Overview and status of the ATLID Featuremask (A-FM) and profile processor (A-PRO)

D.P. Donovan, G-J van Zadelhoff, P. Wang
KNMI

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop
17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

Outline

- Overview of the ATLID Featuremask processor (A-FM)
- Overview of the ATLID Profile processor (A-PRO)
- Overview of the products
  - A-FM (Feature Mask)
  - A-AER (ATLID Aerosol)
  - A-EBD (ATLID Extinction Backscatter and Depolarization)
  - A-TC ATLID Target-Classification)
  - A-ICE (ATLID ICE)
- Recent Changes
- Examples
- Points of attention

A-FM

- **A-FM** provides a feature-mask at the **highest available resolution.**
- A combination of techniques is applied including techniques adapted from image processing. E.g. Hybrid-median filtering.
- Dynamic noise floor determination.

A-FM was initially developed using simulated data but was also applied to CALIPSO and ALADIN data.

Example (Halifax Scene)

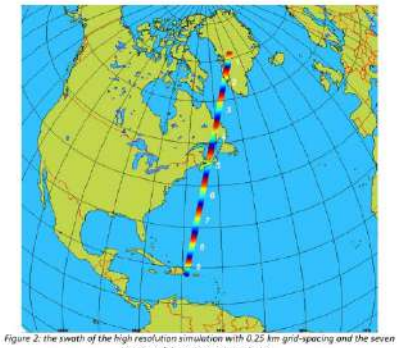
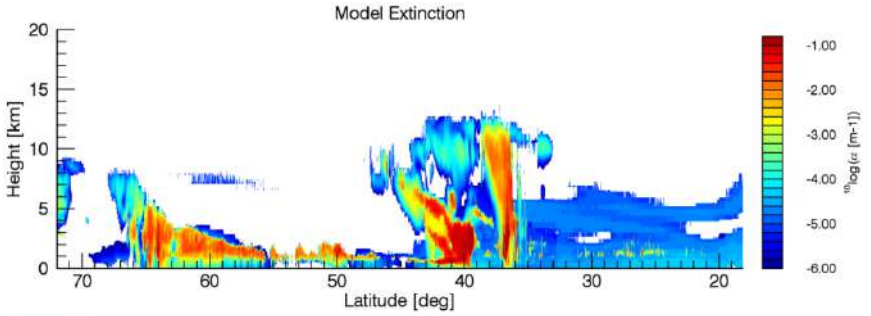
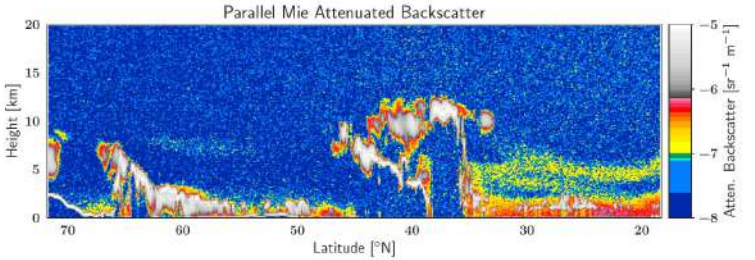
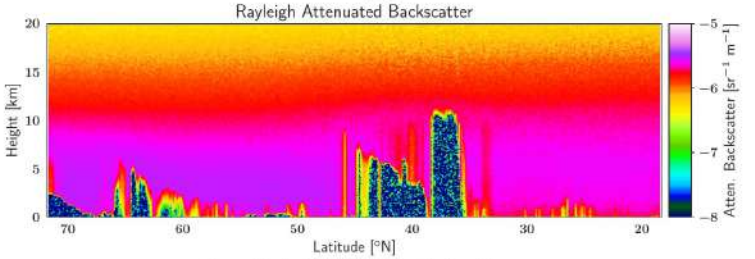
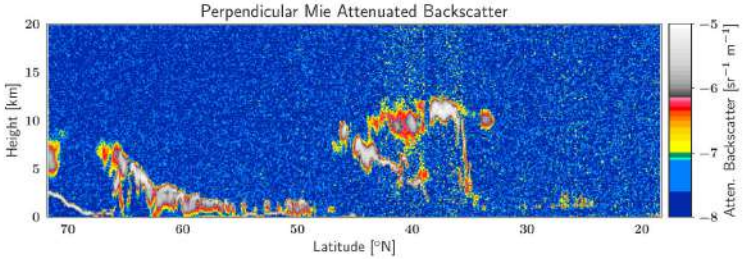


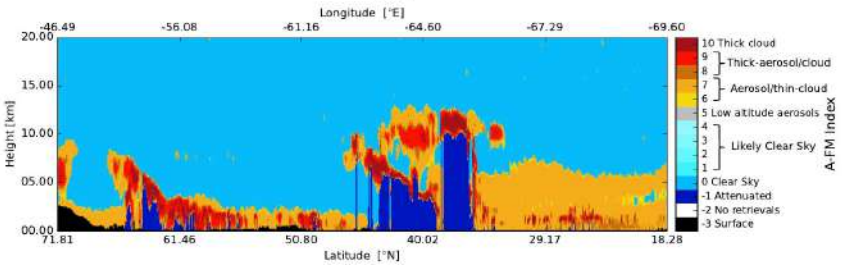
Figure 2: the swath of the high resolution simulation with 0.25 km grid-spacing and the seven section of the separated simulation.











Processor	A-PRO (ATLID Profile processor)
Input Products	1. FeatureMask 2. ATLID L1 3. Auxiliary Met data
Output Products (reported on Joint standard Grid grid)	1. Aerosol and cloud optical properties. 2. Target Classification 3. Aerosol type

EARTHCARE

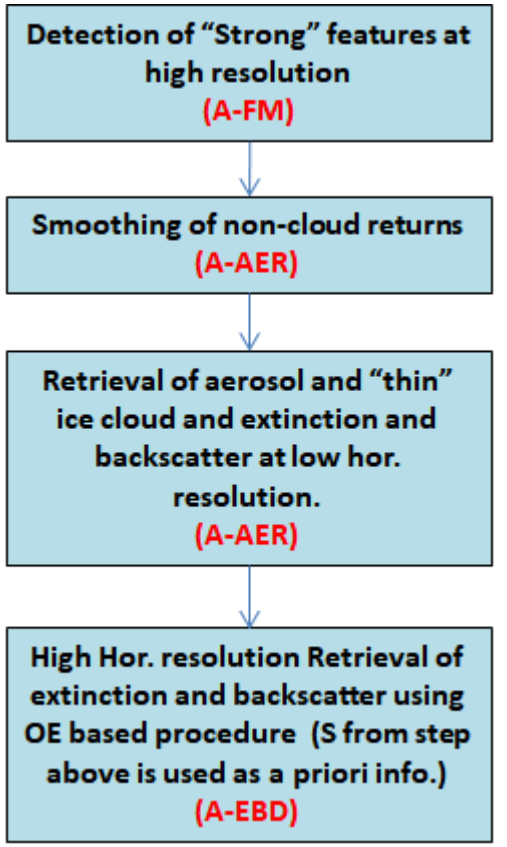
Royal Netherlands Meteorological Institute
Ministry of Infrastructure and Environment.

Brief Description

- **Two Step approach to deriving optical properties**:
  1. "Conventional" HSRL techniques applied to cloud-filtered smoothed fields.
  2. High resolution optimal estimation forward modelling based retrievals.

- Cloud/aerosol discrimination and aerosol typing based on using Backscatter thresholds as well as lidar-ratio (S) and linear depolarization ratio.

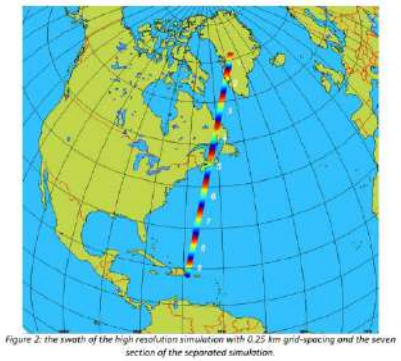
- Cloud phase determination via layer integrated backscatter-vs-integrated depolarization ratio.



A-PRO

- **A-PRO** is a **Multi-scale** procedure for retrieving cloud/aerosol extinction and lidar-ratio(S).
- The multi-scale approach is necessary in order to handle the SNR constraints and the physical size scale difference between clouds and aerosols.

Example (Halifax Scene)



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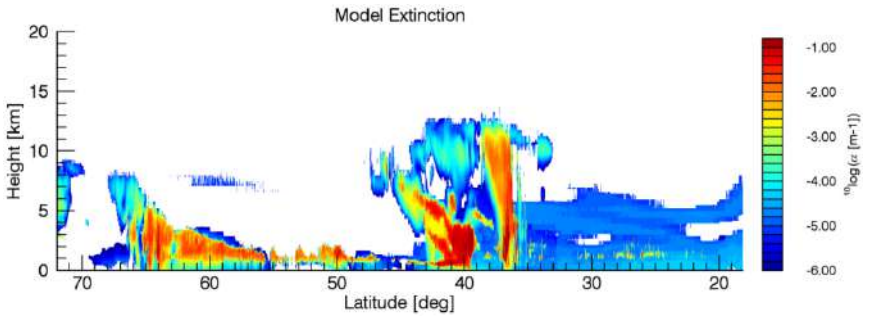
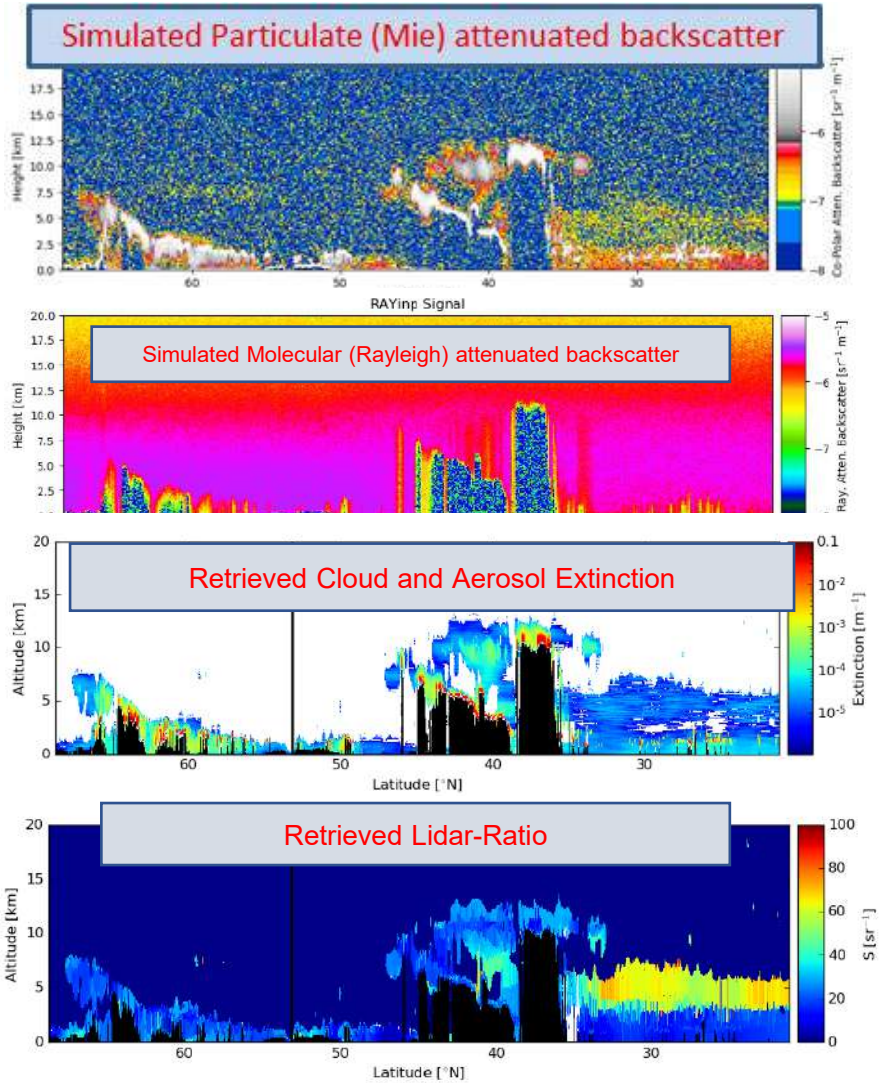
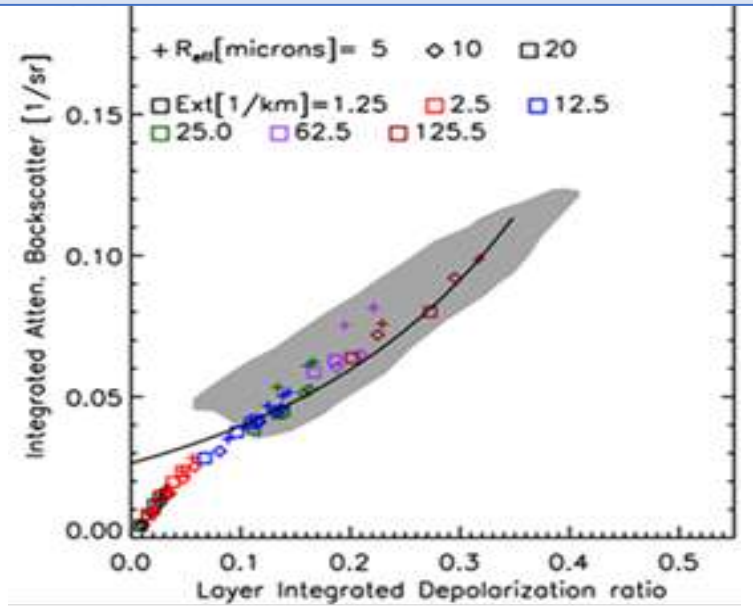




