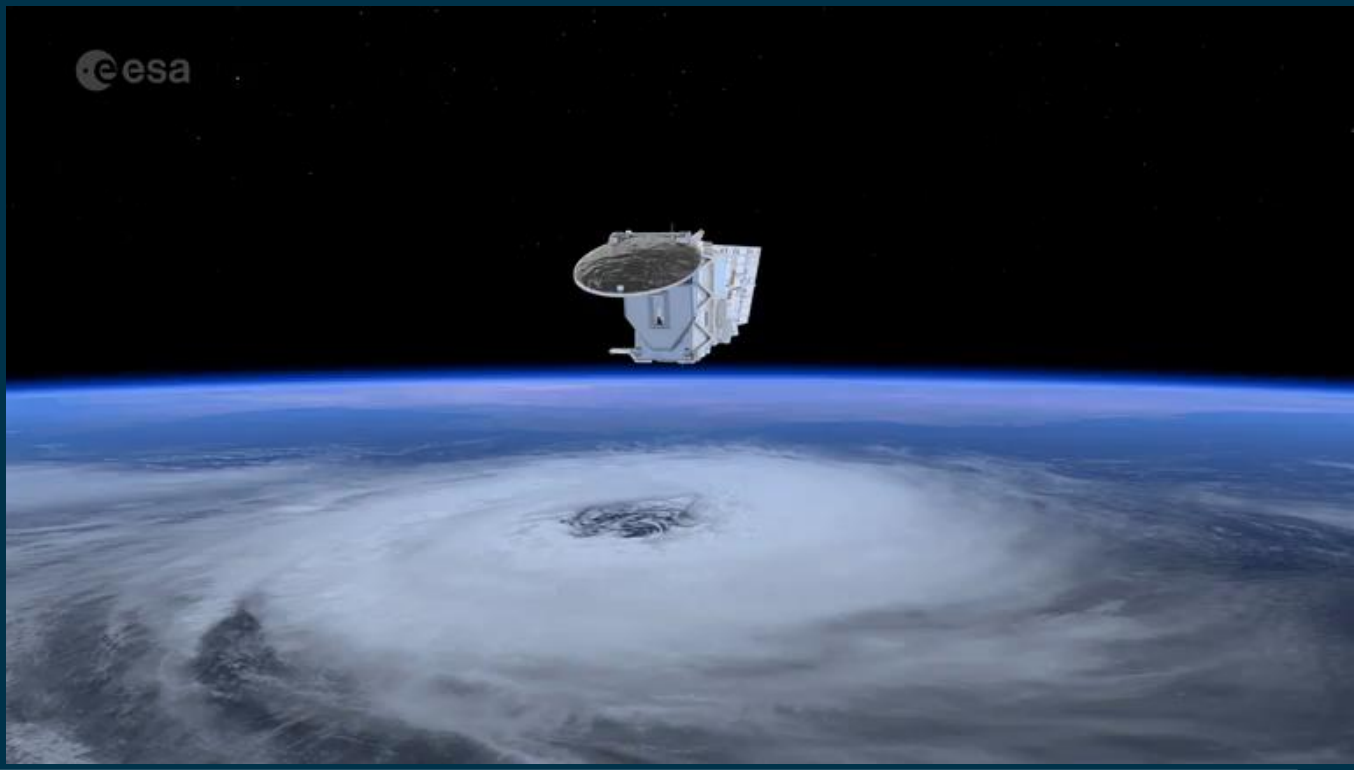
Representing a large team of dedicated L2 processor developers,
Cal-val specialists & ESA personnel

EarthCARE: Linking Clouds, Aerosol and Radiation

Cloud, aerosol and radiation interaction are still the largest source of uncertainty in projections of the future climate, making them critical to improve numerical weather predictions and climate modelling.

The largest uncertainty are due to the diversity of cloud formation processes and the feedback mechanisms depending on cloud macrophysical and microphysical properties

EarthCARE will acquire key observables needed to better understand the role of cloud, aerosol and radiation in climate.



Satellite and Payload

- EarthCARE is a joint venture between ESA and JAXA
- The largest and most complex Earth Explorer to date,
- Sun-sync. orbit @ 393 km,14:00 hours descending node
- Launch April-June 2024.

Cloud Profiling Radar (CPR) - JAXA

94 GHz Doppler, 2.5 m dish (folded in photograph)

Atmospheric Lidar (ATLID)

High-Spectral Resolution Lidar (HSRL), λ=355nm

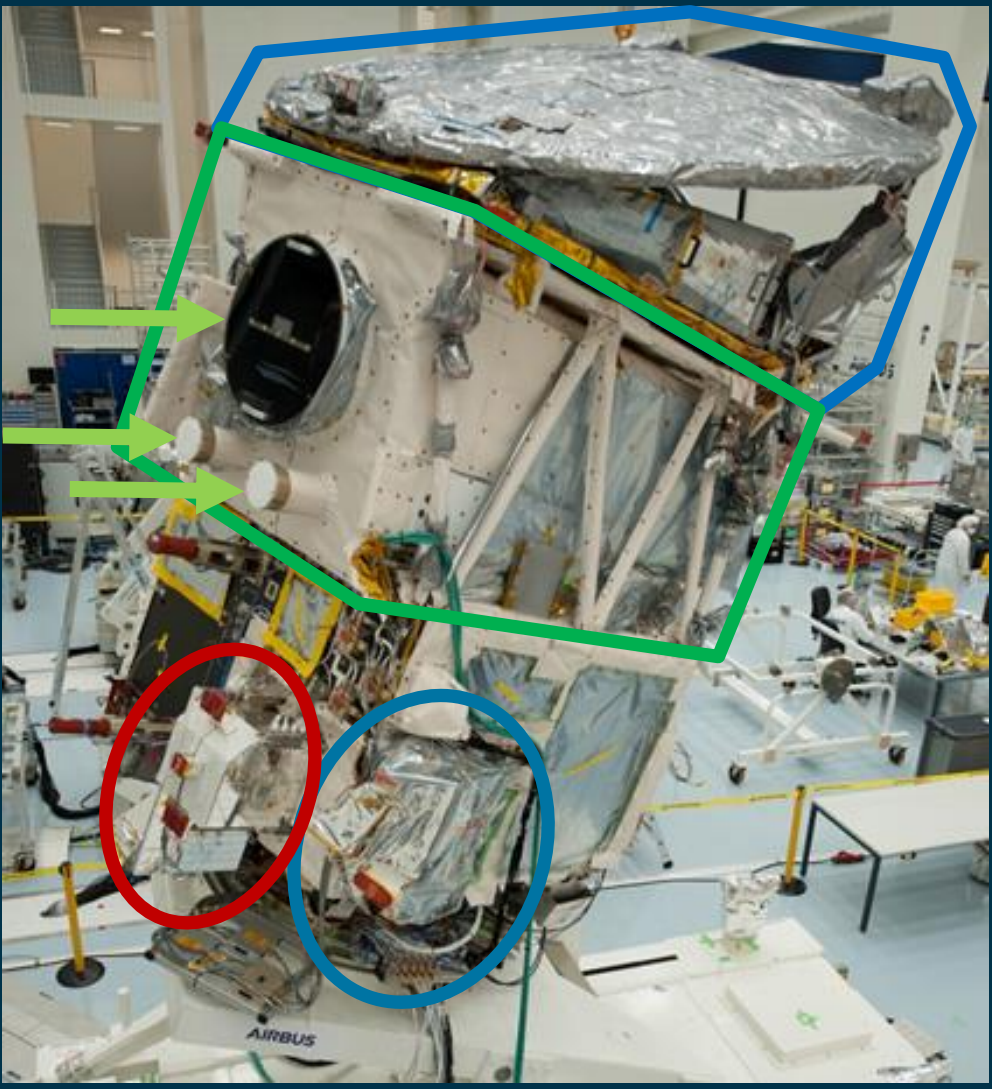
Two redundant transmit telescopes & 60 cm receive tel.

