

# living planet symposium | BONN

23–27 May  
2022

TAKING THE PULSE  
OF OUR PLANET FROM SPACE



## ESA EarthCARE Level 2 Retrievals and Products ESA's Earth, Clouds, Aerosols and Radiation Explorer

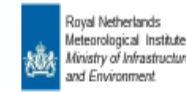
Presented by Gerd-Jan van Zadelhoff (KNMI),

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

26 May 2022: inv-67588

# CARDINAL team

## Clouds, Aerosol, Radiation – Development of Integrated ALgorithms



- Cloud, aerosol and radiation interaction are currently the largest source of uncertainty in projections of the future climate, making them critical to improve numerical weather predictions and climate modelling.
- A full L2 processing chain has been developed and evaluated using modelled scenes.
- The processing chain will provide 14 single instrument products and 11 multi-instrument products.
- All processors have been designed and implemented by the L2 team and will run as is in the PDGS. Providing the entire processing chain (tested as chain) is part of the team's responsibilities.
- The L2 team in the CARDINAL project will remain until the end of the commissioning phase.



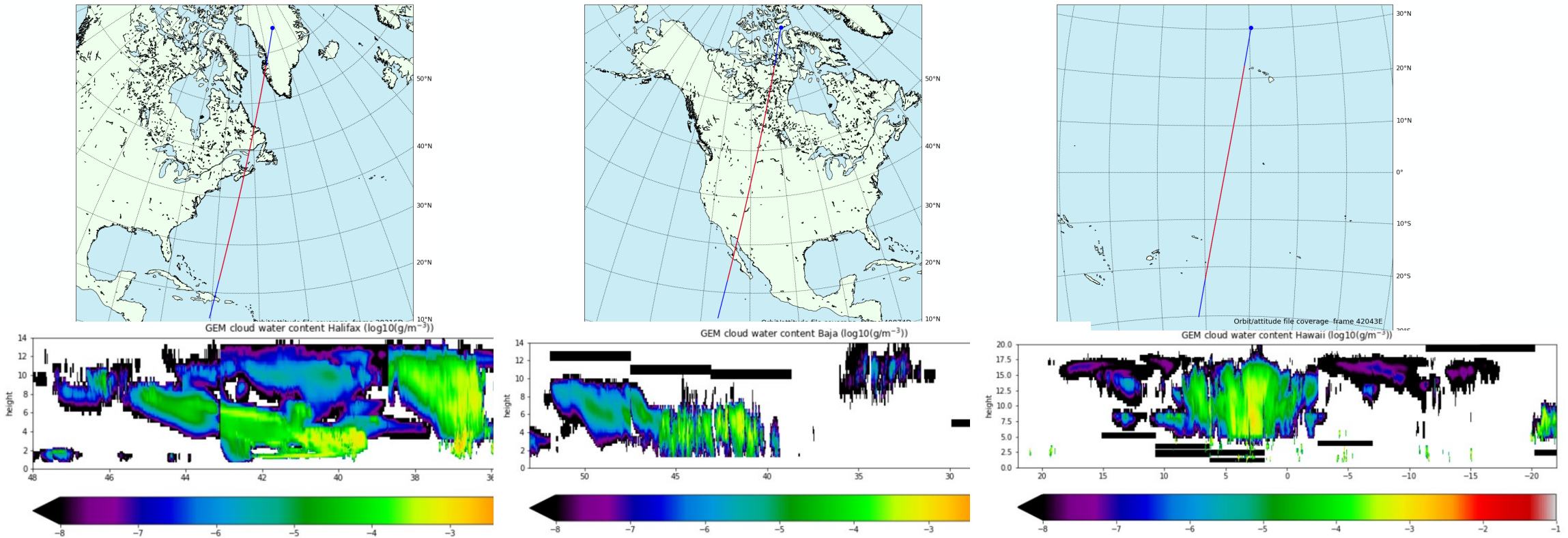
# Algorithm testing

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"* → paper submission target is September 2022