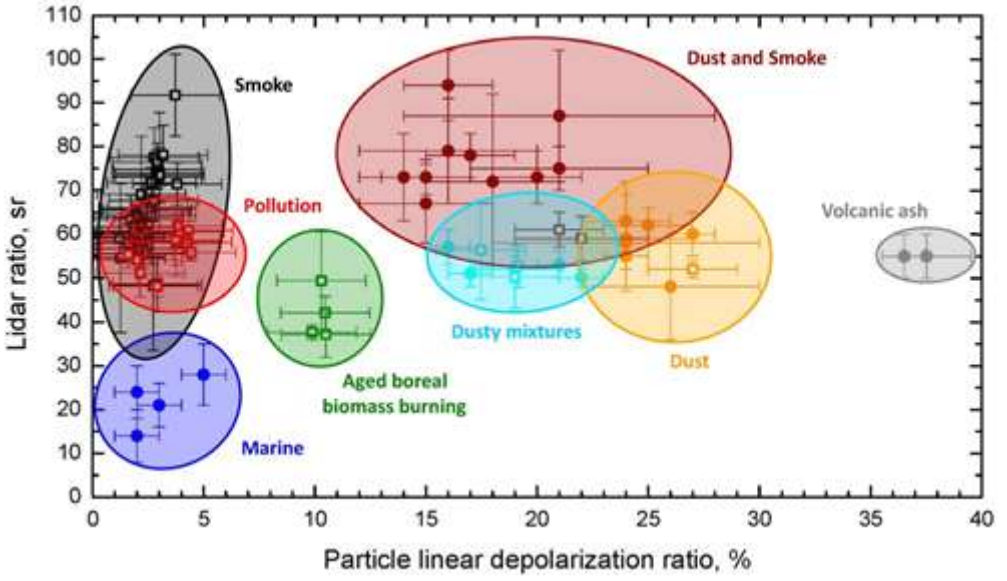
Target Classification (A-TC)

-Cloud/Aerosol separation based on combination of thresholds
and, in the case of thin-ice-vs-aerosol, depol. and lidar-ratio

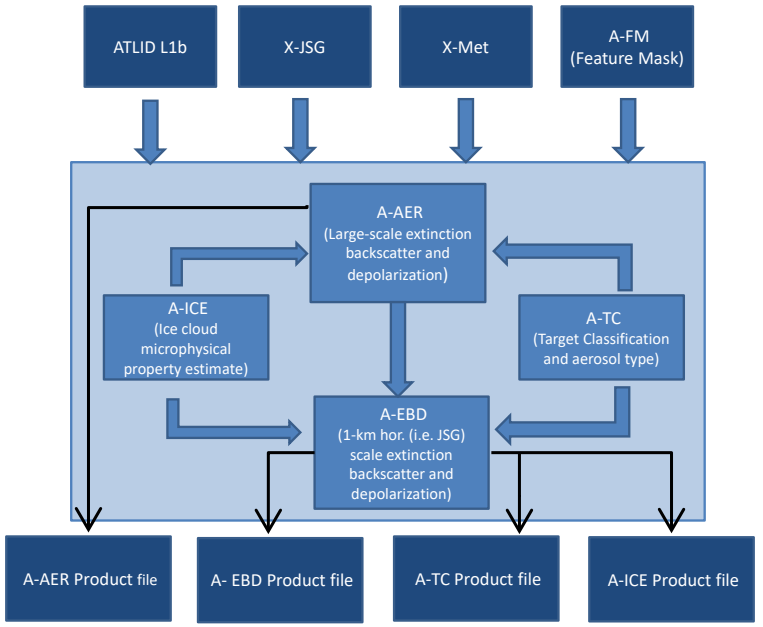
Cloud phase based on integrated depol. -vs-integrated attenuated backscatter



Aerosol type based on depol.-vs-lidar-ratio

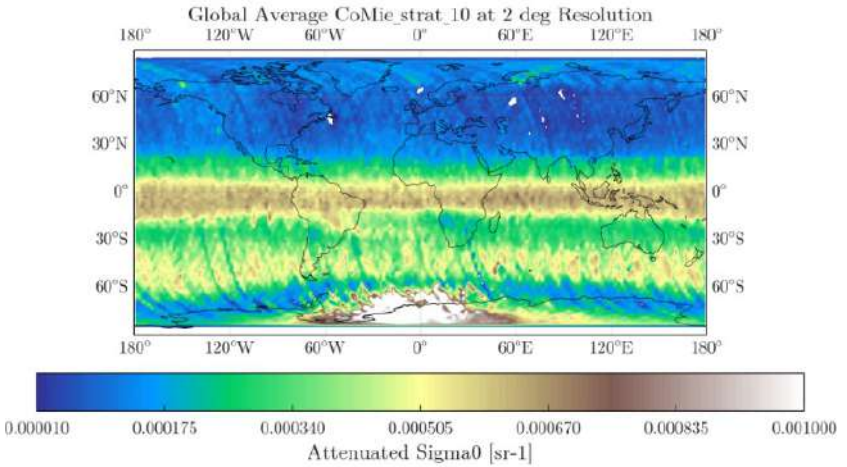


A-PRO Processor (A-AER, A-EBD, A-TC and A-ICE products)



Product	Algorithm	Main Variables	Resolution (All products reported on 1-km JSG grid)
A-AER	Conventional HSRL retrieval optical properties and Target Classification	"Thin cloud" and aerosol • Extinction • Backscatter • Lidar-ratio • Target Type	100-300 meter vert. 100-200 km hor.
A-EBD	Optimal Estimation Forward-modelling retrieval	Cloud and aerosol • Extinction • Backscatter • Lidar-ratio	100 meter vert 1-km For "strong-targets" 50 km For "weak" targets (Med-Res) 150 km For "weak" targets (High-Res)
A-TC	Target classification based on T,S,depol,extinction	Multi-scale Cloud and aerosol classification	100 meter vert 1-km For "strong-targets" 50 km For "weak" targets (Med-Res) 150 km For "weak" targets
A-ICE	IWC and Effective Size using a T,Ext parameterization	IWC Reff	1-km for "strong" ice clouds 150-km for "weak" ice clouds

Recent developments



A-FM

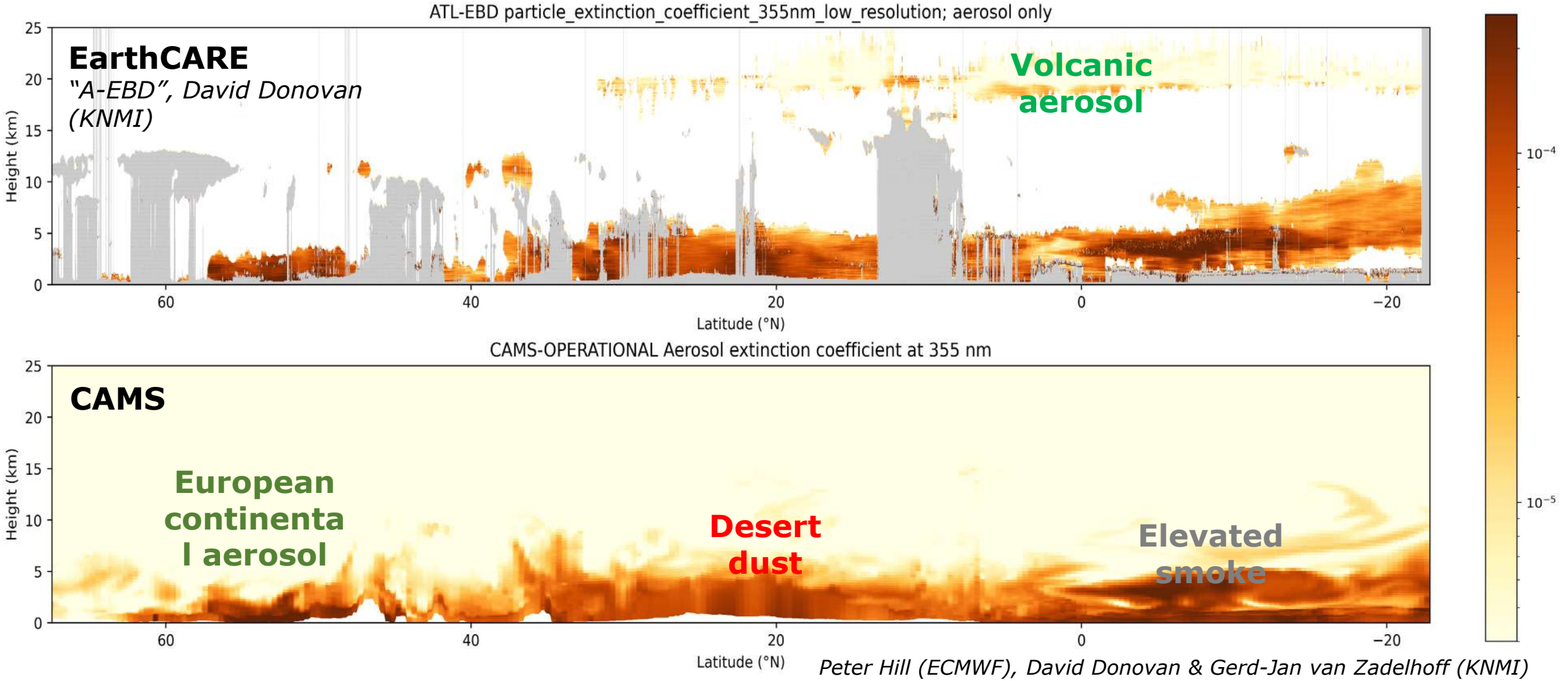
- Rayleigh Tau added to output…useful for (off-line) down-stream processing and evaluation.
- Integrated signals added to output

A-PRO

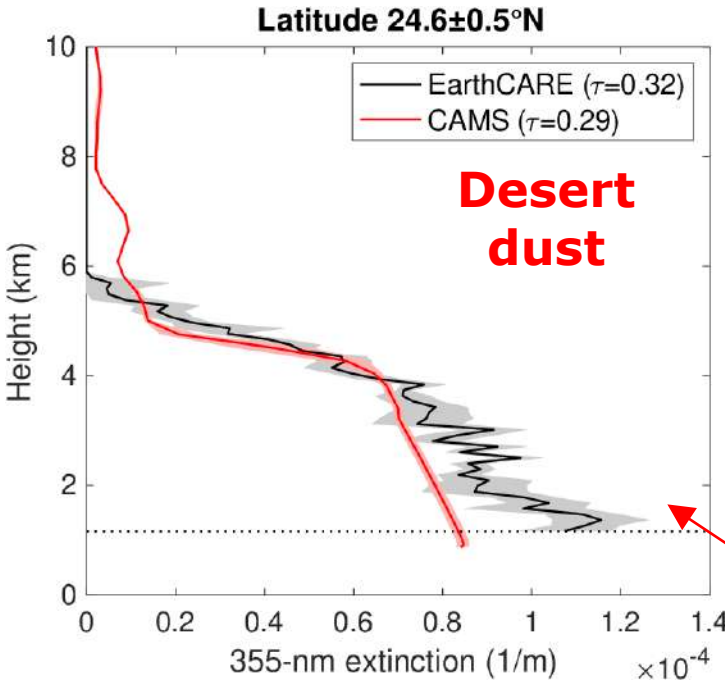
- Use of X-JSG vertical grid (Top-Down).
  - Version 11.40 produces outputs on the vertical JSG grid (previous version used the ATLID Native Grid).
- A-TC
  - Combination of bug-fixes and Ad-Hoc screening improved miss classification of pixels as being attenuated.
  - Misidentification of thick aerosol layers as ice clouds. (Addressed in 11.40-rc5)