Multi-Spectral Imager (MSI)

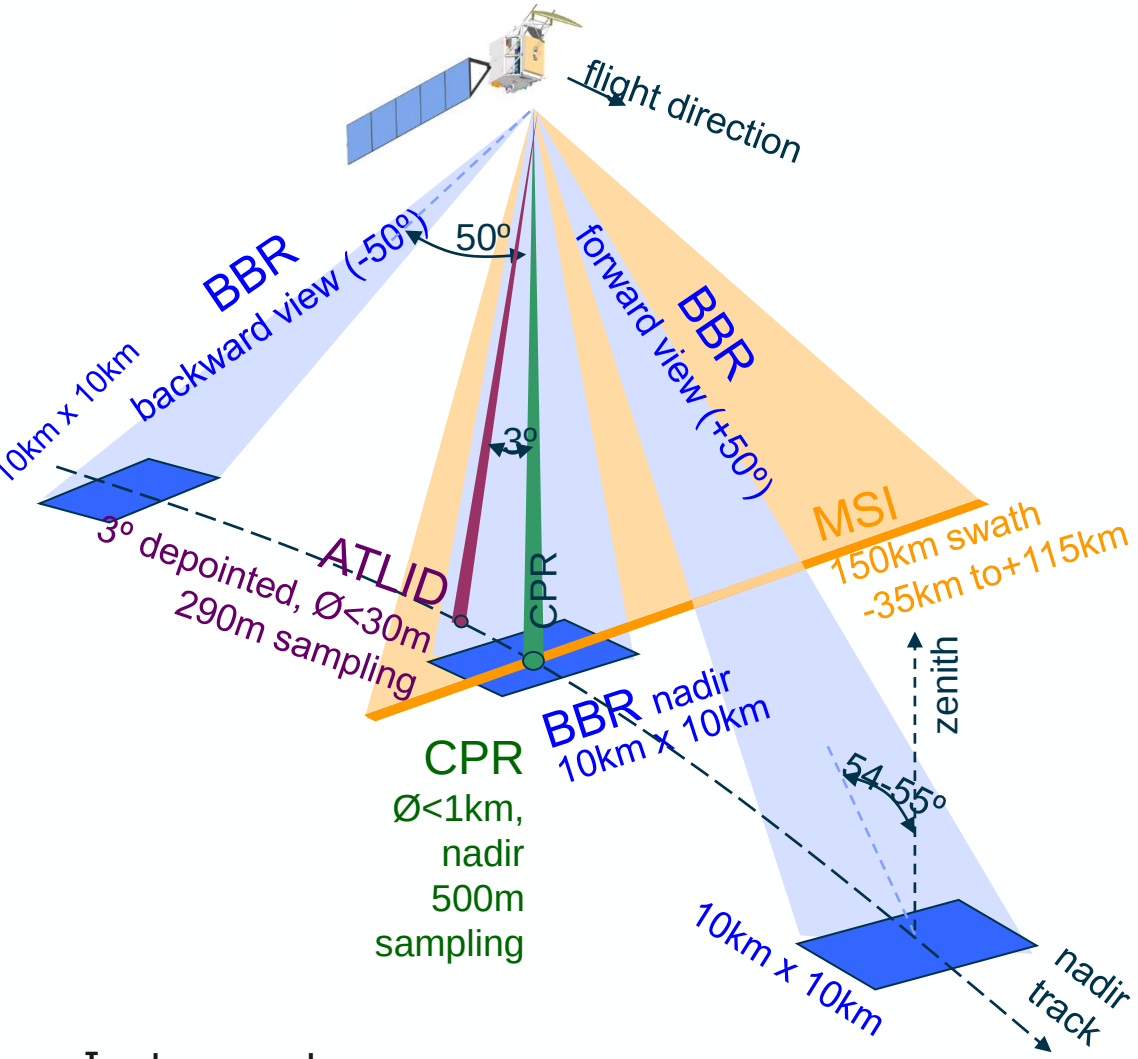
pushbroom, 4 solar + 3 TIR channels

Broad-Band Radiometer (BBR)

2 Channels: Solar + Thermal; 3 fixed FoV

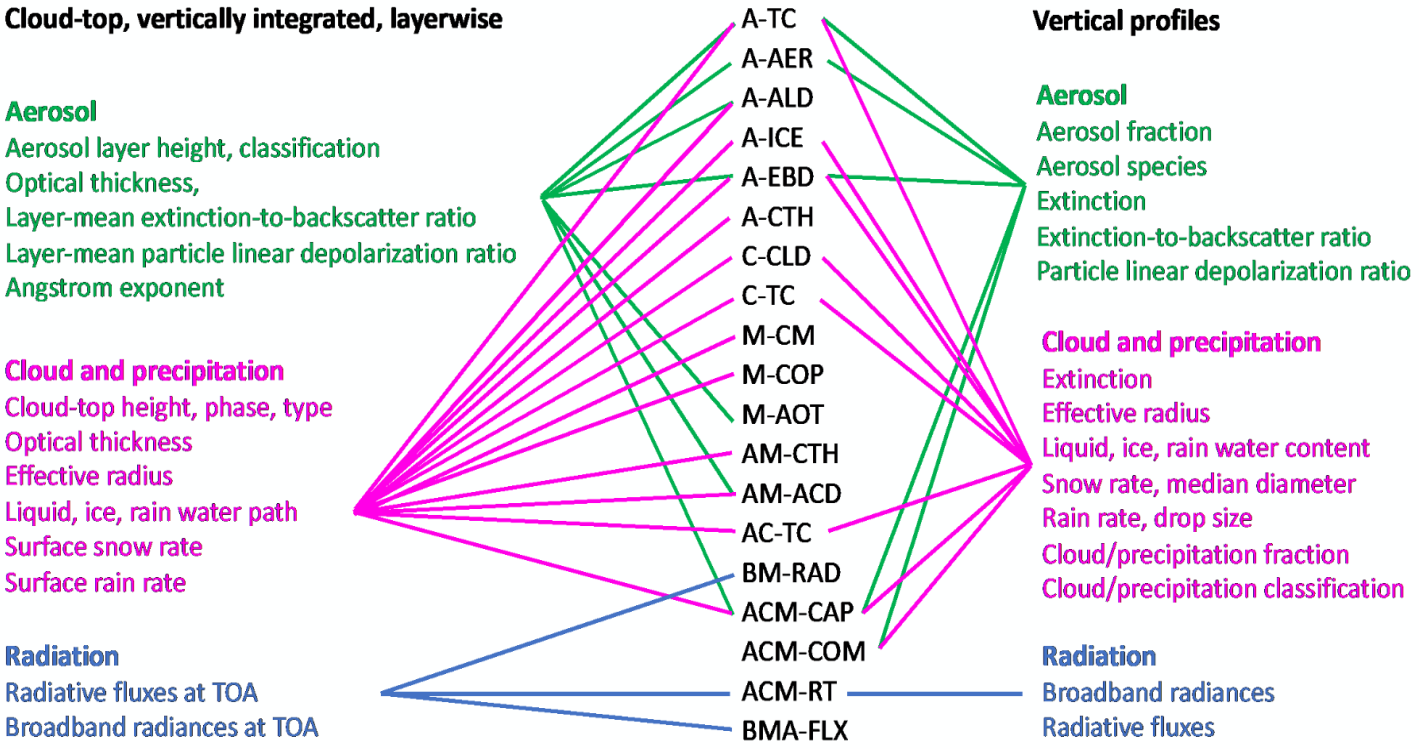


Photos courtesy Airbus



Instruments:
CPR Radar: backscatter & Doppler
ATLID Lidar :attenuated back-scatter
(molecular, particular, cross-polar channels)
MSI Imager: radiance & TB
BBR:TOA radiances and fluxes