**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**

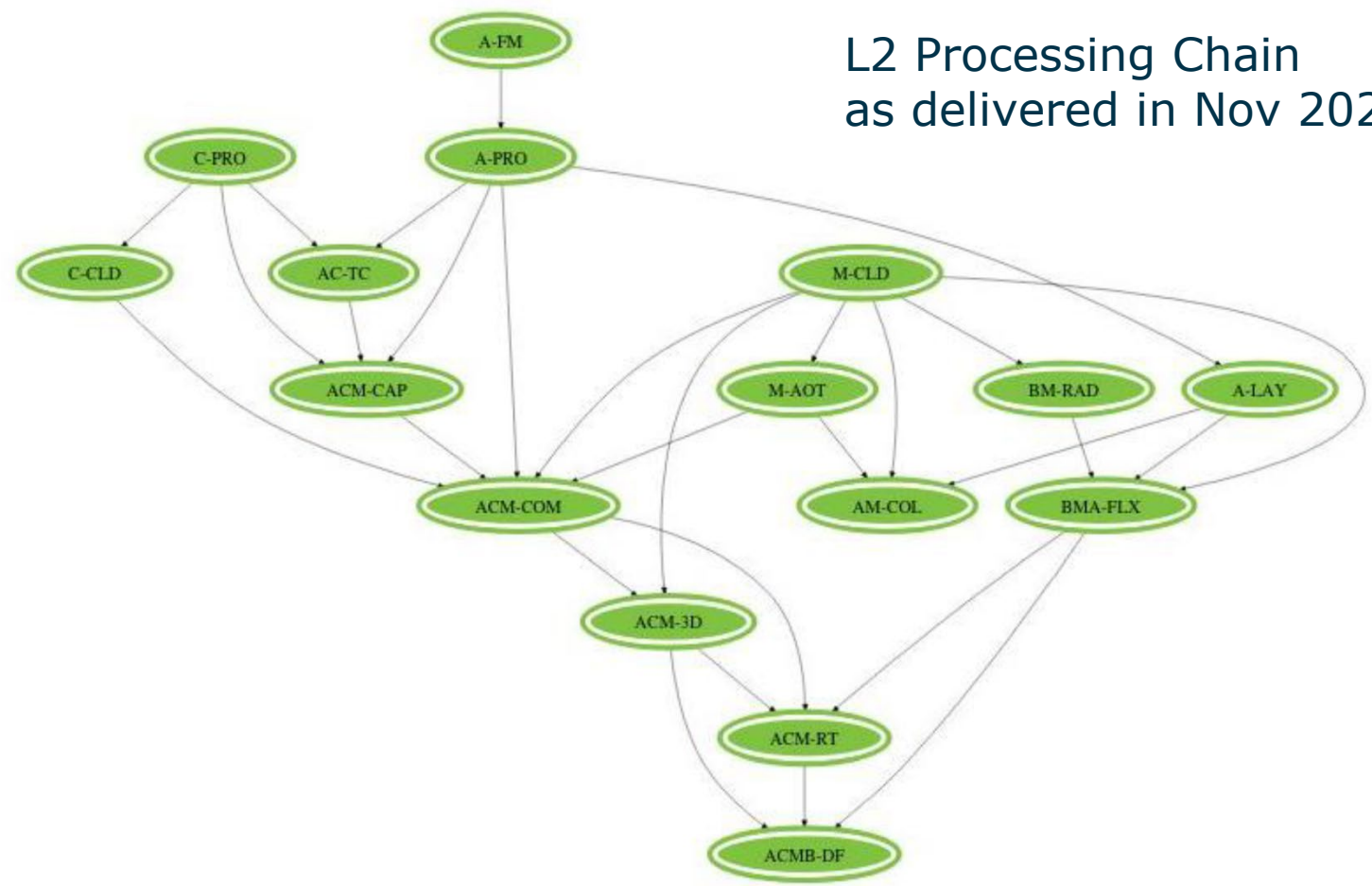
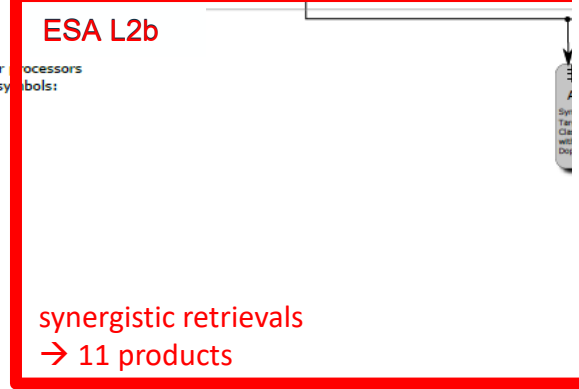
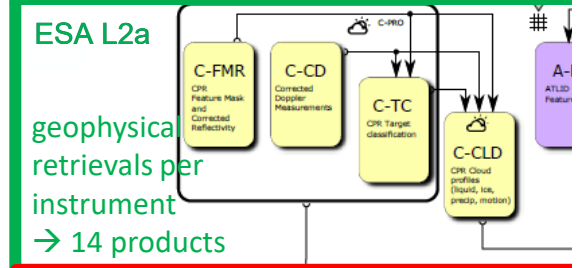
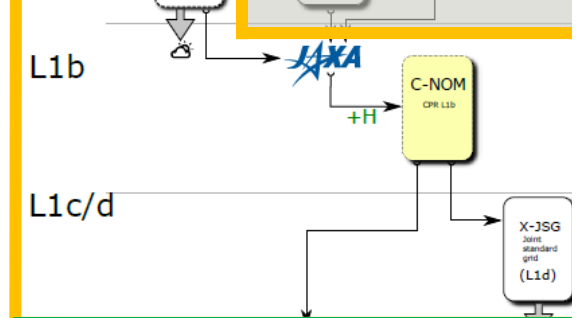
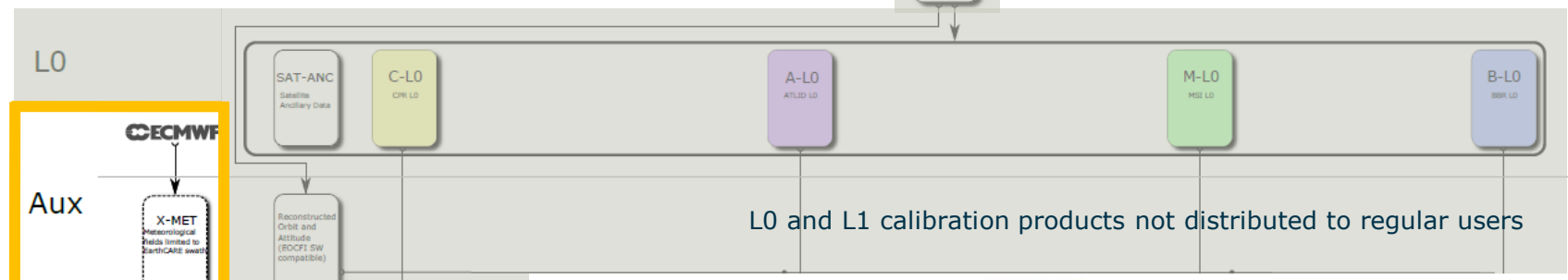
# EarthCARE Data Product Tree