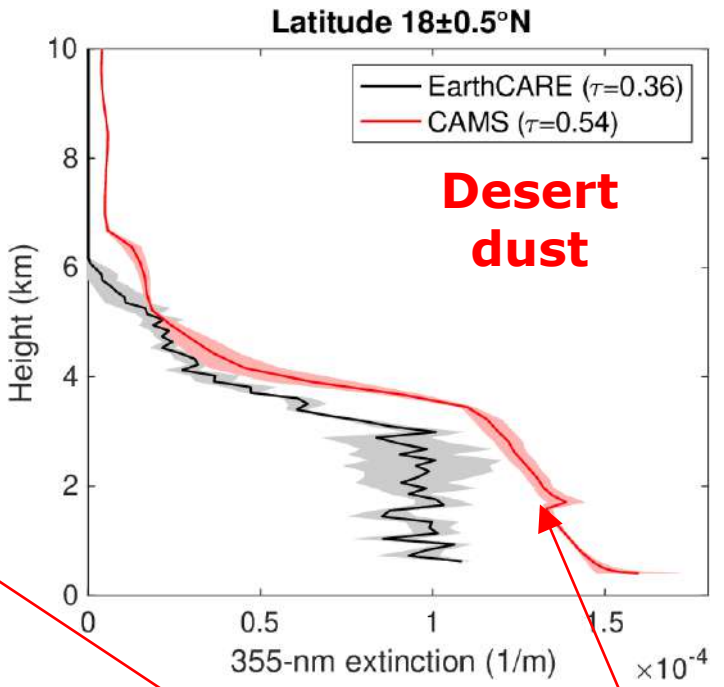
Comparison of extinction profiles between EarthCARE and CAMS forecasts

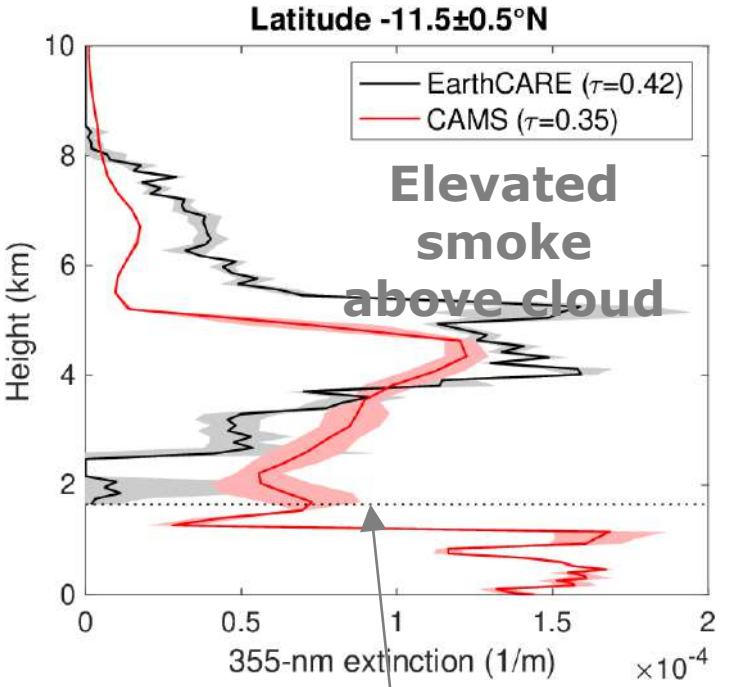
- CAMS: Copernicus Atmosphere Monitoring Service, ECMWF's air quality forecast
- EarthCARE lidar saw widespread stratospheric aerosol from Mt Ruang eruption, Indonesia, 16 April 2024

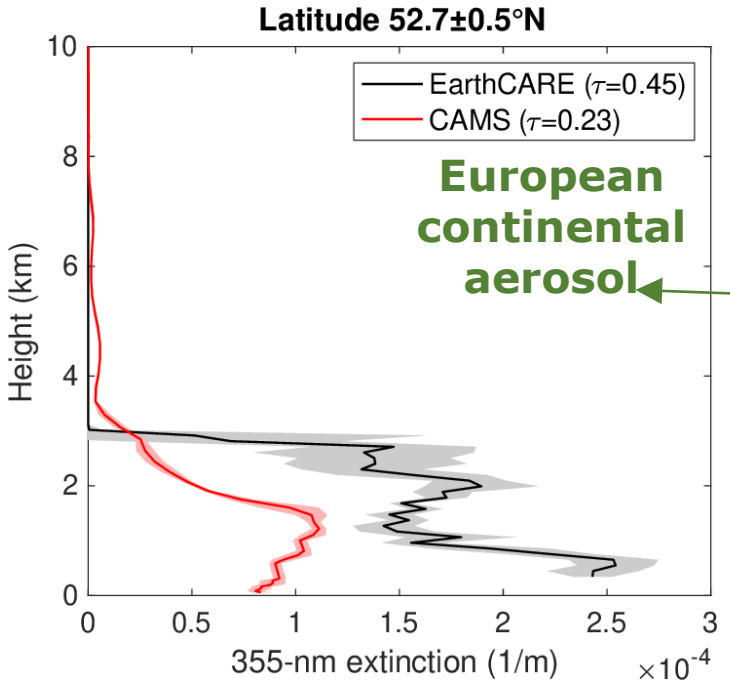


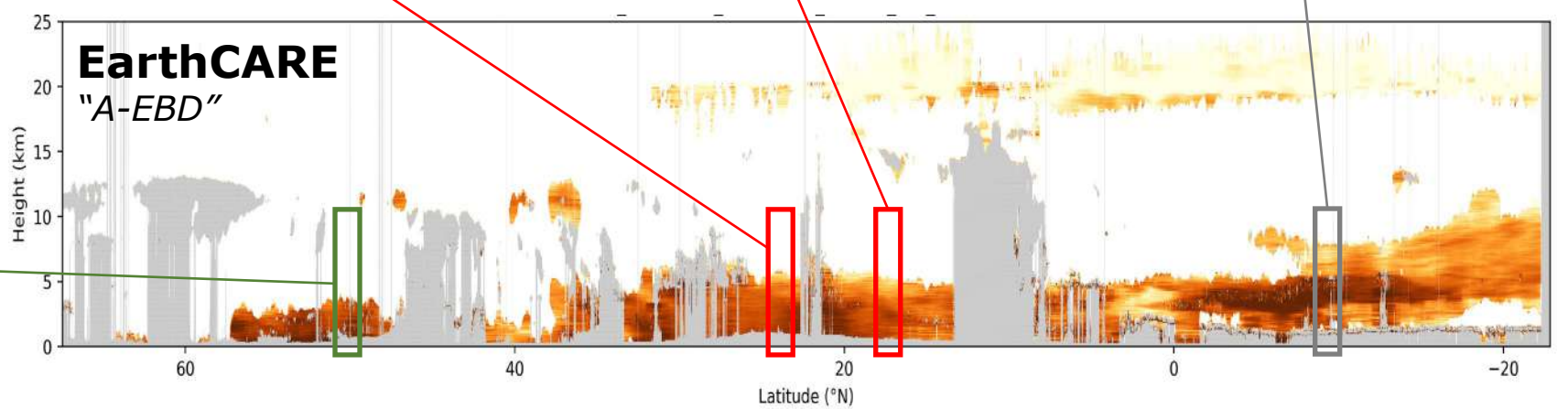
Peter Hill (ECMWF), David Donovan & Gerd-Jan van Zadelhoff (KNMI)







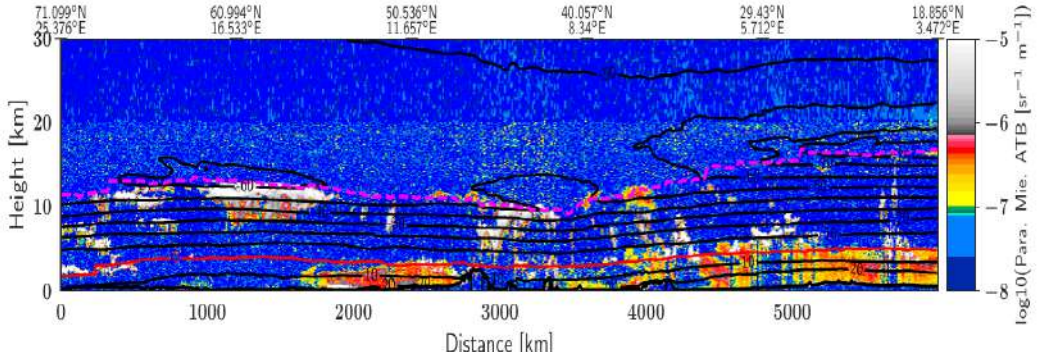


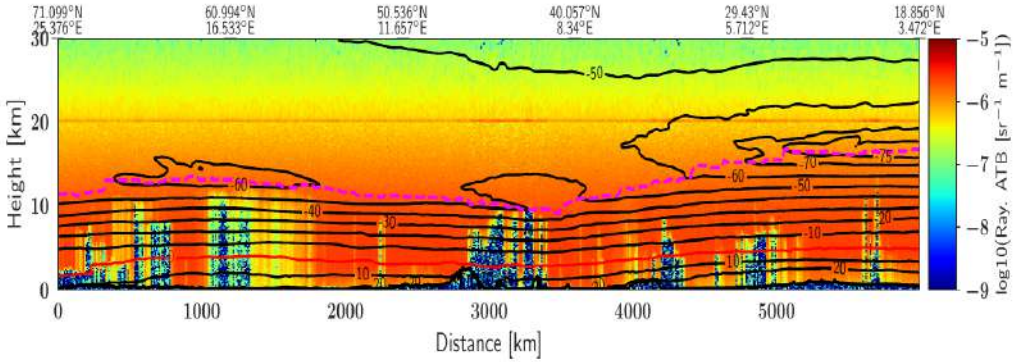


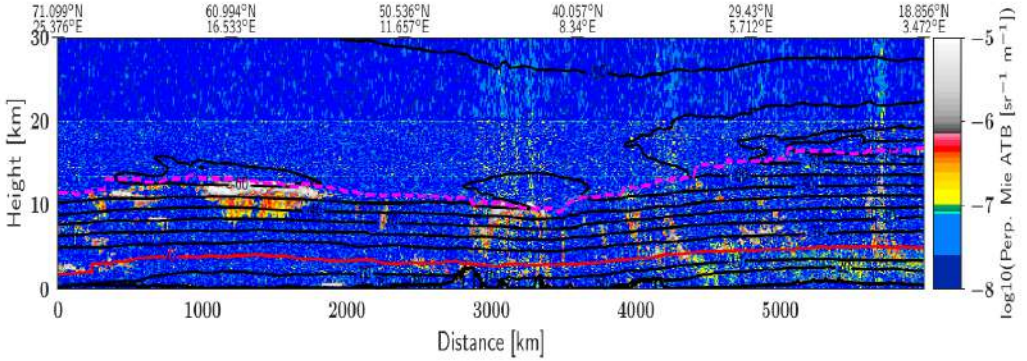
- *CAMS profiles are mostly good - have never been able to evaluate aerosol profiles globally with such resolution & accuracy, nor above clouds!*
- *ECMWF is working on assimilating EarthCARE into CAMS…*

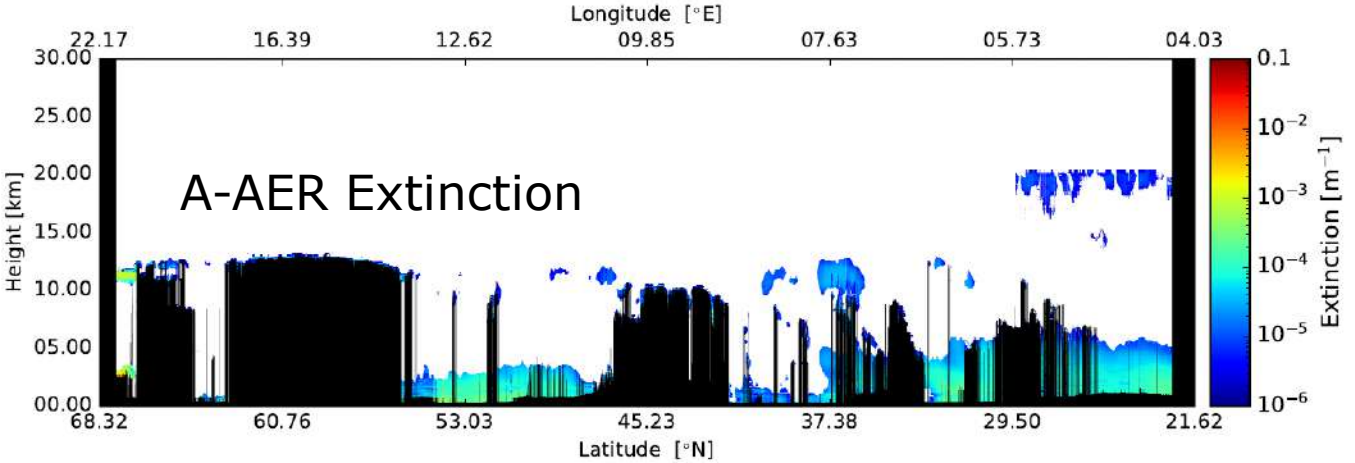
Robin Hogan, Peter Hill (ECMWF)