ESA will provide 25 L2-Science Products

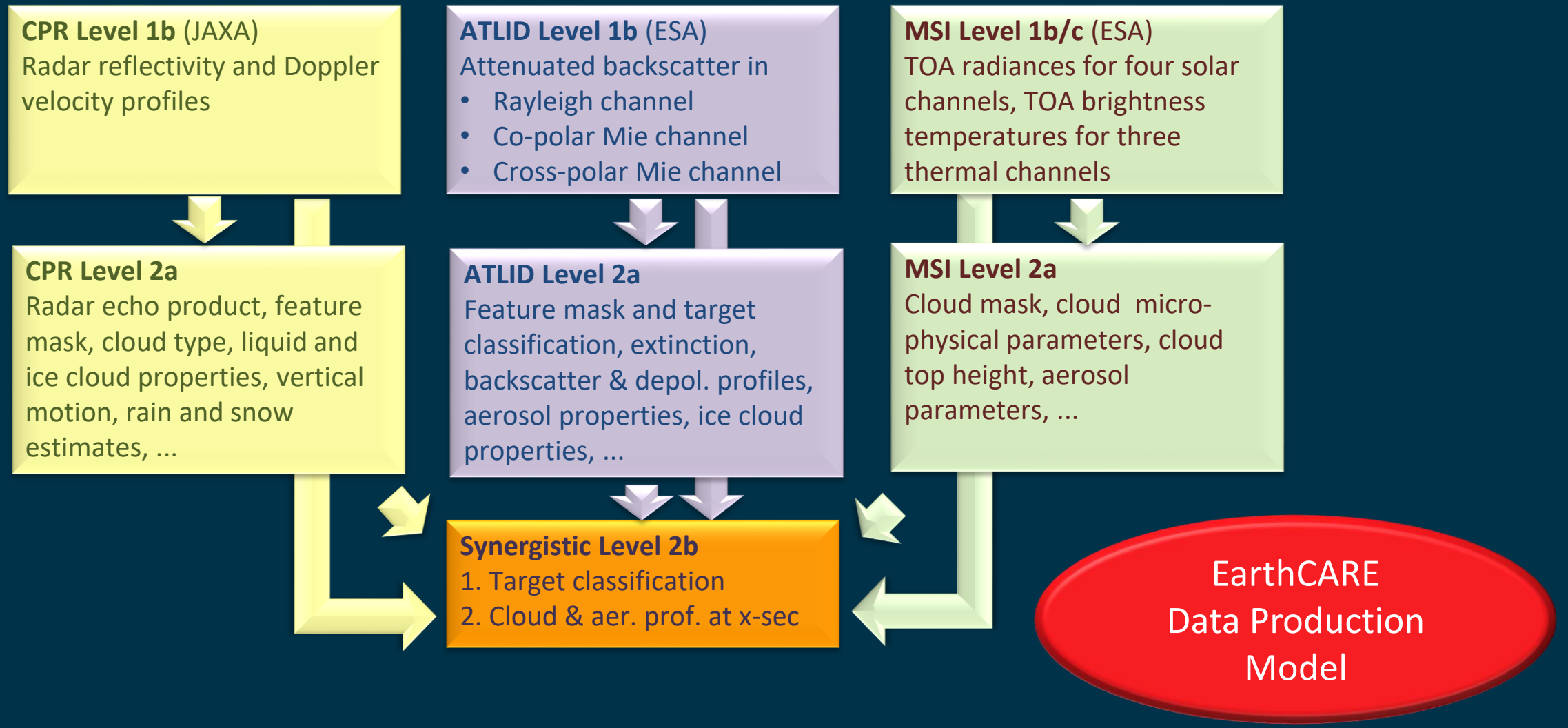


EarthCARE Retrievals:

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

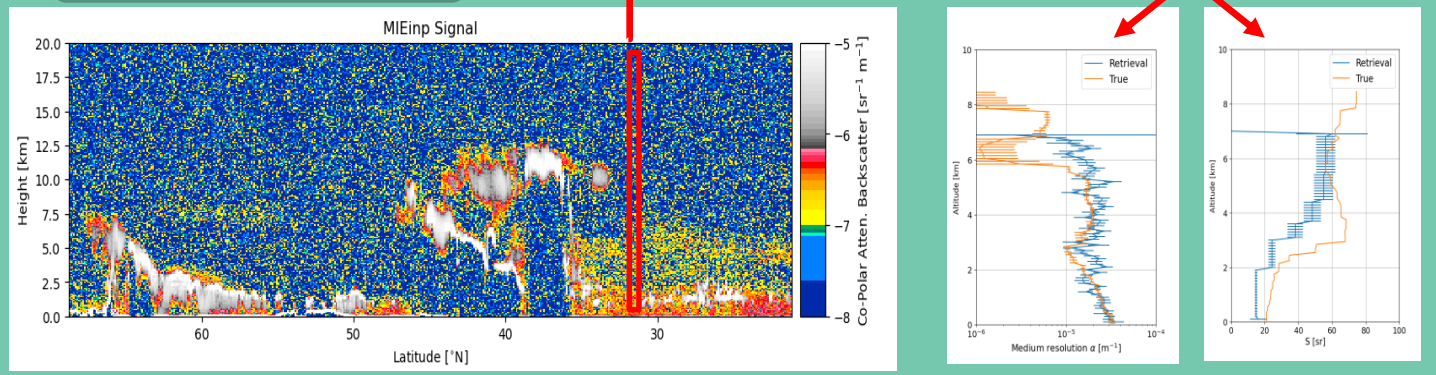

CPR Level 1b (JAXA)
Radar reflectivity and Doppler velocity profiles
ATLID Level 1b (ESA)
Attenuated backscatter in
• Rayleigh channel
• Co-polar Mie channel
• Cross-polar Mie channel
MSI Level 1b/c (ESA)
TOA radiances for four solar channels, TOA brightness temperatures for three thermal channels
CPR 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

Aerosol Retrievals

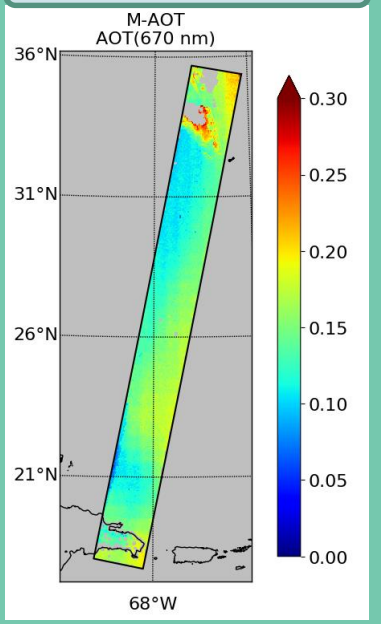
EarthCARE production model

Legend

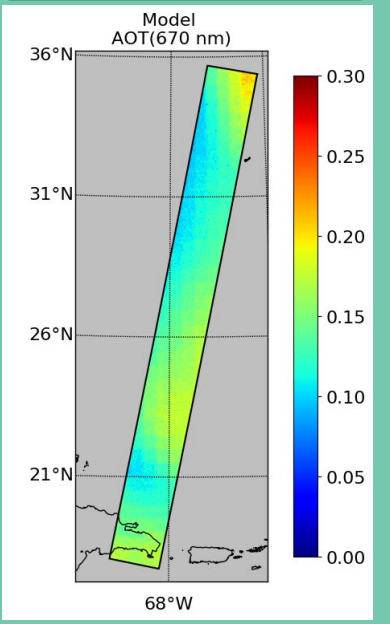
A-EBD α & S (355 nm)



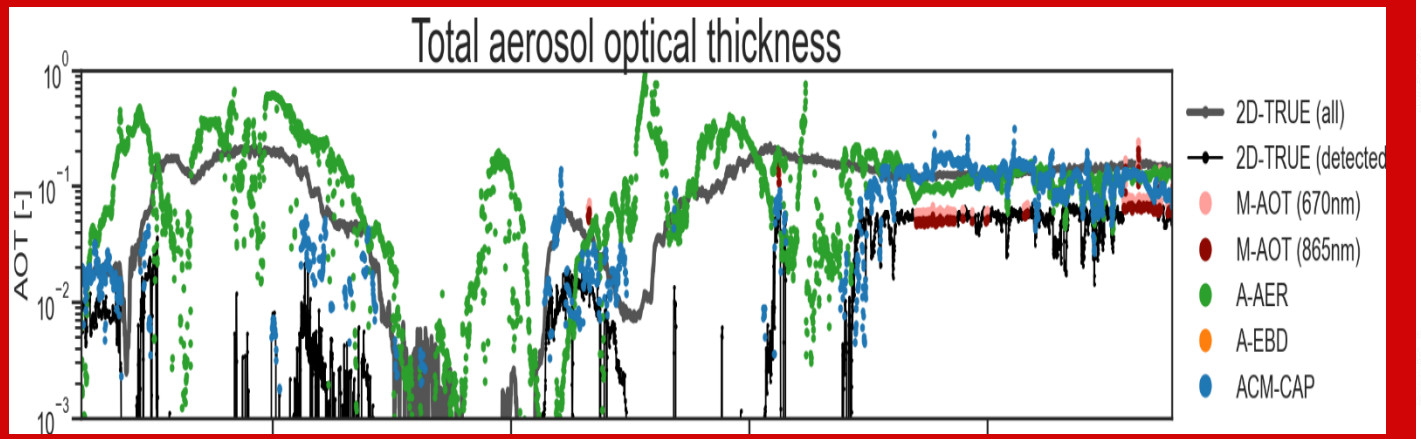
M-AOT AOT(670 nm)