**ESA data products** will be produced operationally by the ESA ground segment located at ESRIN.

**JAXA data products** fall in two categories: **Standard Products** and **Research Products** (see next **uji**)

**Legend**

- CPR (Yellow)
- ATLID (Purple)
- MSI (Green)
- BBR (Blue)
- Synergy (Grey)
- Other (White)
- Produced externally (JAXA, ...)
- reuse of calibration product(s) from previous processor runs
- Products produced by single processor
- Inputs (solid arrow)
- Tentative inputs (dashed arrow)
- +H Add XML header file
- Products used by other processors as indicated by these symbols:
  - # X-JSG
  - X-MET



L2 Processing Chain as delivered in Nov 2021

Legend

CPR

MSI

Syner

Produced externally (JAXA, ...)

reuse of calibration product(s) from previous processor runs

Products by single

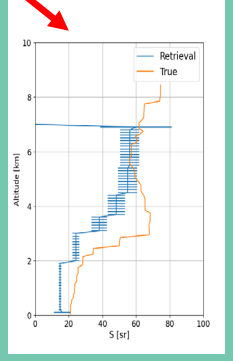
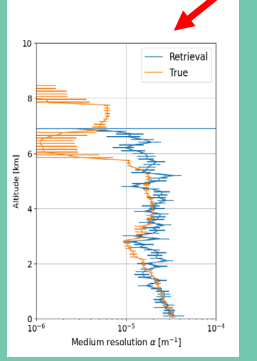
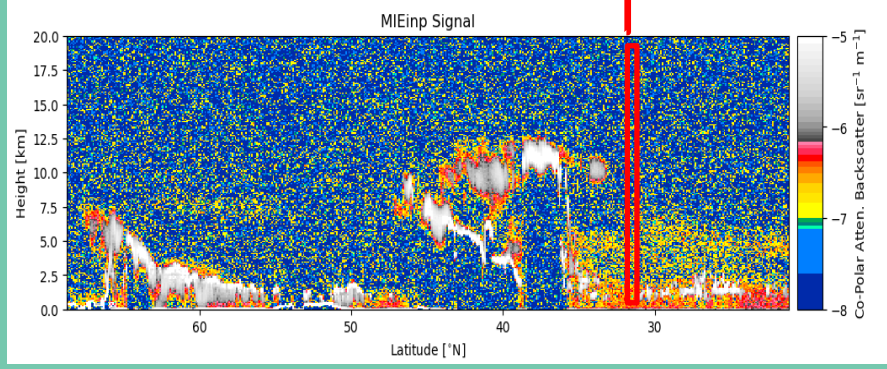
Prod as in

# X-)

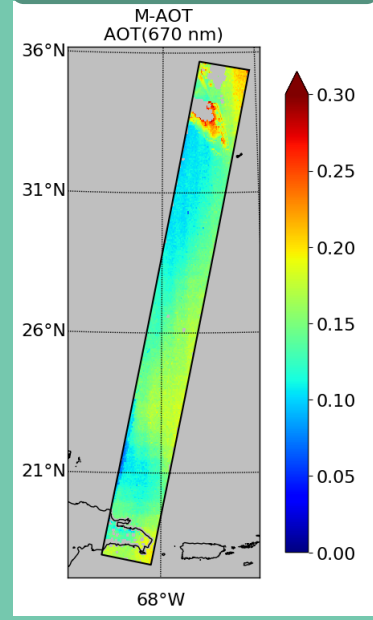
X-)



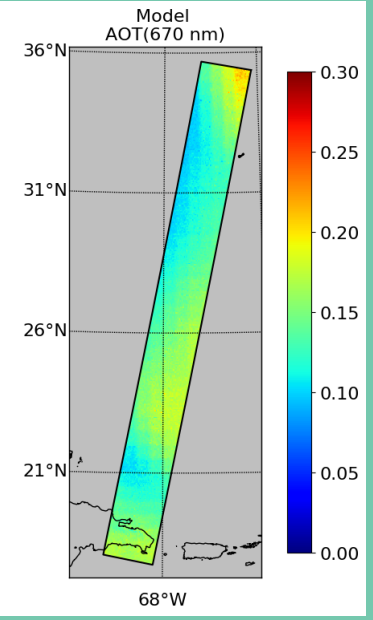
## A-EBD $\alpha$ & S (355 nm)