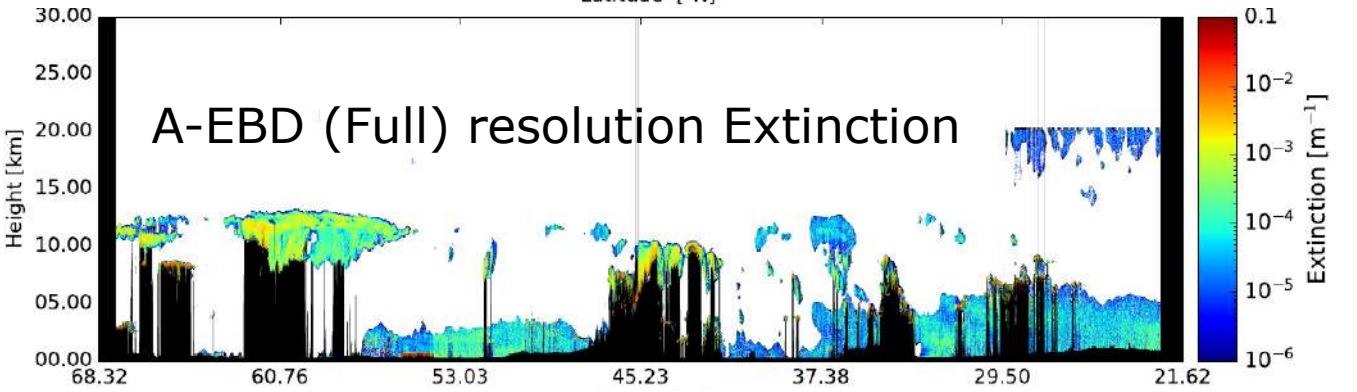
Differences in products by resolution and technique