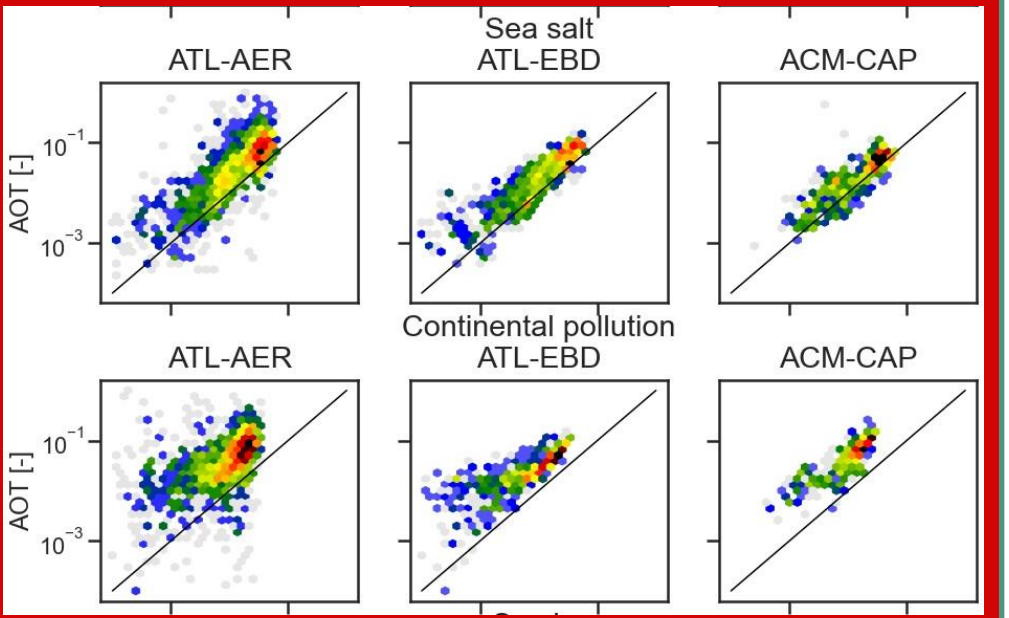


Model AOT(670 nm)

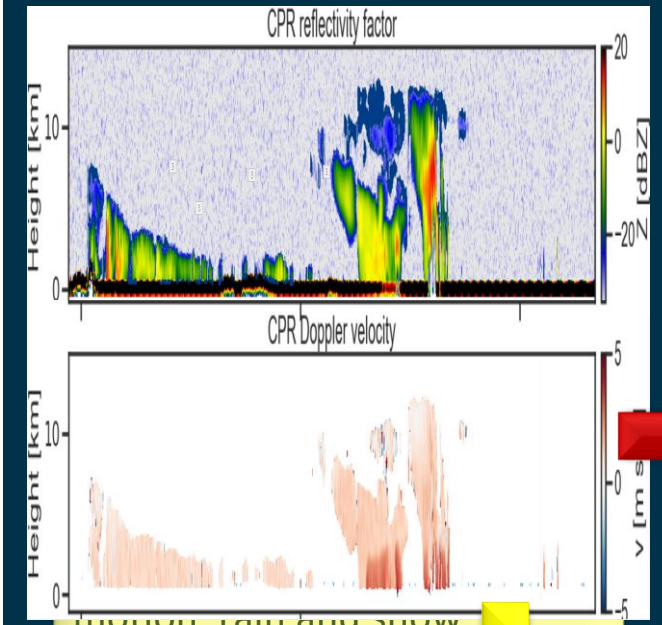


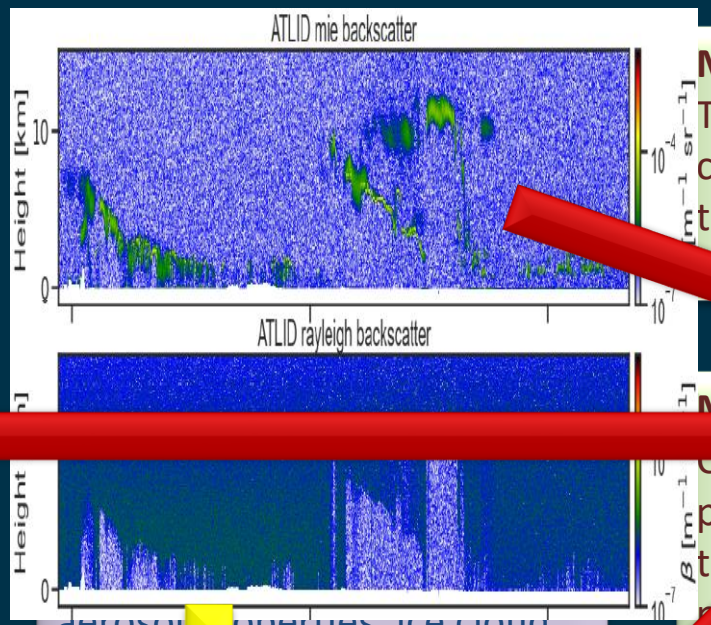
Comparison/evaluation of L2a & L2b aerosol retrievals





acknowledgements: KNMI, FuB, ECMWF





MSI Leve
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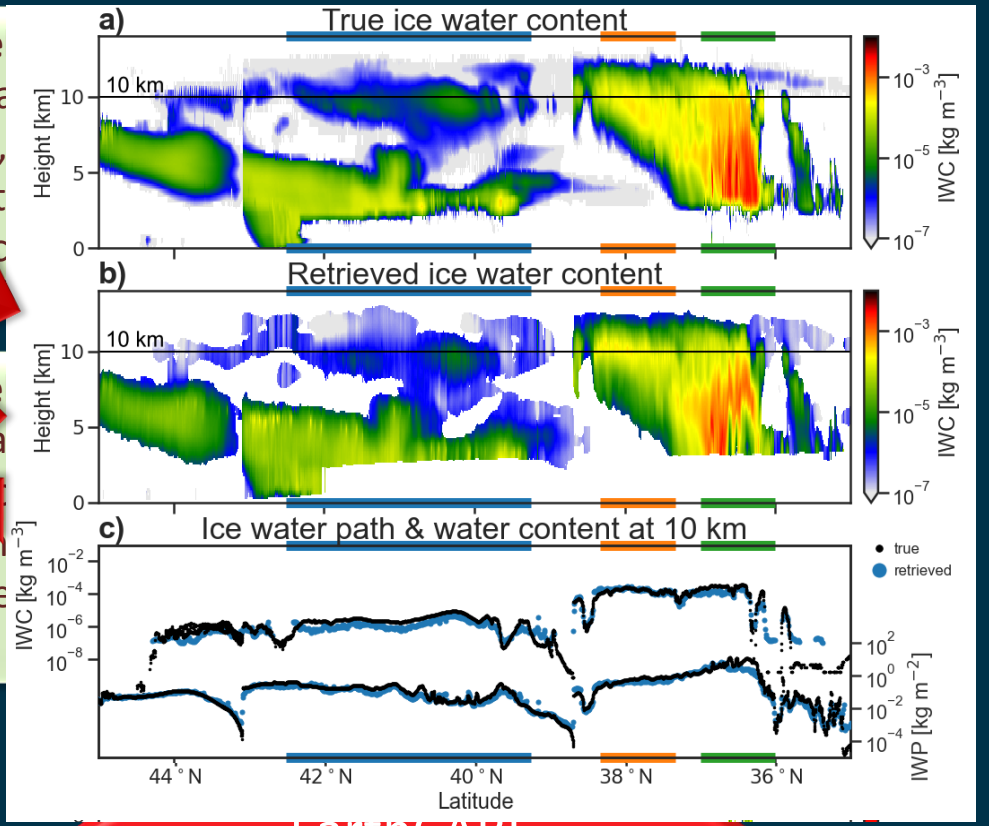
motion, rain and snow estimates, ...