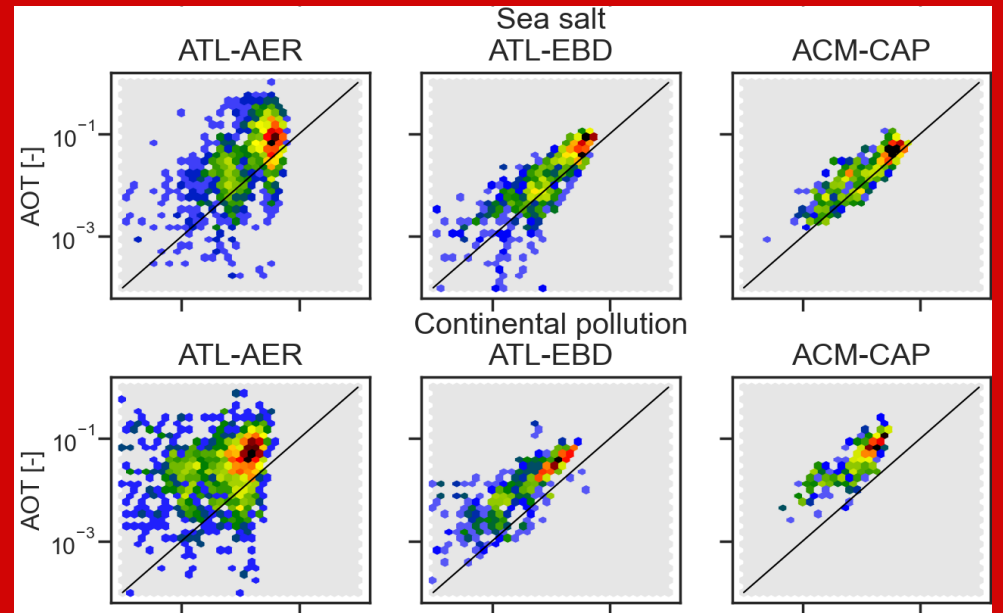
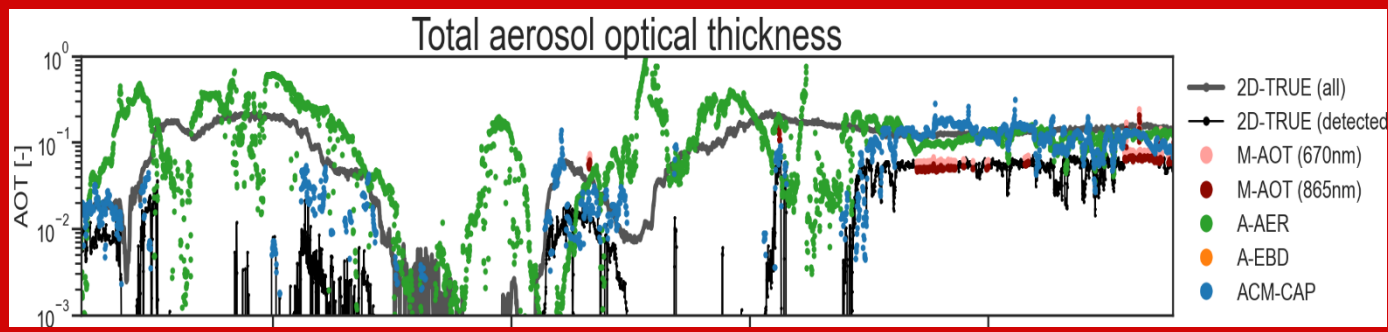
## M-AOT AOT(670 nm)

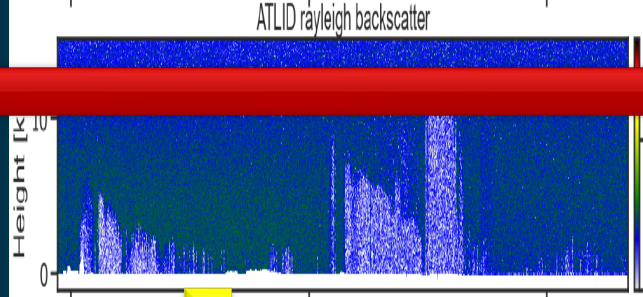
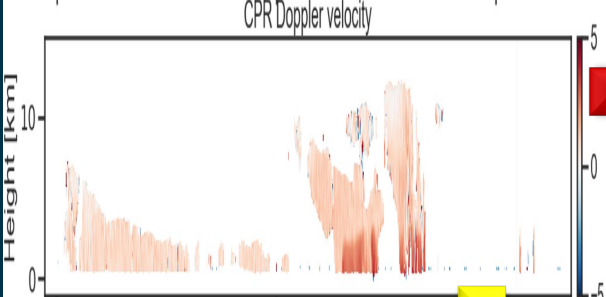
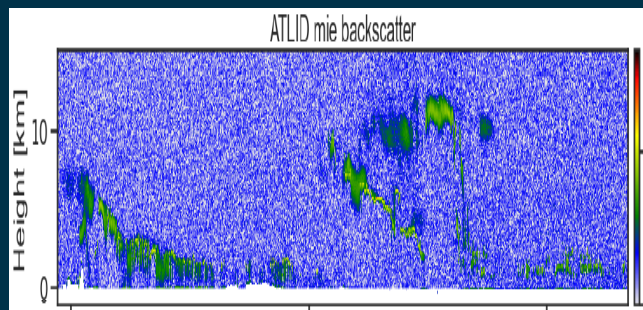
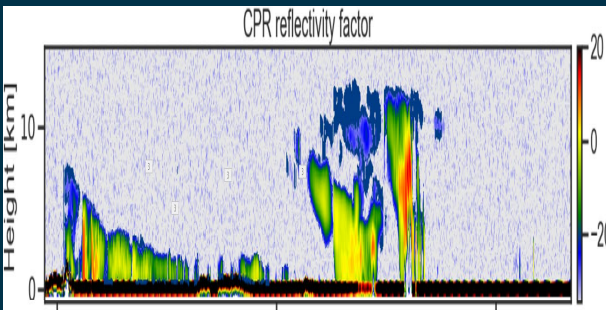