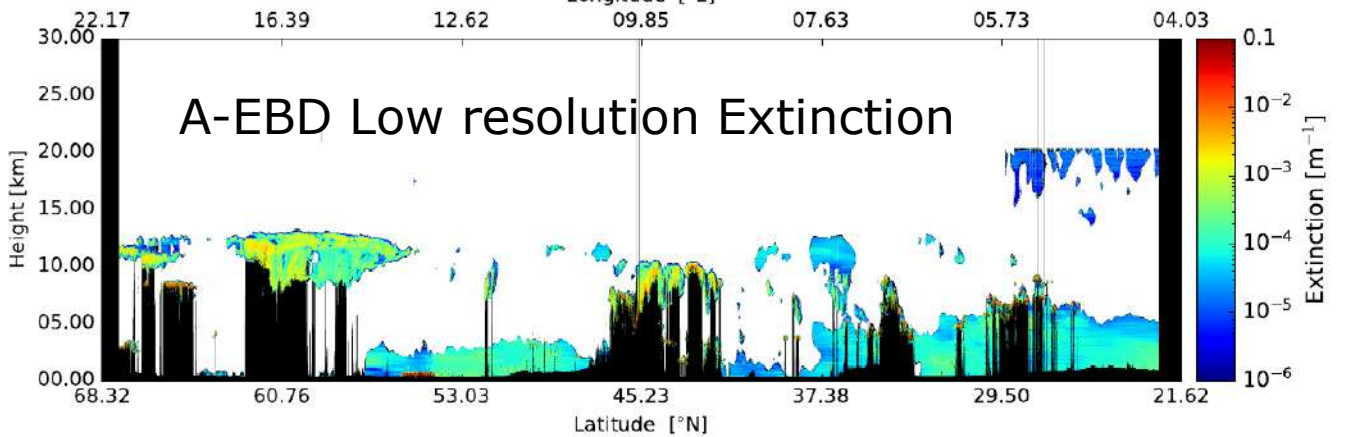




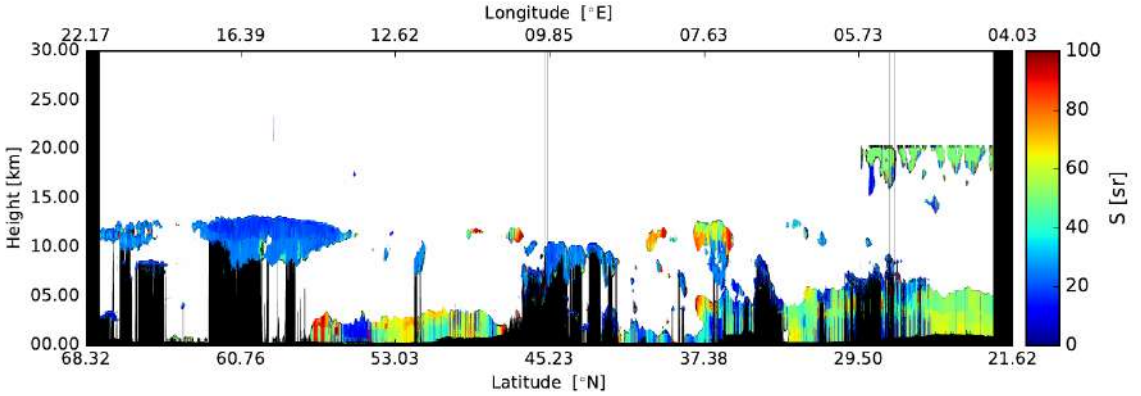


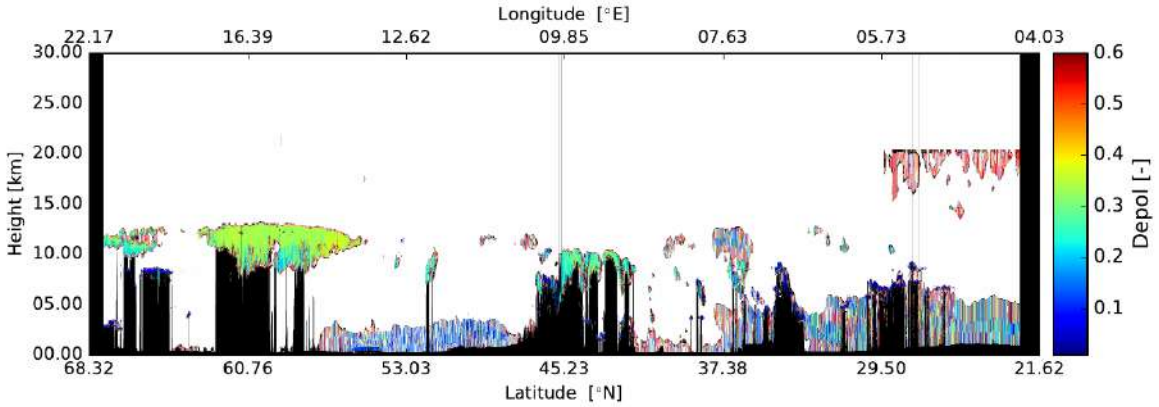


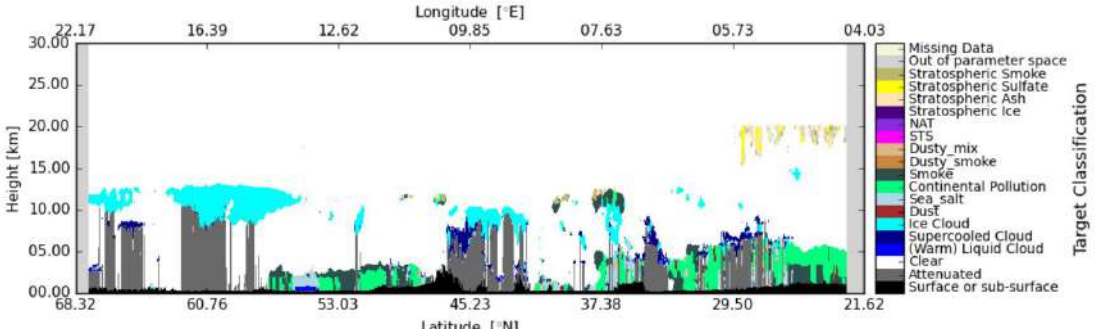




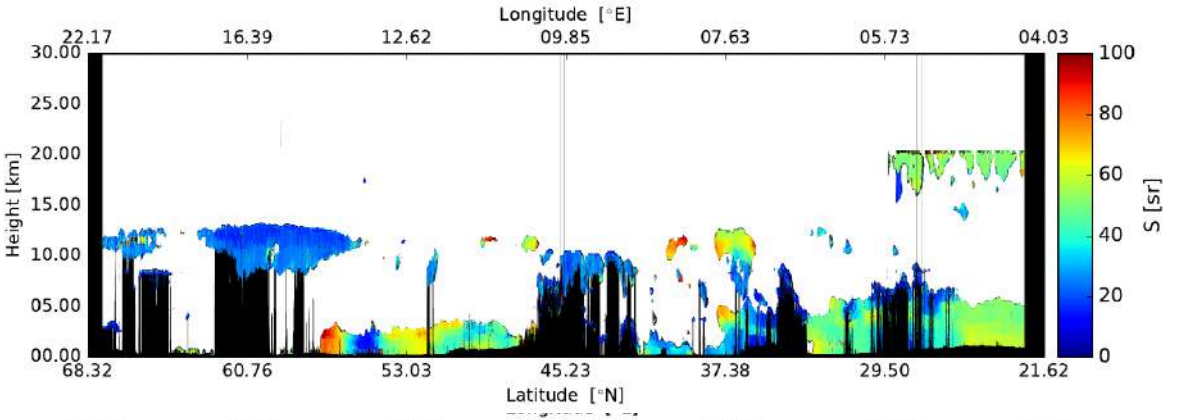
EBD Full resolution

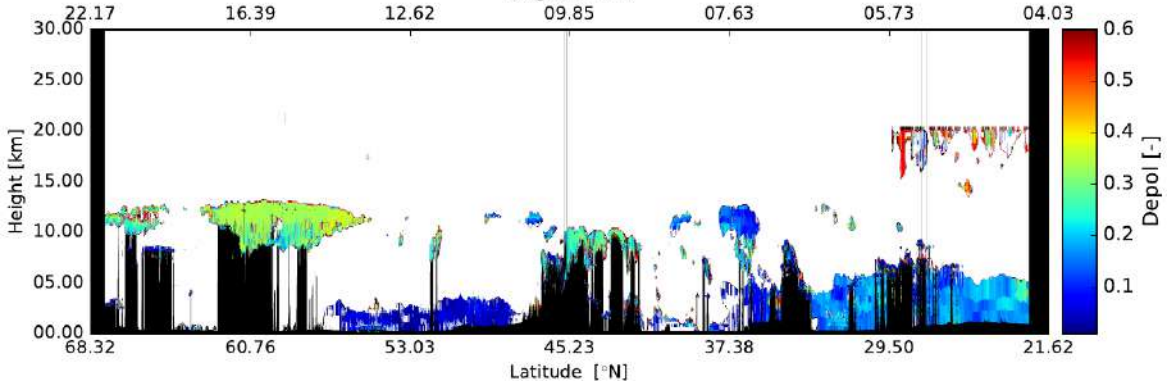


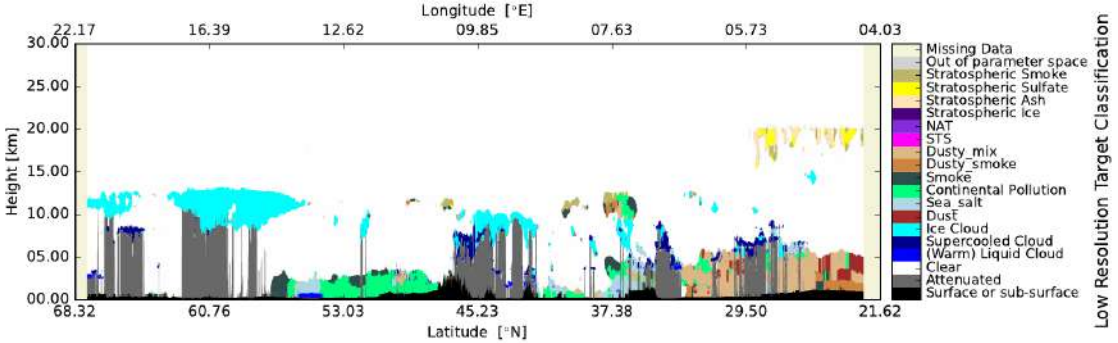




EBD Low resolution







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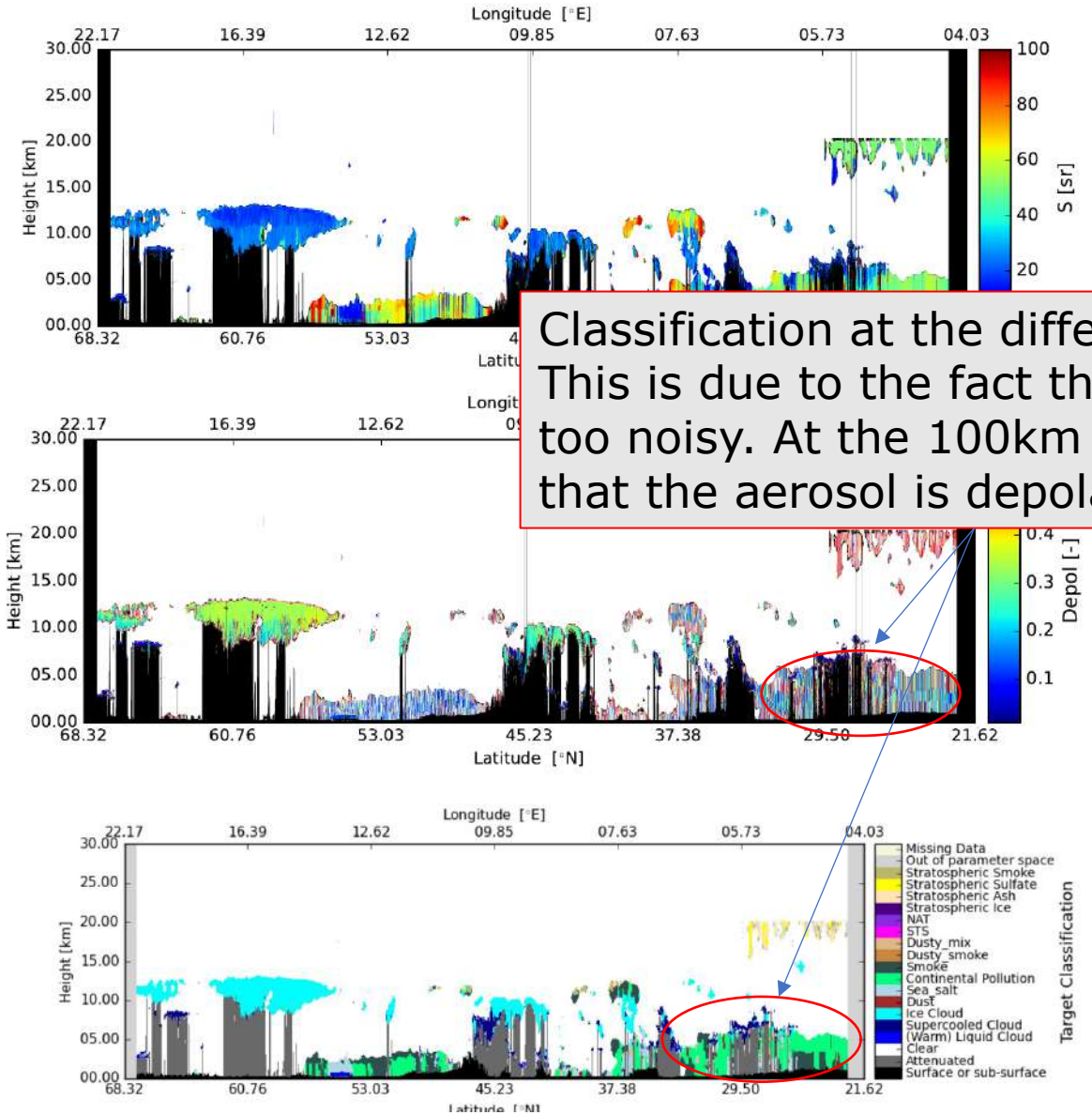
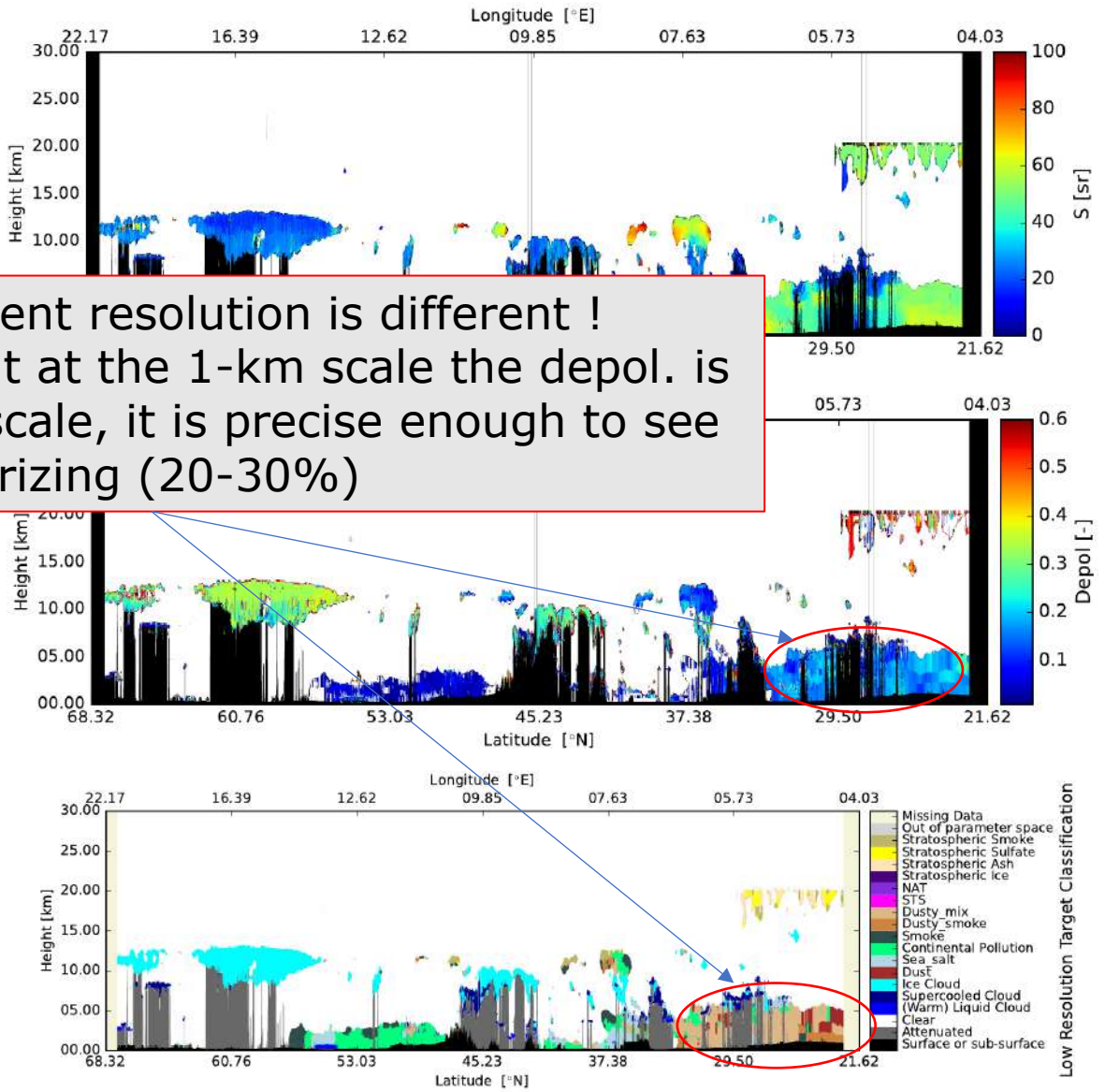
EBD Low resolution





Classification at the different resolution is different !
This is due to the fact that at the 1-km scale the depol. is too noisy. At the 100km scale, it is precise enough to see that the aerosol is depolarizing (20-30%)

Some Points of Attention when using A-PRO

Data is reported on JSG Grid (1-km hor. 100 m vert.) !

- But resolution can be very different !
  - Horizontal resolution of products is 1-JSG pixel for clouds but different resolutions (e.g. 50 and 150 km) for aerosols (and thin clouds).
  - Vert resolution of Extinction is 100 m (EBD) and 1km AER but S, depol and R_{eff} are layer-based !
  - A-LAY product supplies consistent layer-averaged quantities.

If you need to do your own along-track averaging, do not do it blindly.

- Respect the classification and quality-flags !
- For S, compute the extinction weighed average !
- Beware when clipping e.g. do not ignore negative values when averaging.
- For depolarization ratio: Compute the backscatter weighted average.

- Like almost all L2 products the data files contain margins ! This data may not be valid (consult the quality status variables)! Use only data between the “frameStartCoordinates” and “frameStopCoordinates” e.g. if you are stitching together frames.

Summary

08 Aug 2023

Detection of aerosol and cloud features for the EarthCARE atmospheric lidar (ATLID): the ATLID FeatureMask (A-FM) product

Gerd-Jan van Zadelhoff, David P. Donovan, and Ping Wang

Atmos. Meas. Tech., 16, 3631–3651, https://doi.org/10.5194/amt-16-3631-2023, 2023

▸ Short summary

12 Sep 2024 | Highlight paper

The EarthCARE lidar cloud and aerosol profile processor (A-PRO): the A-AER, A-EBD, A-TC, and A-ICE products

David Patrick Donovan, Gerd-Jan van Zadelhoff, and Ping Wang

Atmos. Meas. Tech., 17, 5301–5340, https://doi.org/10.5194/amt-17-5301-2024, 2024

- Algorithms appear to be functioning well but there is certainly room for improvement.
- Feedback on accuracy and precision welcome..but also usability !
  - E.g. Is 40 km a good choice for the “medium” EBD resolution or does 10km make more sense ?

Testing ATLID(-like) approaches using ALADIN observations

- AEL-FM and AEL-PRO have been adapted to ALADIN measurements !
  - Implemented in the operational processor.
  - AEL-FM resembles A-FM more completely than AEL-PRO resembles A-PRO
    - E.g. Aeolus lacks depol. Measurements ➔ Aerosol type determination is problematic and and simplified ice/water discrimination compared to ATLID

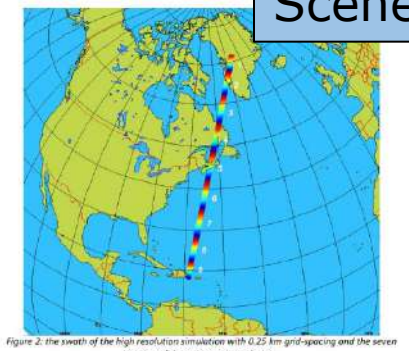
- Validation is ongoing using:
  - Terrestrial Lidar data
  - Comparisons with CALIPSO.
  - Comparisons with OMI AOT.

AEL-FM and AEL-PRO

- **AEL-FM** and **AEL-PRO** are Aeolus algorithms based on EarthCARE developments (**A-FM and A-PRO**)
- **AEL-FM** provides a feature-mask at the **highest available resolution.**
- **AEL-PRO** is a **Multi-scale** Optimal-Estimation procedure for retrieving cloud/aerosol extinction and lidar-ratio(S).
- The multi-scale approach is necessary in order to handle the SNR constraints and the physical size scale difference between clouds and aerosols.

A-PRO and A-FM have been developed and tested using extensive realistic simulations (example Below and Right)…but they are only simulations. Aeolus has provided the opportunity to apply these algorithms to real data and benefit both missions !