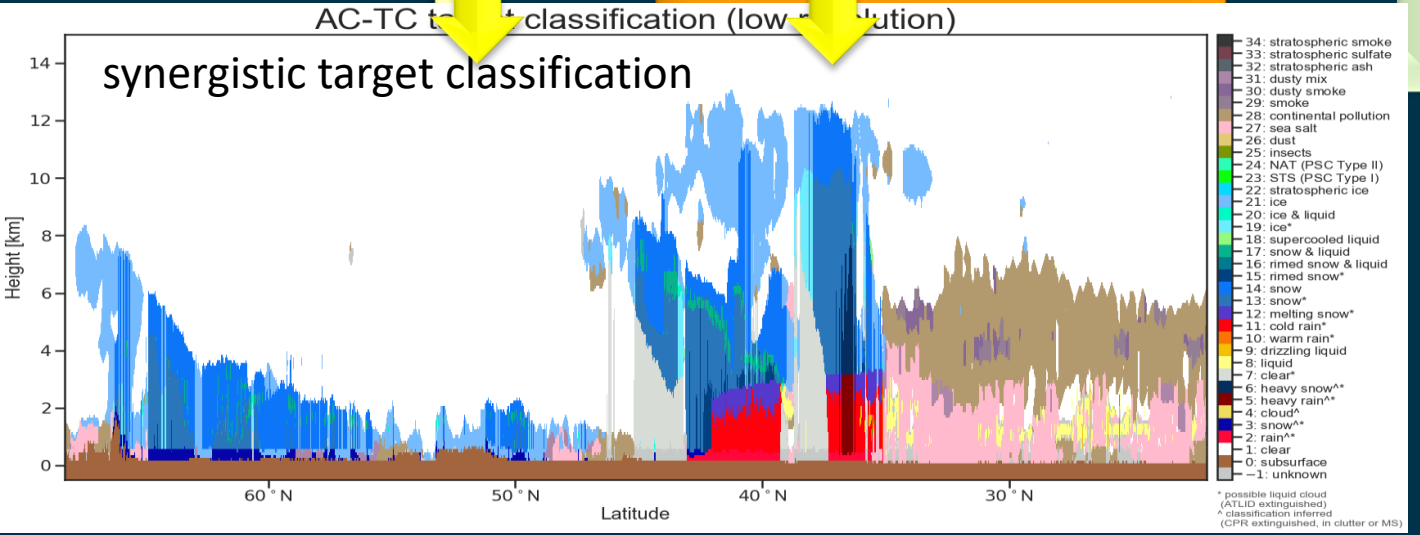
aerosol properties, ice cloud properties, ...



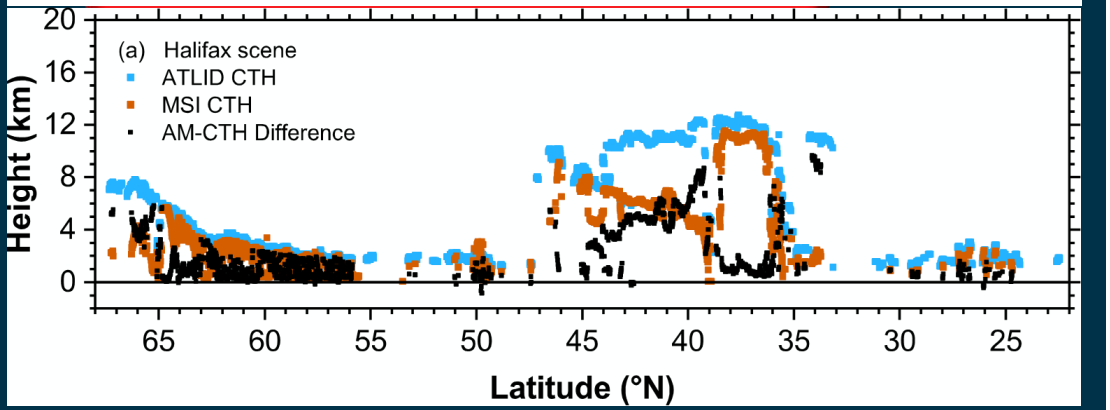
Synergi Level 2b

EarthCARE

AC-TC t classification (low lution)



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



acknowledgements: KNMI, LATMOS, ECMWF, TROPOS

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TOA radiances for four solar channels, TOA brightness

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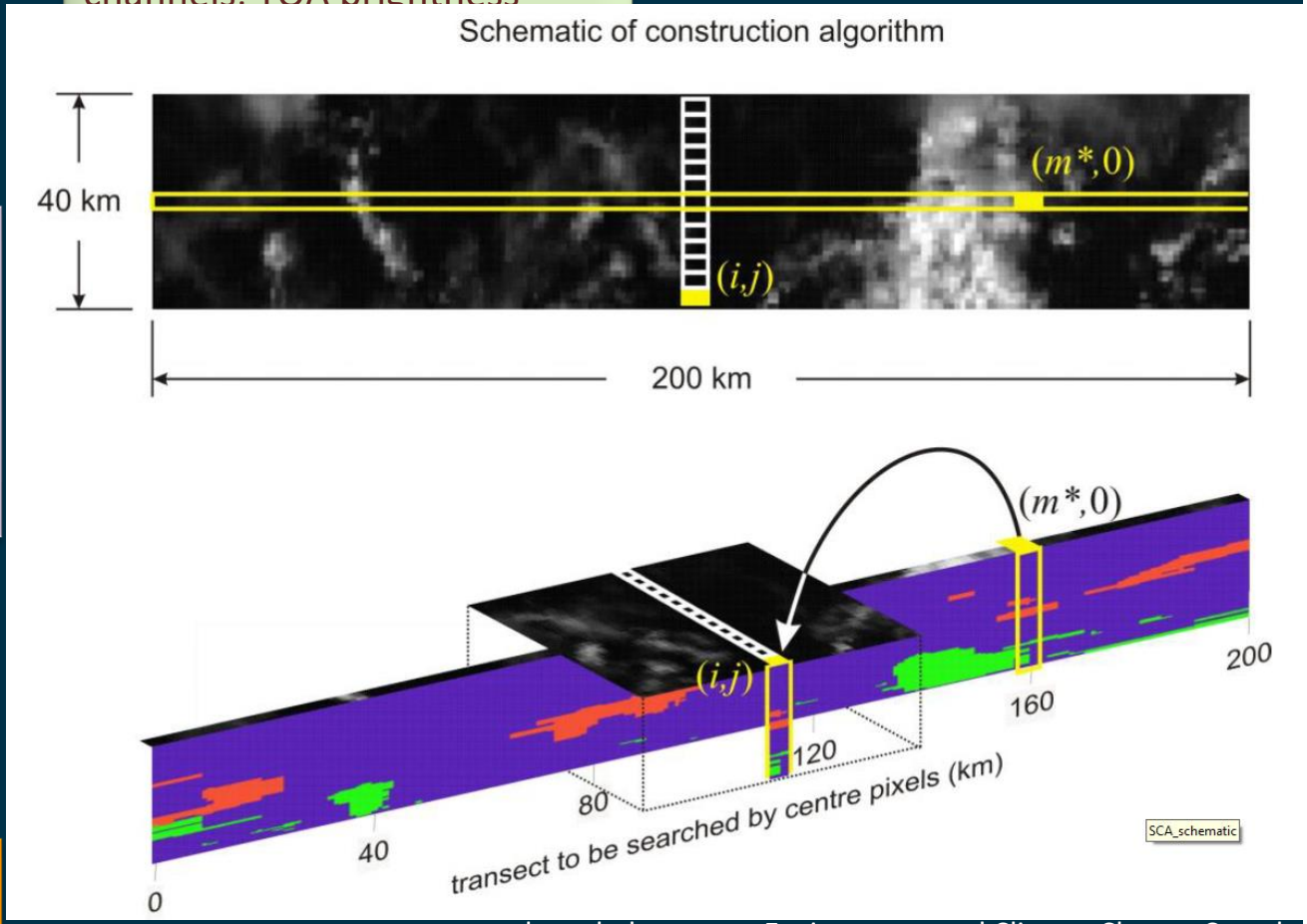
Feature mask and target classification, extinction, backscatter & depol. profiles, aerosol properties, ice cloud properties, ...