## Model AOT(670 nm)



## Comparison/evaluation of L2a & L2b aerosol retrievals





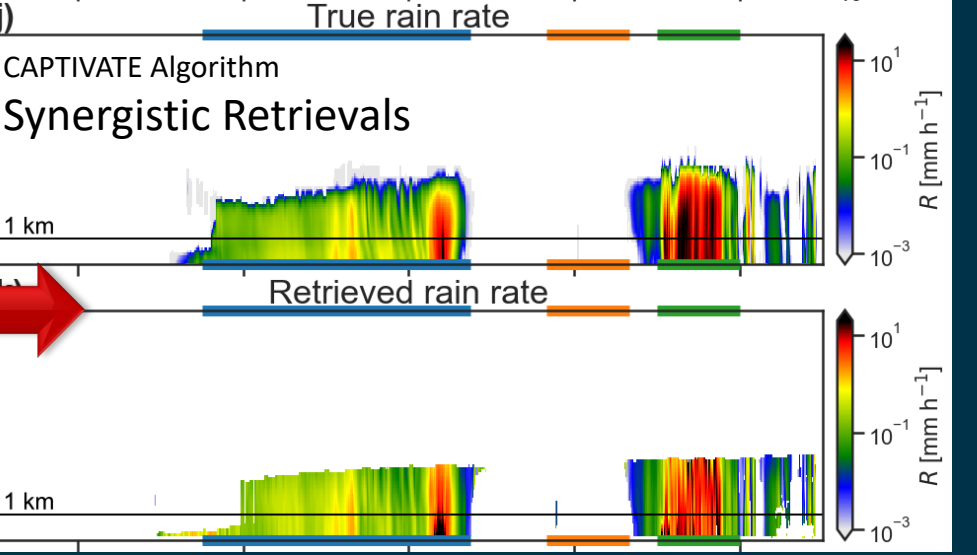
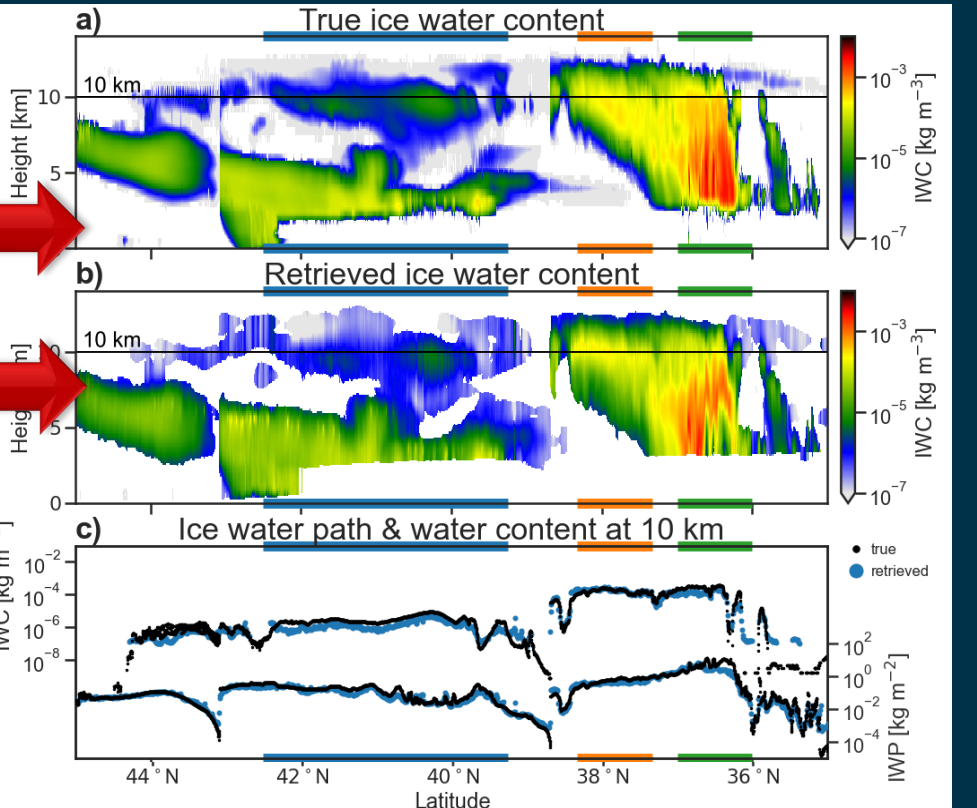
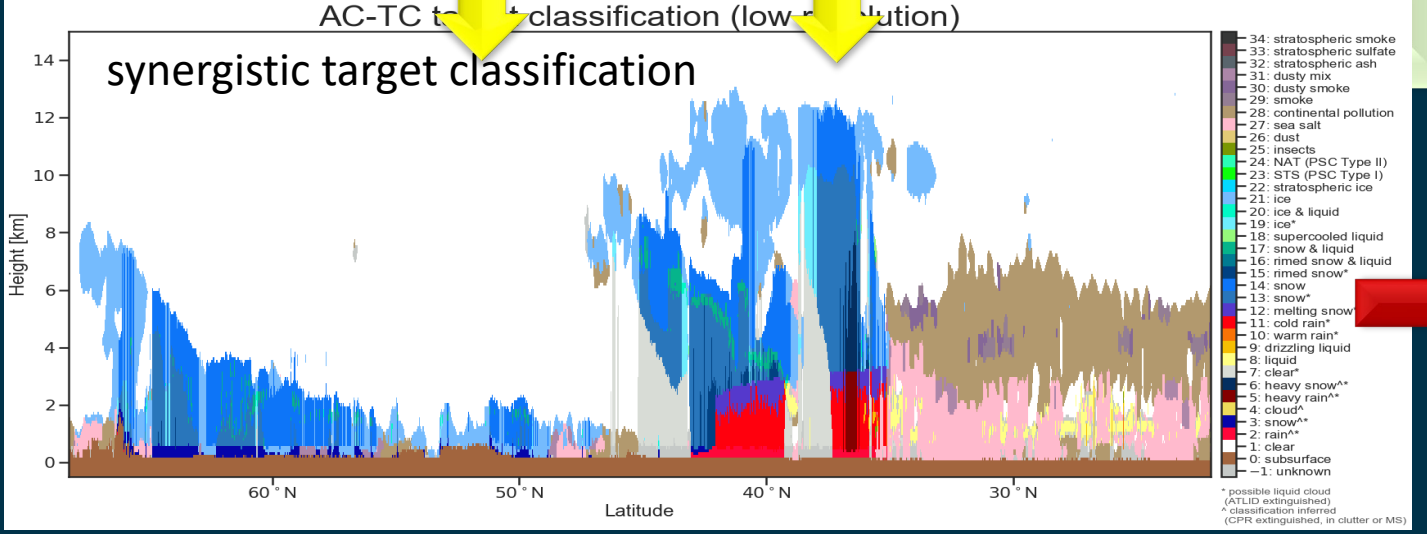
MSI Level  
TOA radiance  
channels,  
temperature  
atmospheric