Example (Halifax Scene)



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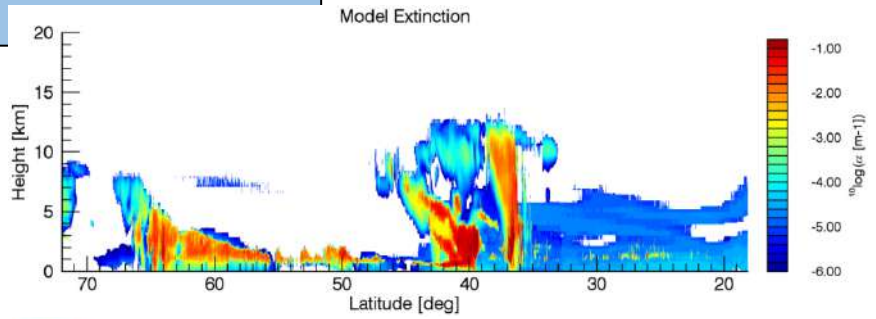
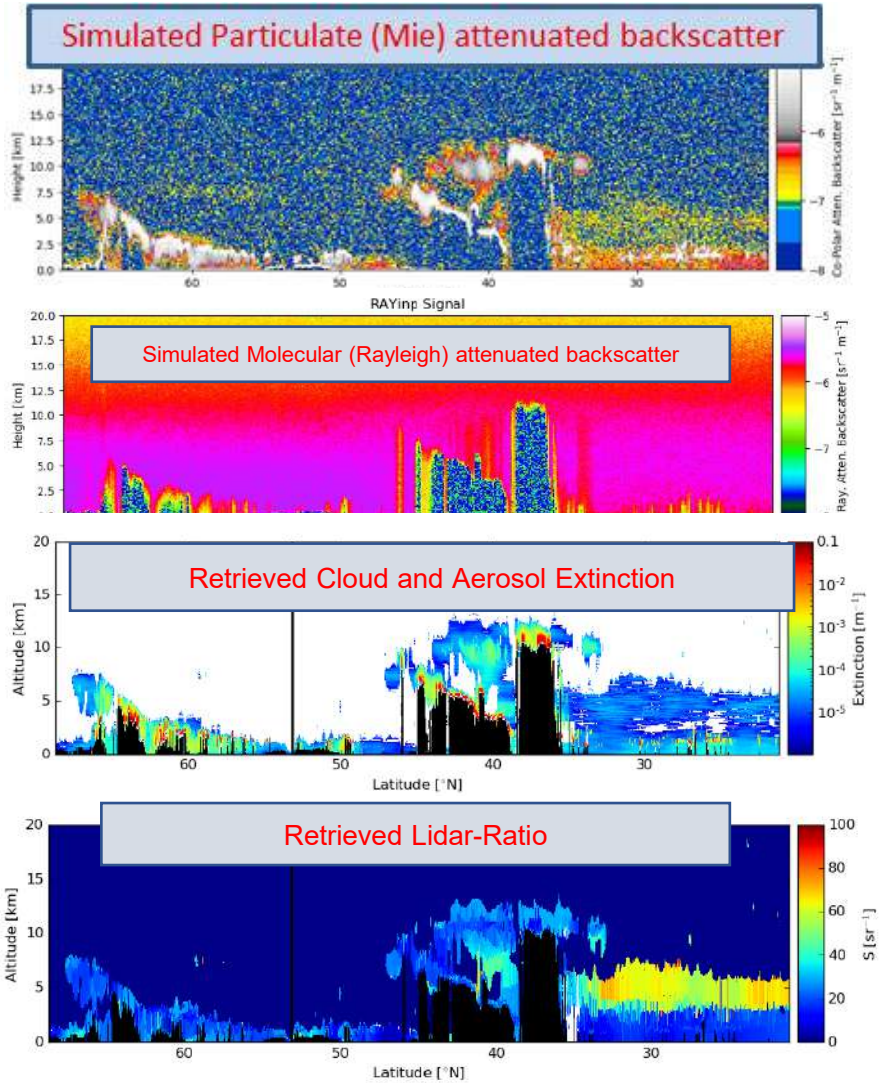
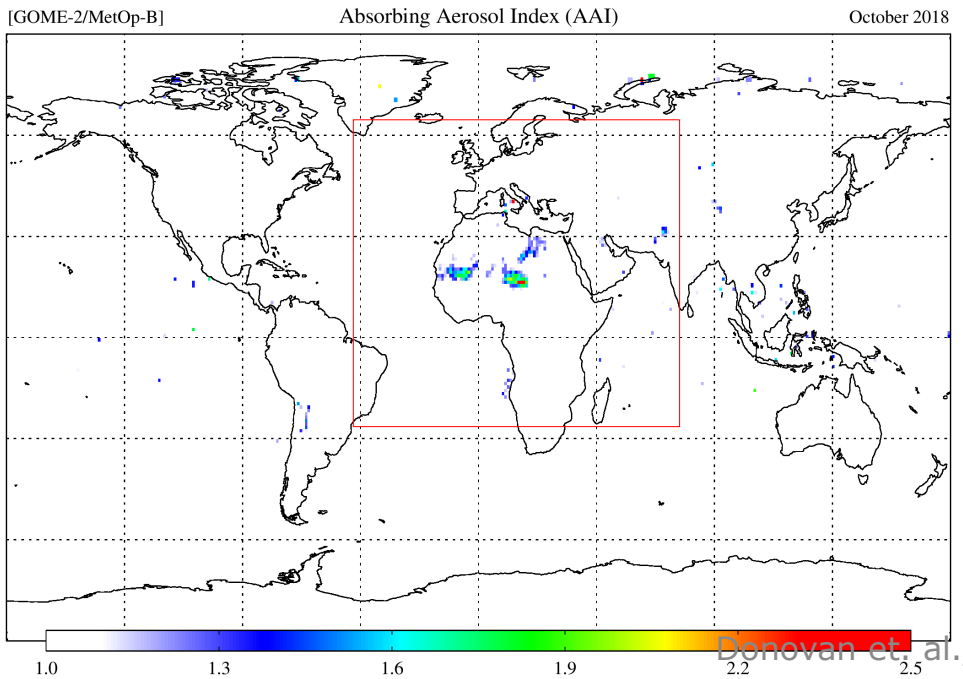


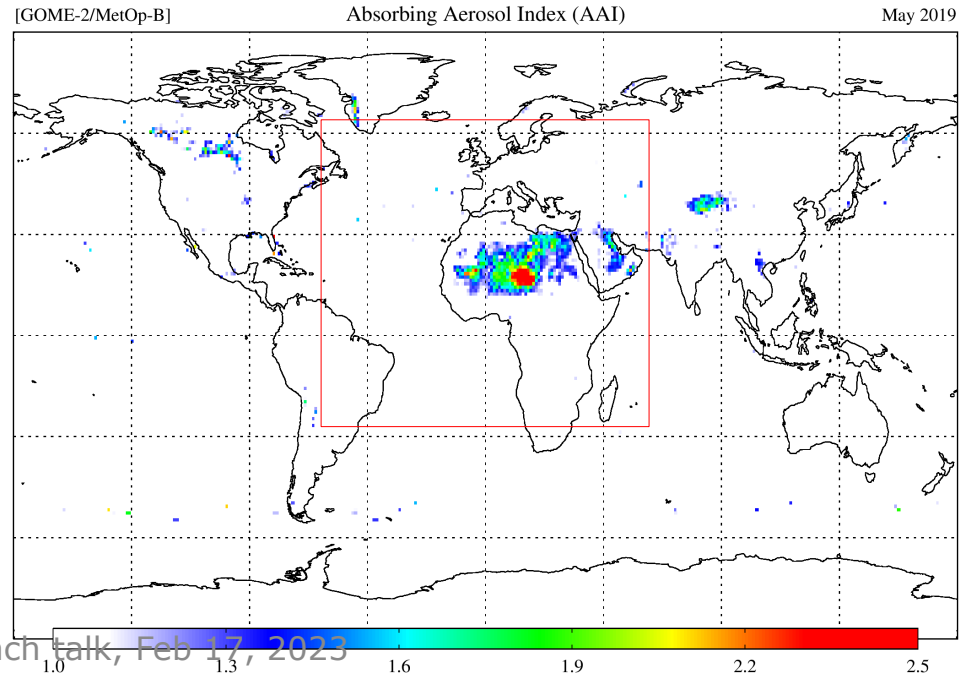
EARTHCARE aeolus DISC



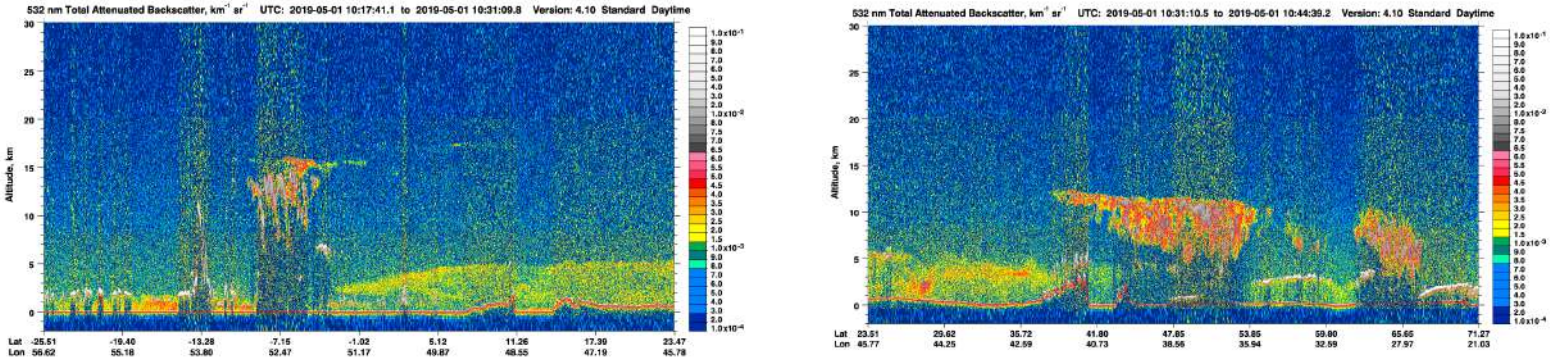
Selection of Calipso and Aeolus data

- Lat [-50, 50], Lon [-60, 60] ,
- time difference < 4 hr
- Lon difference < 2 degree
- Lat closest
- Calipso: CAL_LID_L2_05kmAPro-Standard-V4
- Aeolus: L1 B14 reprocessed data, AEL-FM v4, AEL-PRO v1.4.2

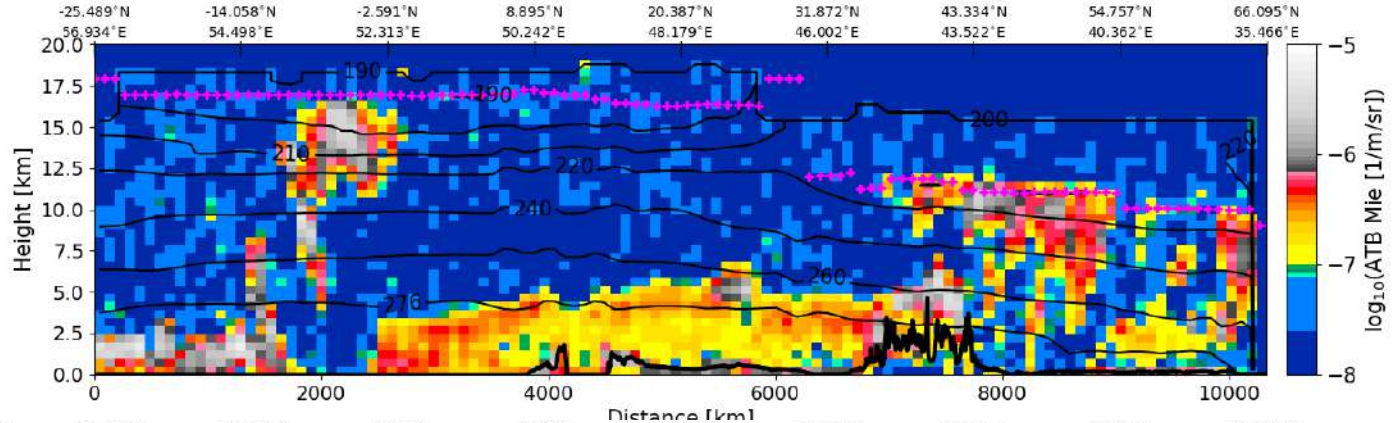




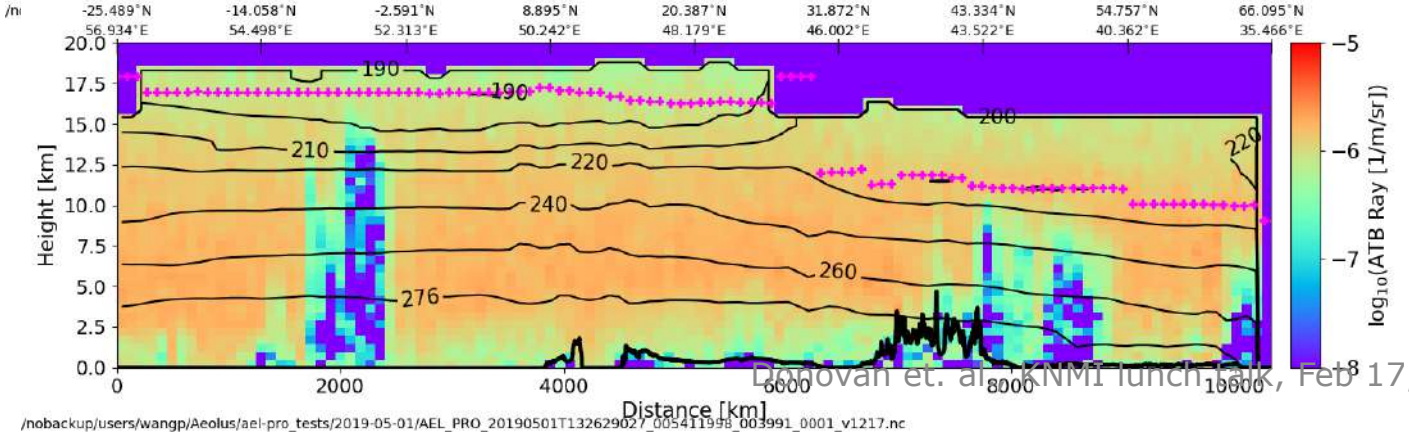
AEL-PRO PP orbit 3991 on 2019-05-01 vs Calipso total ATB at 532 nm