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

3D Scenes Construction
Expand syn. retrievals across-track using MSI; ≈40km wide

Radiative Transfer Products
calculated radiances, fluxes, heating rate profiles



acknowledgements: Environment and Climate Change Canada

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

CPR Level 2a
Radar echo product, f
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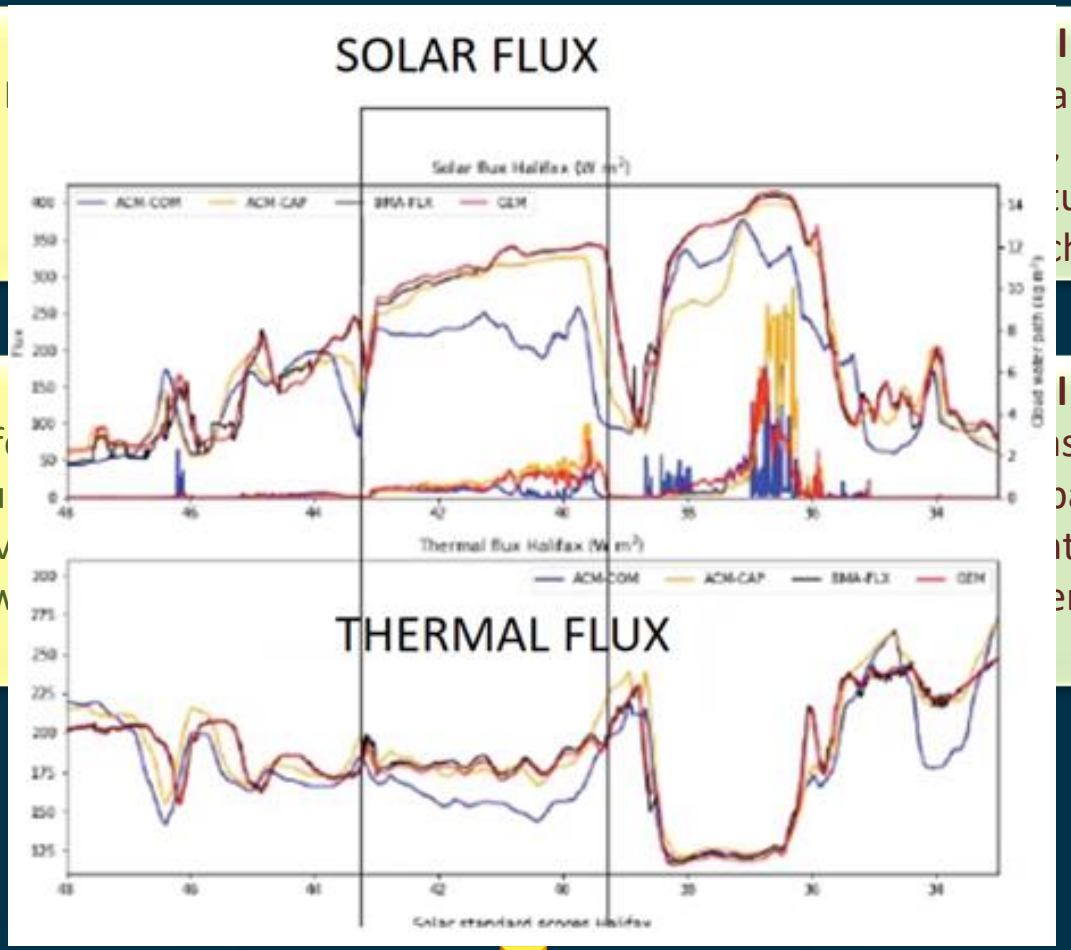

l 1b/c (ESA)
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, TOA brightness
tures for three
channels

l 2a
sk, cloud micro-
parameters, cloud
t, aerosol
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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

EarthCARE
Data Production
Model

3D Scenes Construction
Expand syn. retrievals across-track using MSI; ≈40km wide

Radiative Transfer Products
calculated radiances, fluxes, heating rate profiles

Assessment
Comparison of calculated fluxes and radiances to BBR observations

acknowledgements: ECCC, ECMWF,

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'
- Two Horizon projects are under negotiation which will focus on the interaction of clouds-aerosol & radiation, use of EarthCARE data is mandatory.
- Major improvements on the description of cloud, aerosol and radiation interaction within models are expected in the near future & EarthCARE (and AOS after that) will play a major role in this

The EarthCARE L2 processing chain is almost ready to deliver long anticipated, unique and crucial data products, to address uncertainties in the influence of clouds and aerosols on the incoming solar and outgoing thermal radiation.

Acknowledgments

The EarthCARE Joint Mission Advisory Group

Co-chairs: *A.J. Illingworth, H. Okamoto*

Members: *L. Baldini, A. Battaglia, H. Chepfer, N. Clerbaux, J. Cole, J. Delanoë, D. Donovan, J. Fischer, S. Groß, R. Hogan, T.Y. Nakajima, T. Nishizawa, Y. Ohno, M. Satoh, K. Suzuki, N. Takahashi, U. Wandinger*

Observers: *S. Kato, G. Stephens, B. Stevens, D. Vane, D. Winker*

A. J. Illingworth *et al.*

The EarthCARE satellite: The next step forward in global measurements of clouds, aerosols, precipitation and radiation

http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-12-00227.1

Level 2 Team

- **ATLID retrievals**
  G.-J. van Zadelhoff, D. Donovan, P. Wang, J. de Kloe (KNMI, Netherlands), U. Wandinger, M. Haarig (TROPOS, Germany)
- **CPR products**
  P. Kollias, B. Puigdomenech (McGill University, Canada); A. Battaglia (University of Torino, Italy)
- **MSI retrievals**
  A. Hünerbein, S. Bley (TROPOS, Germany); N. Docter, R. Preusker, J. Fischer (Free University of Berlin, Germany)
- **BBR radiances and estimated fluxes**
  N. Clerbaux, A. Velazquez, E. Baudrez (Royal Meteorological Institute Belgium); C. Domenech, R. Garcia Maranon (GMV Madrid), J. Fischer, N. Madenach (Free University of Berlin, Germany)
- **Synergistic ATLID & MSI retrievals**
  U. Wandinger, A. Hünerbein, M. Haarig (TROPOS, Germany)
- **Synergistic CPR & ATLID & MSI retrievals**
  R. Hogan, S. Mason (ECMWF, UK); J. Delanoë, A. Irbah (LATMOS, France)
- **Radiation products (from retrievals) & closure**
  H. Barker, J. Cole, M. Shephard, Z. Qu (Environment and Climate Change Canada); N. Villefranque (LMD/IPSL, France)

ECMWF: Assimilation

M. Janiskova, M. Fielding

GMV: processor integration

M. Ruiz, C.Bos

ESA: ESTEC+ESRIN

T. Fehr, J. Von Bismarck, M. Eisinger, A. Hoffmann, R. Koopman, P. Deghaye, K. Wallace, C. Caspar, C. Stella, S. Rusli, A. Piro, B. Abis. (T. Wehr)