Cloud macro  
physical prop  
top height  
parameters

motion, rain and snow  
estimates, ...

aerosol properties, ice cloud  
properties, ...

**Synergistic Level 2b**



### 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

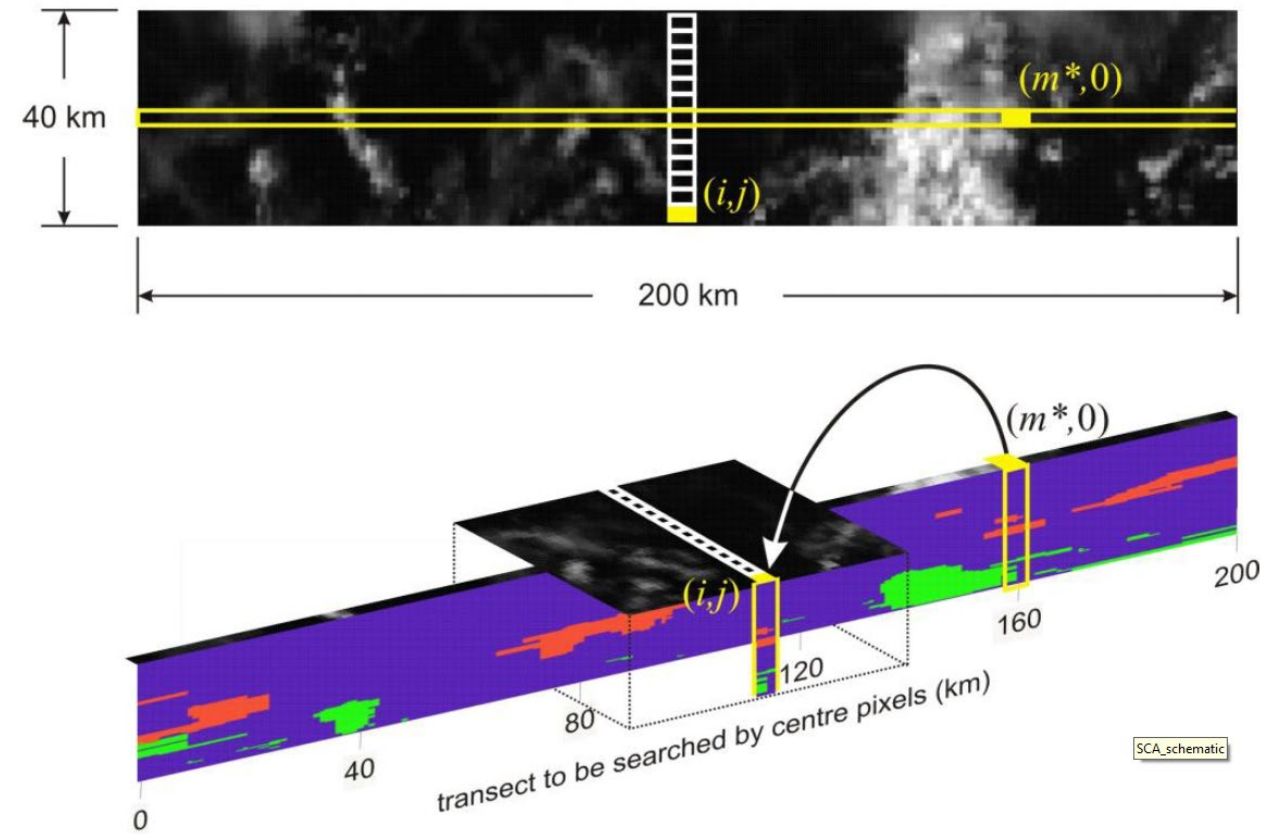
### 3D Scenes Construction

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

### Radiative Transfer Products

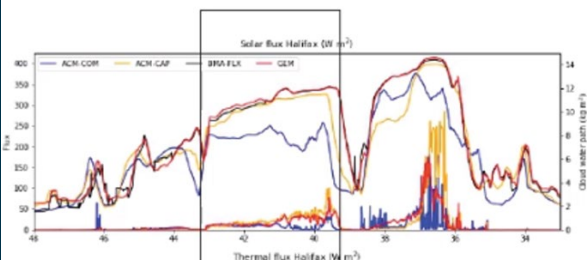
calculated radiances, fluxes, heating rate profiles