Calipso ATB at 532 nm

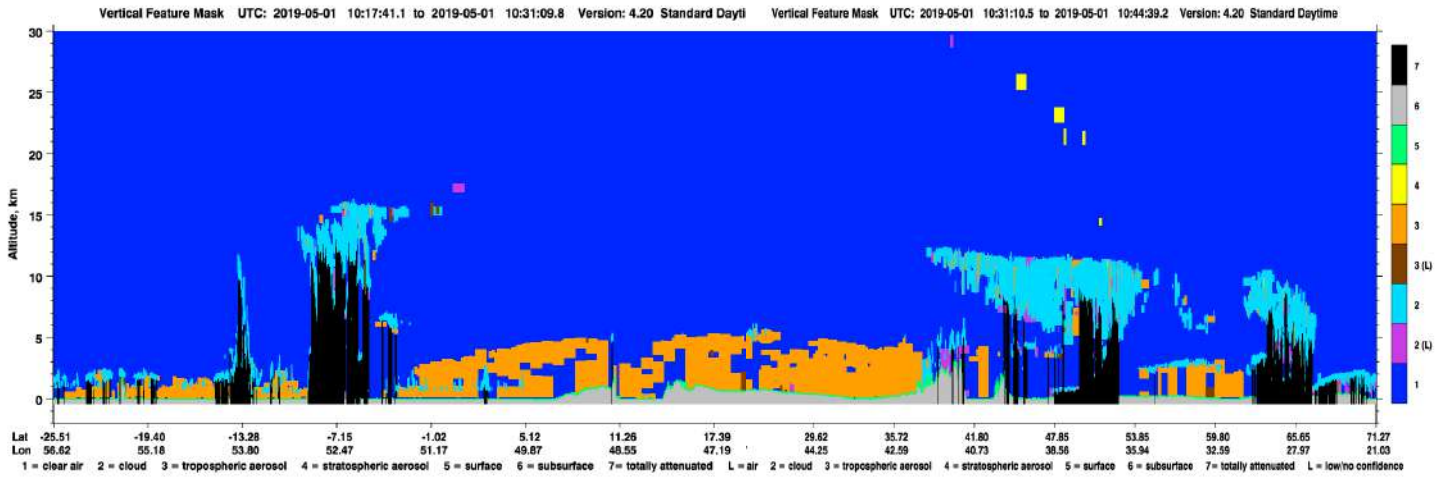


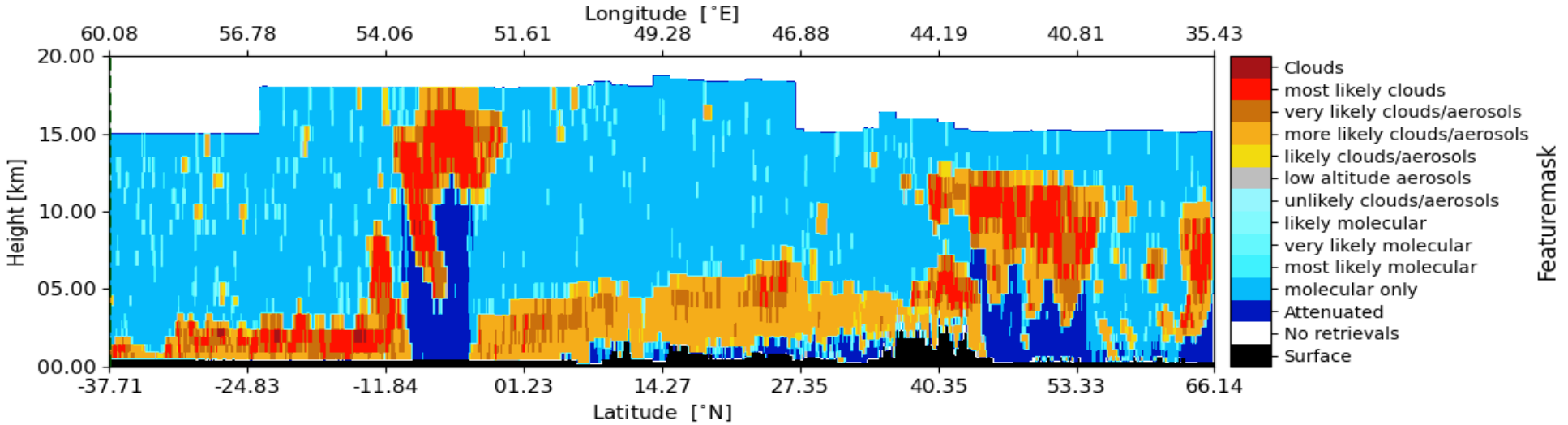
Aeolus ATB Mie at 355 nm



Aeolus ATB Ray at 355 nm

AEL-FM PP feature mask orbit 3991 on 2019-05-01 vs Calipso VFM





Very similar aerosol features and cloud features

Calipso browser images V4.1 are downloaded from https://www-calipso.larc.nasa.gov/products/lidar/browse_images/production/

Aeolus feasuremask AEL-FM PP 2019-05-01 3991

Example Comparison with CALIPSO

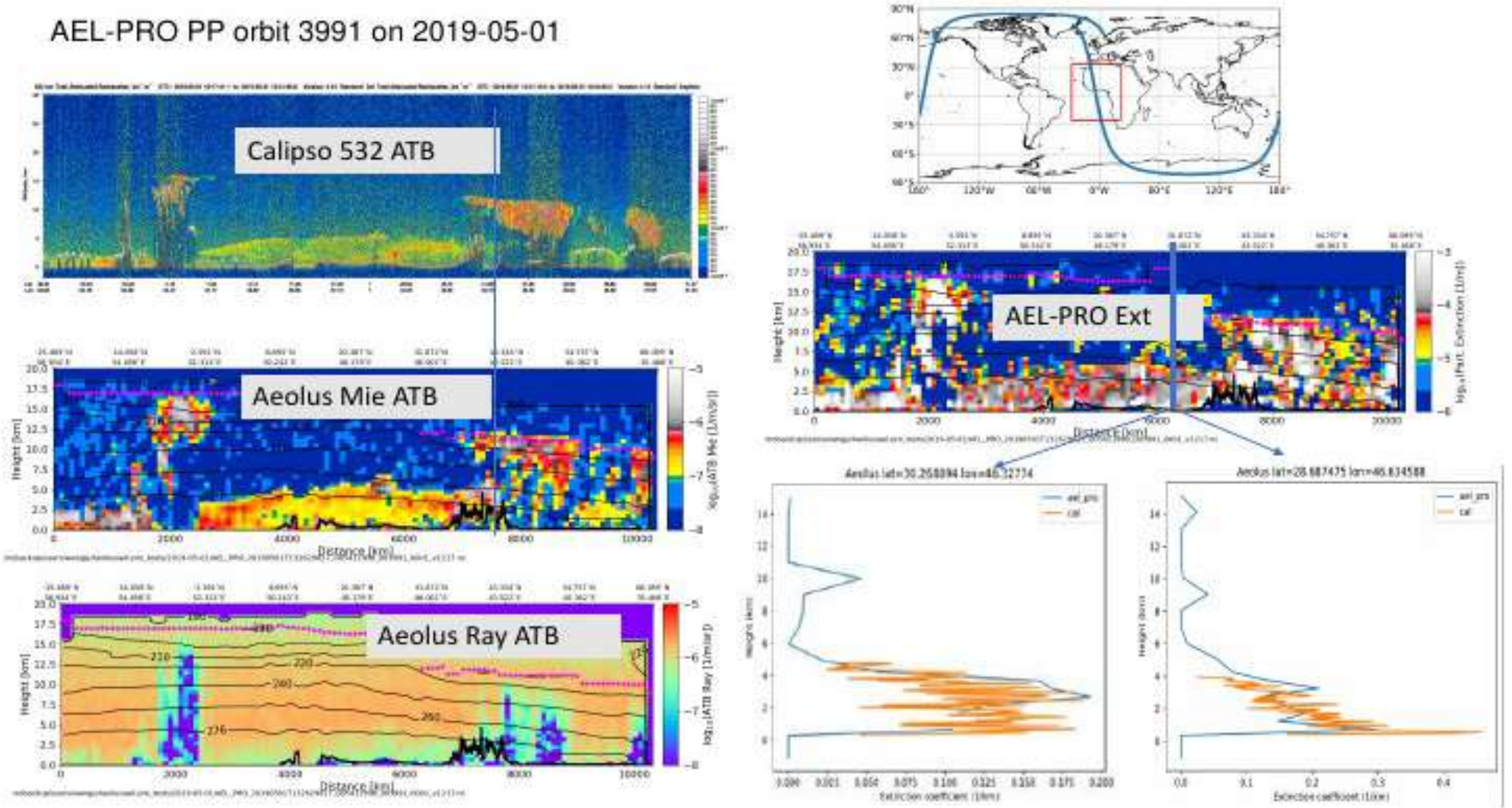
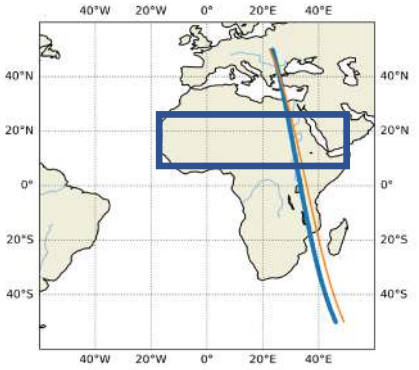
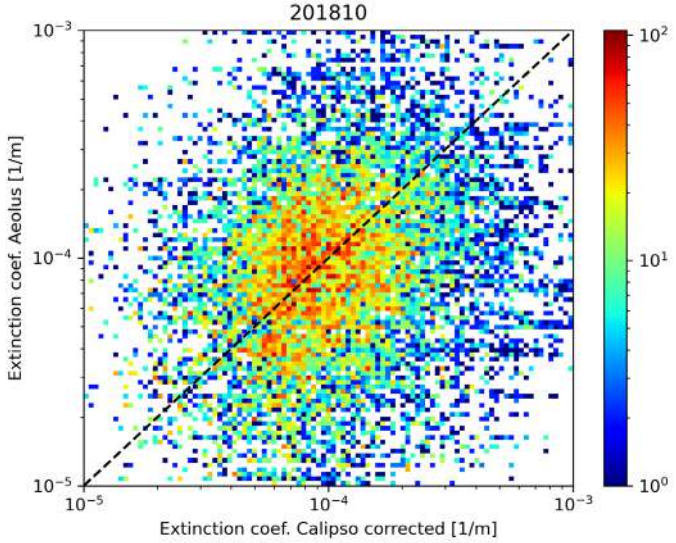


Fig. 4. CALIPSO and ALADIN ATBs and extinction retrieval within an orbit section within a few 10s of km and 3.5 hrs on May 01, 2019.