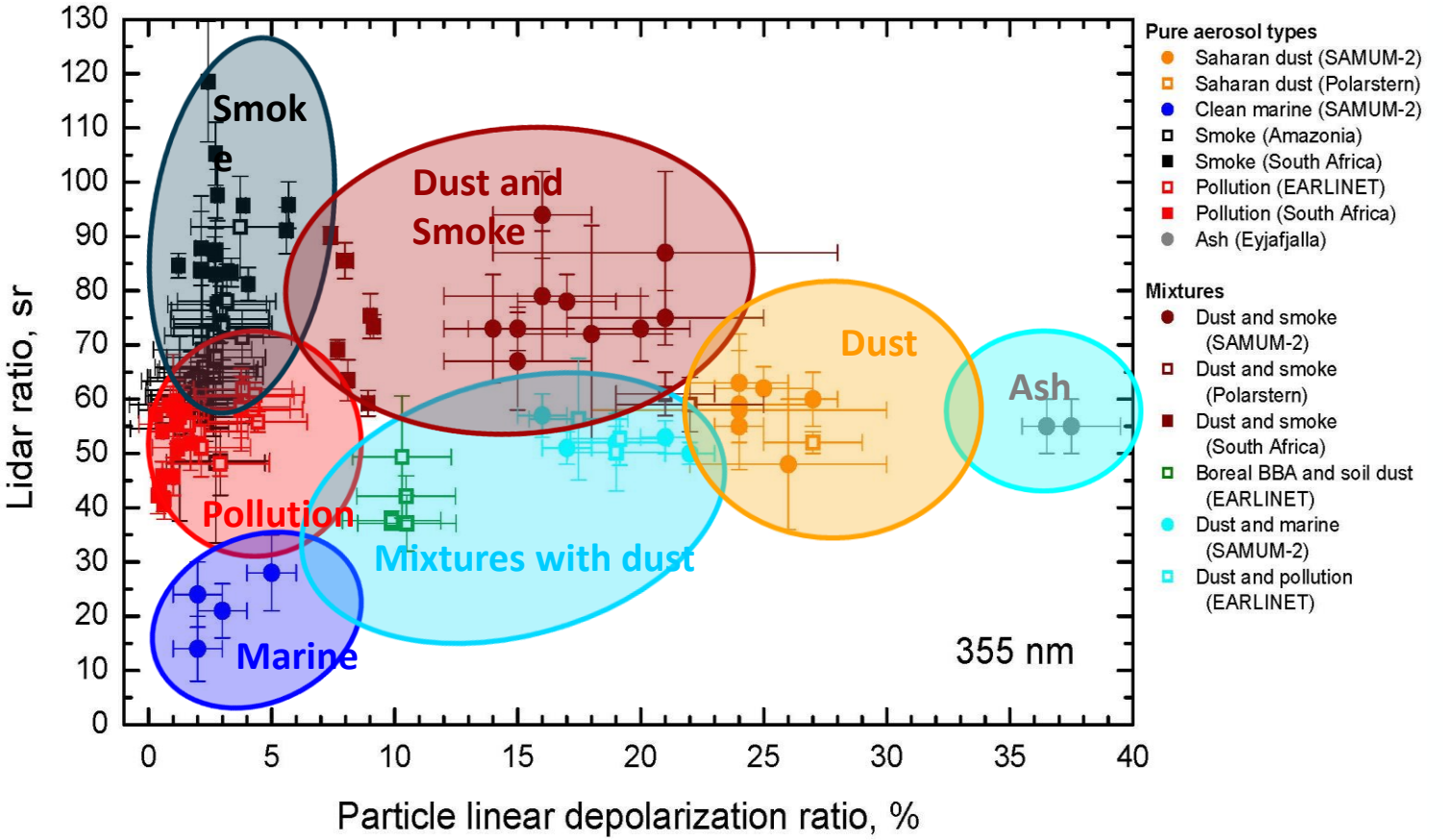
Calibration & Validation

E. Marinou (NOA), H. Baars (TROPOS)

HETEAC (Hybrid End-to-End Aerosol Classification)

U. wandinger

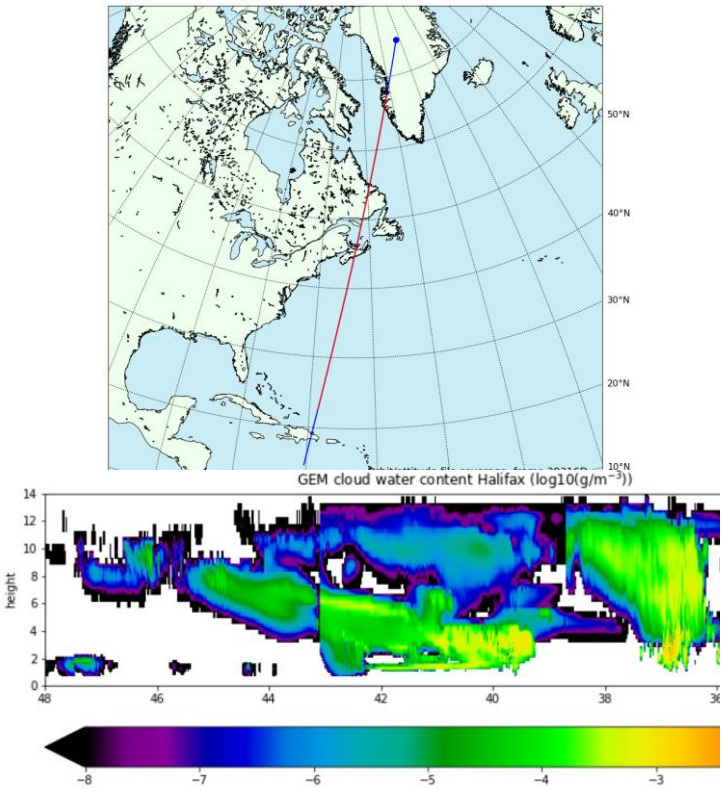
- **Aerosol classification** model developed for EarthCARE and implemented in ECSIM
- To connect **microphysical, optical** and **radiative** properties of pre-defined aerosol components
- 4 basic aerosol components with **prescribed microphysical properties** to calculate mixtures
- **Radiation closure for aerosol** from ATLID & MSI with BBR