Schematic of construction algorithm

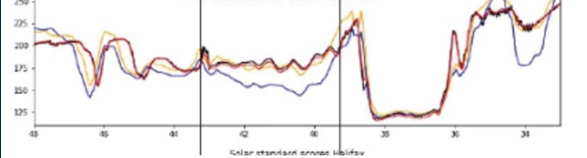


acknowledgements: Environment and Climate Change Canada

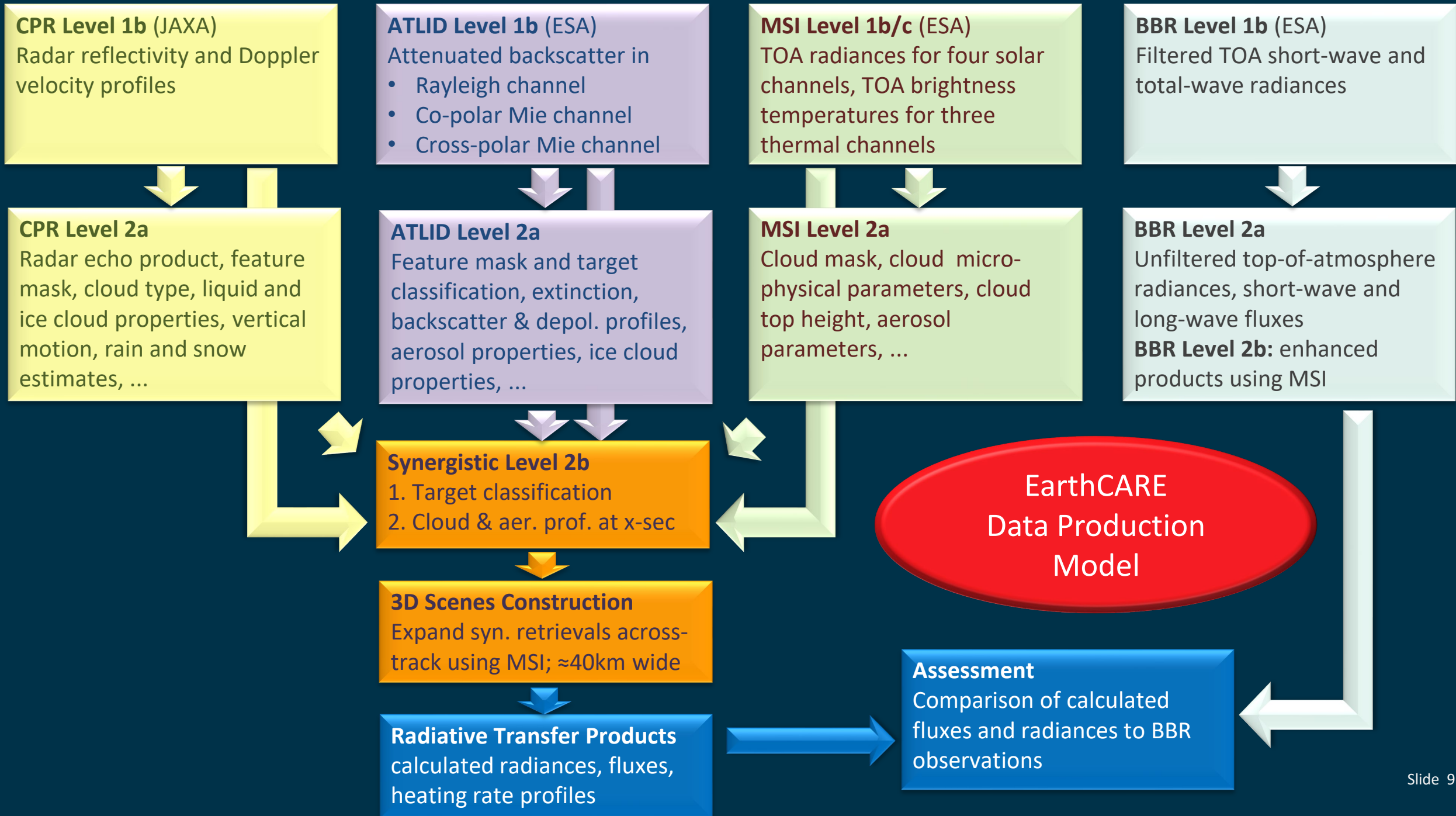
### SOLAR FLUX



### THERMAL FLUX







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**

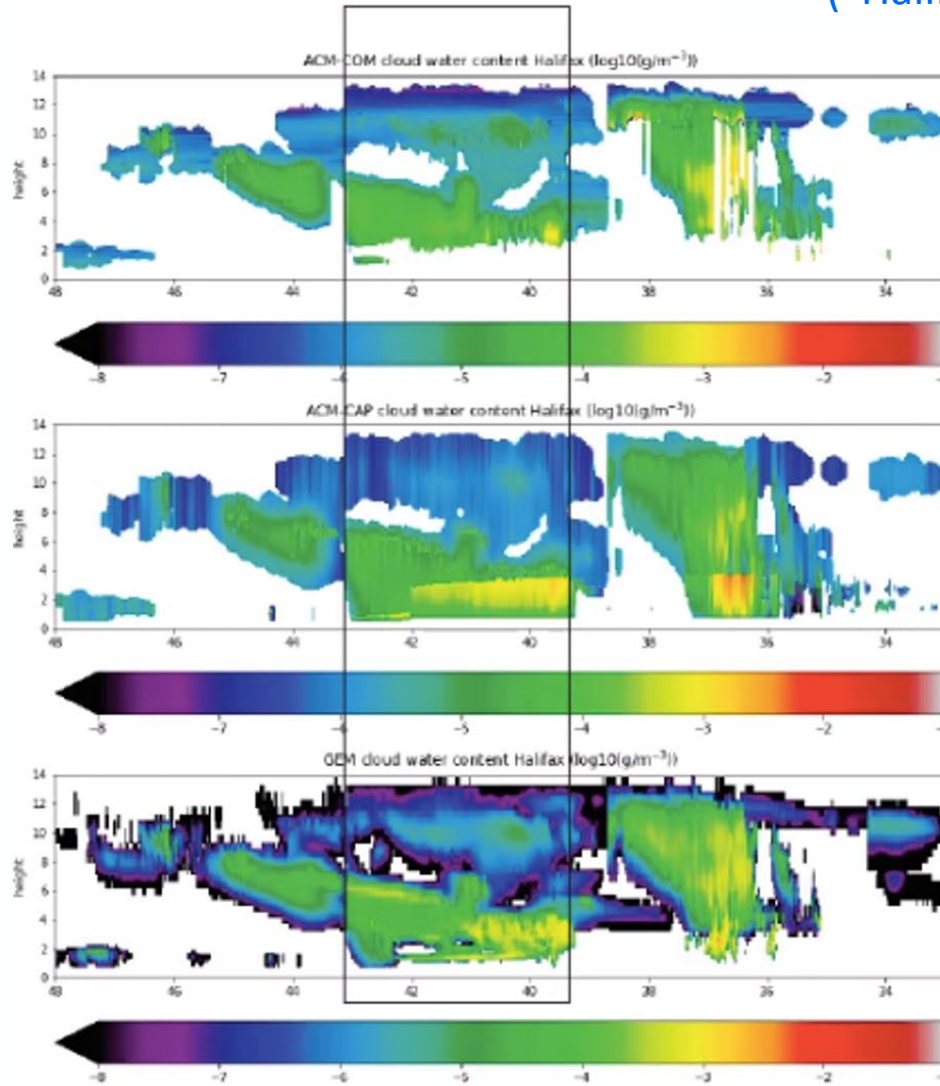
Synergistically retrieved cloud scene, CAPTIVATE algorithm (Opt. Estimation with complex state vector)

**FLUX IN YELLOW**

Model truth (Canadian Weather Model GEM)

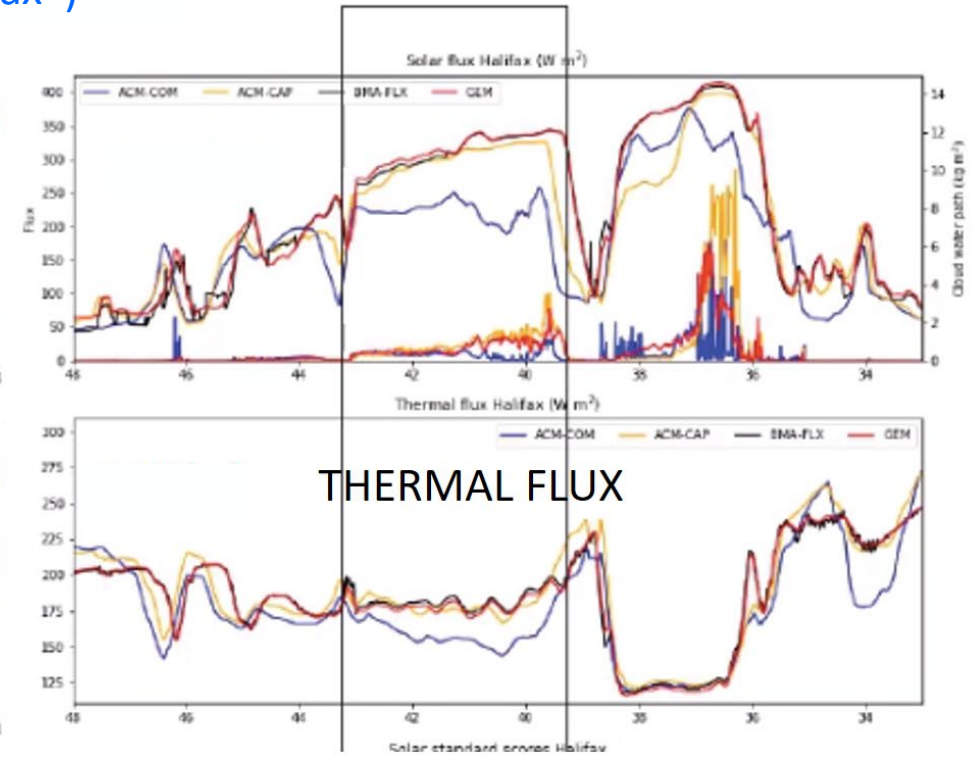
**FLUX IN RED**

Cloud water content



Test Scene (“Halifax”)

SOLAR FLUX



→ “Composite” clouds are too dull and too cold



# Conclusions:

- Cloud, aerosol and radiation interaction are currently the largest source of uncertainty in projections of the future climate, making them critical to improve numerical weather predictions and climate modelling.
- 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
- The L2 team has been assembled and is ready for the commissioning phase!

**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.**

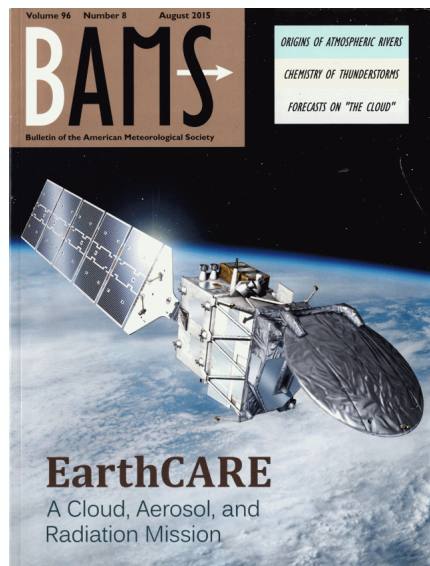
# Acknowledgments

## 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)

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

## Calibration & Validation

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