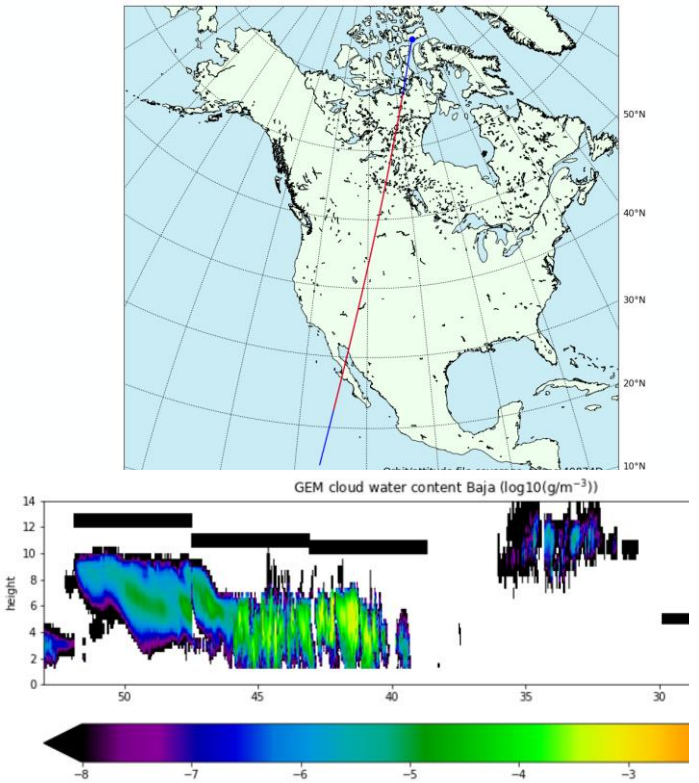
Algorithm testing

Three high-resolution scenes from the Canadian GEM model have been generated

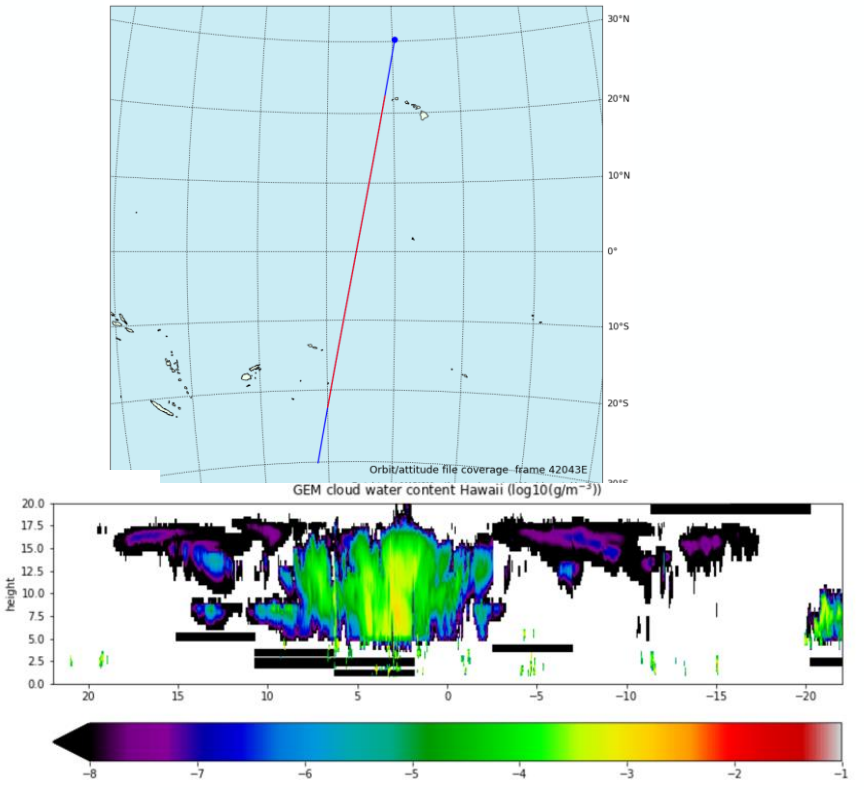
"Halifax" scene



"Baja" scene



"Hawaii" scene



Level 2 products produced by European/Canadian team
(based on simulated Level 1 data produced by science team)

Level 1 data produced by ESA processors
A-NOM, M-NOM, M-RGR, B-NOM, B-SNG

Level 2 **Algorithm Theoretical Basis Descriptions** to be published in *Atmospheric Measurement Techniques Special Issue on "EarthCARE Level 2 algorithms and data products"* → so far 20+ papers and more to come

Retrievals and "Closure"

Example of work in progress

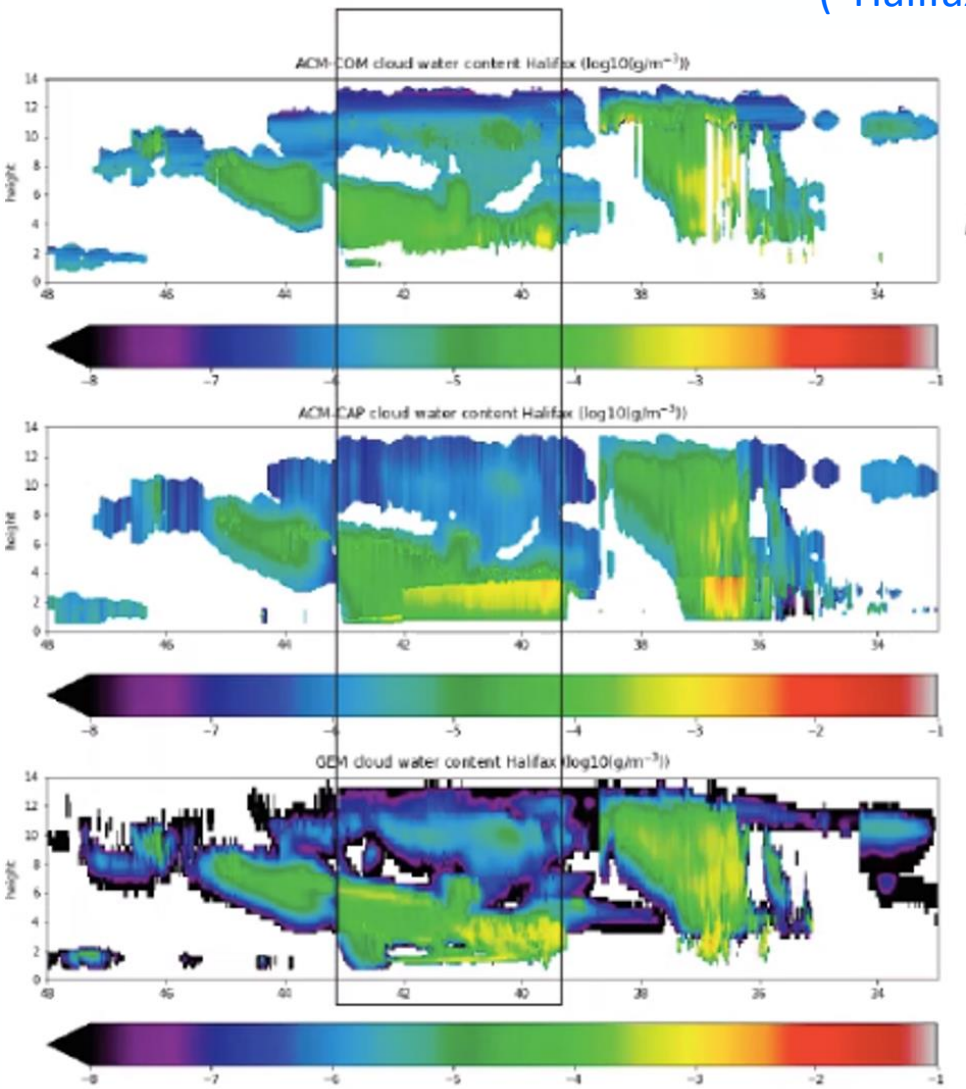
Reconstructed cloud scene based on radar-only + lidar-only + imager-only cloud retrievals ("Composite" product)
FLUX IN BLUE

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

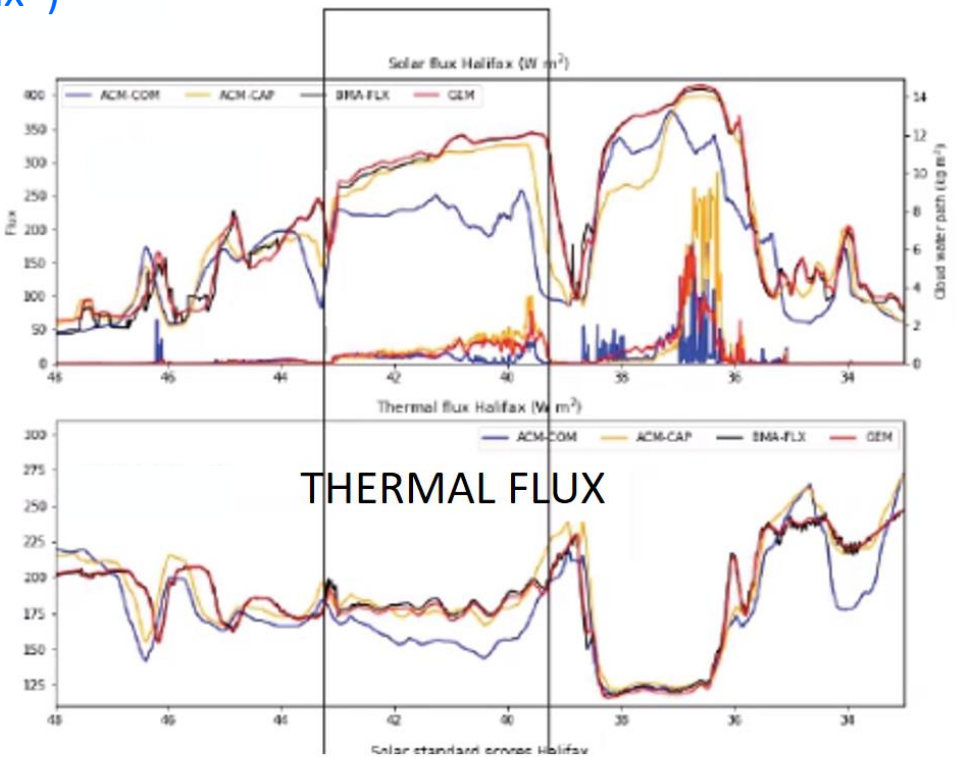
Model truth (Canadian Weather Model GEM)
FLUX IN RED

Cloud water content

Test Scene ("Halifax")



SOLAR FLUX



→ "Composite" clouds are too dull and too cold