Calipso and Aeolus aerosol extinction coefficients 2018-10

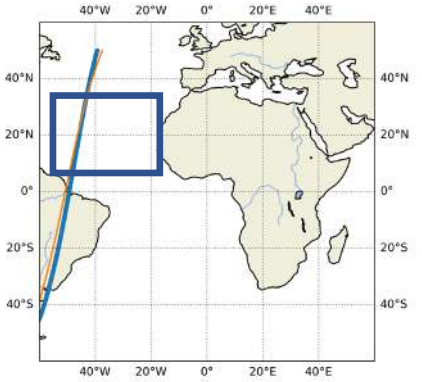
Dust

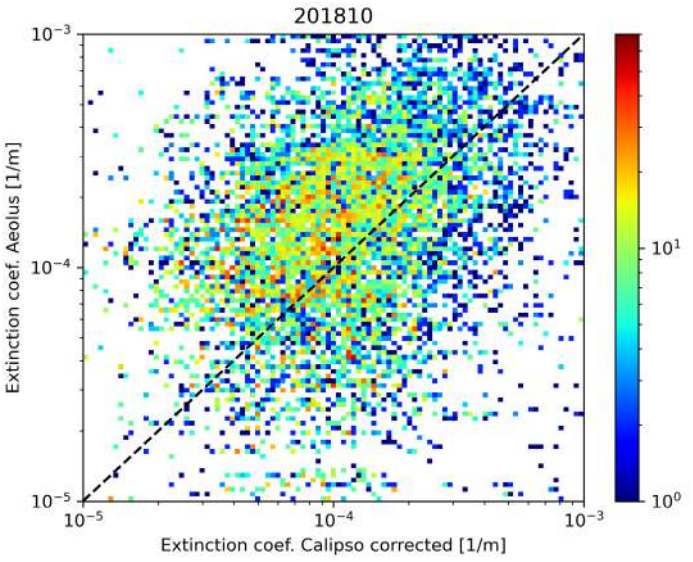




Region 1

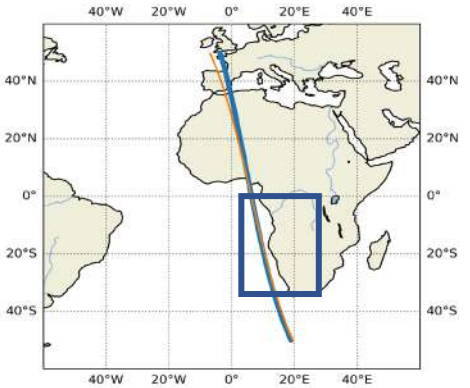
Dust over ocean

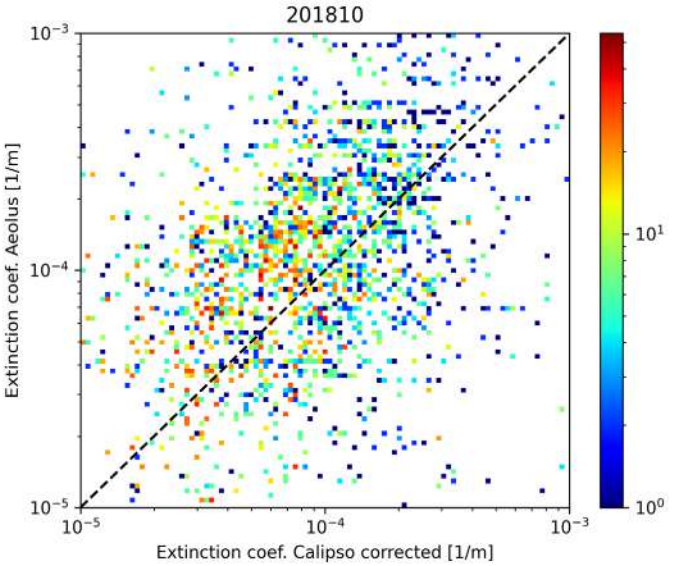




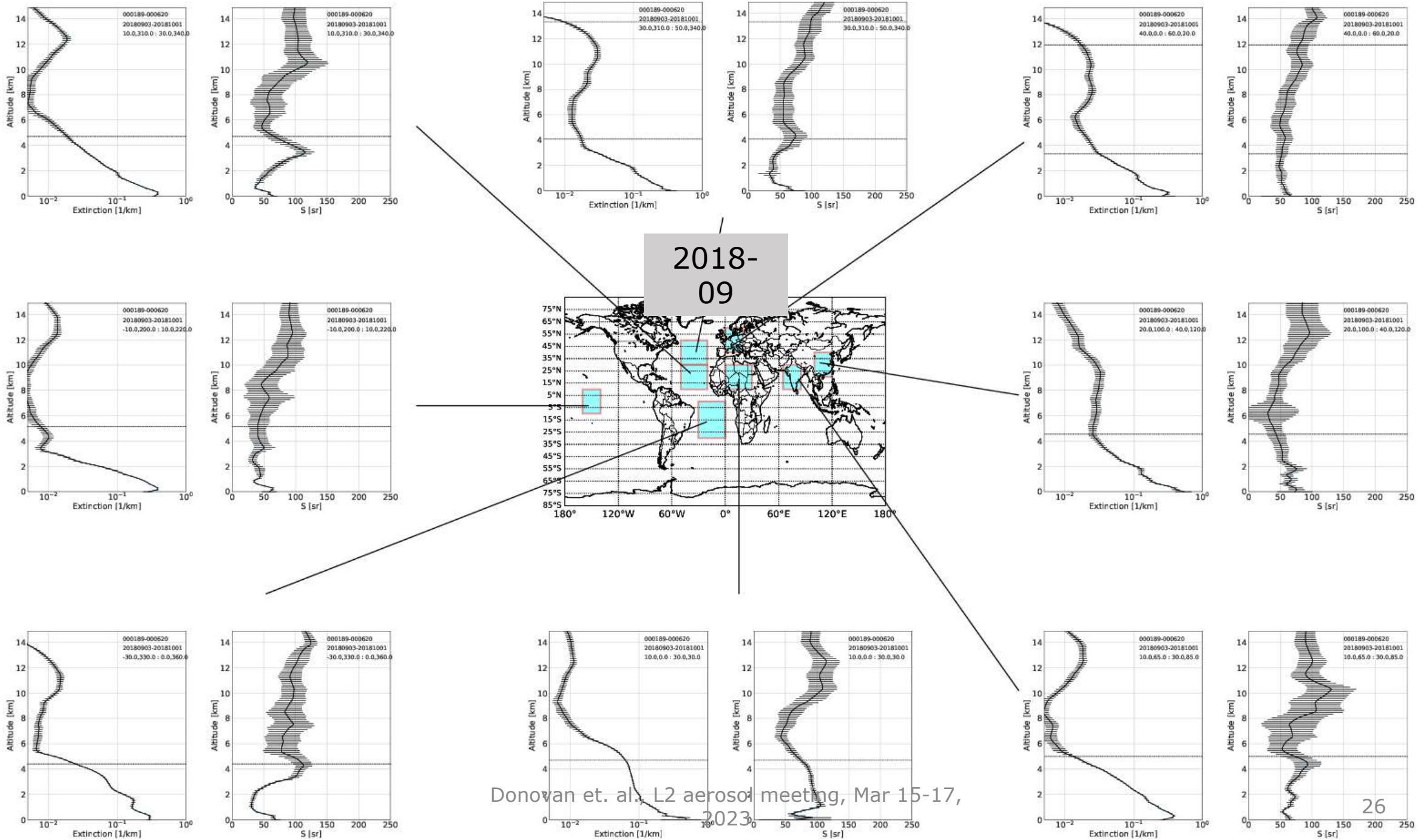
Region 2

Smoke

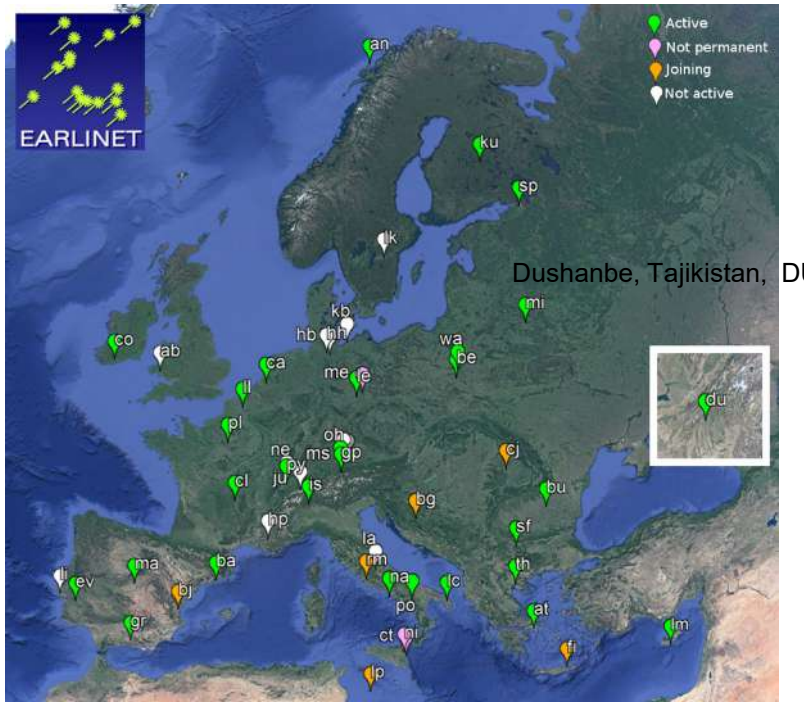




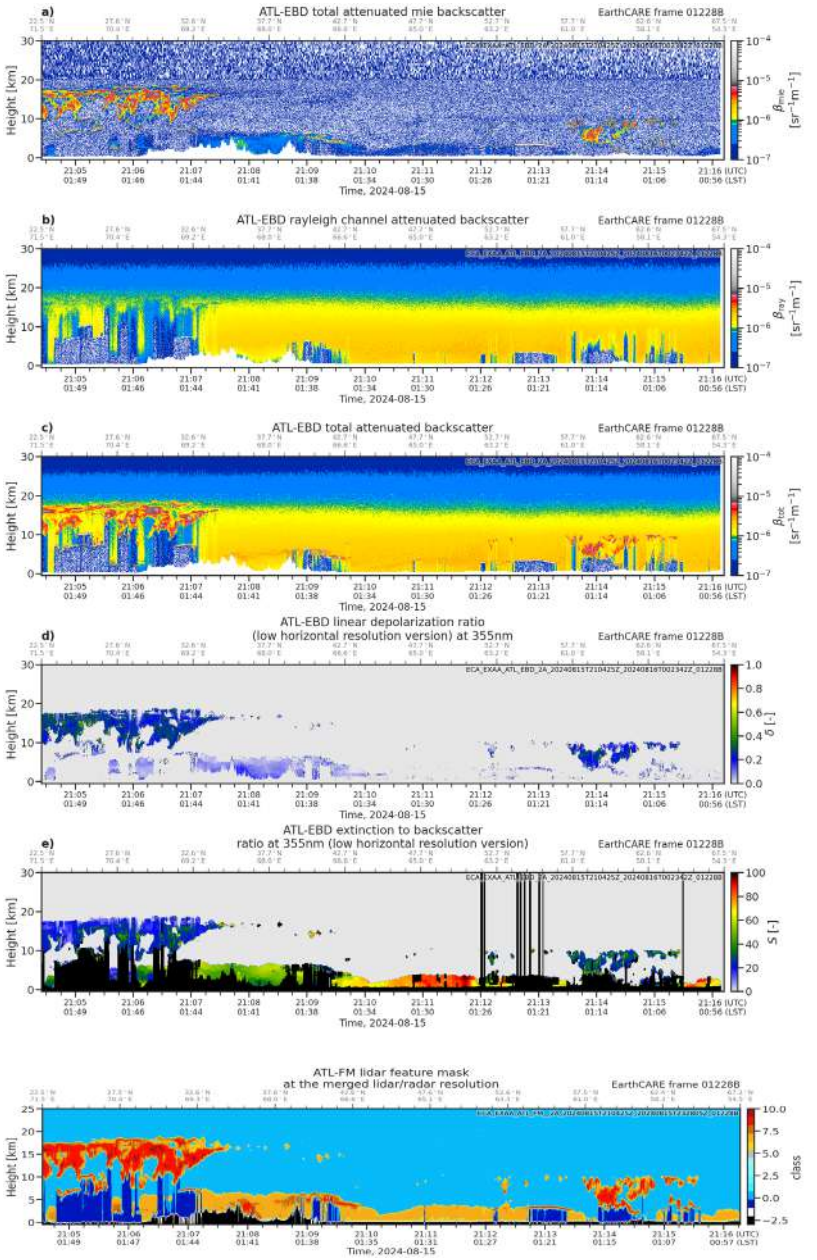
Region 3

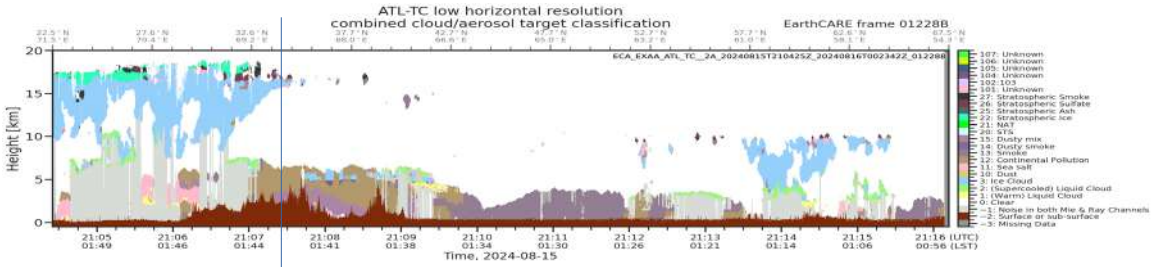

2018-09
Altitude [km]
Extinction [1/km]
S [sr]

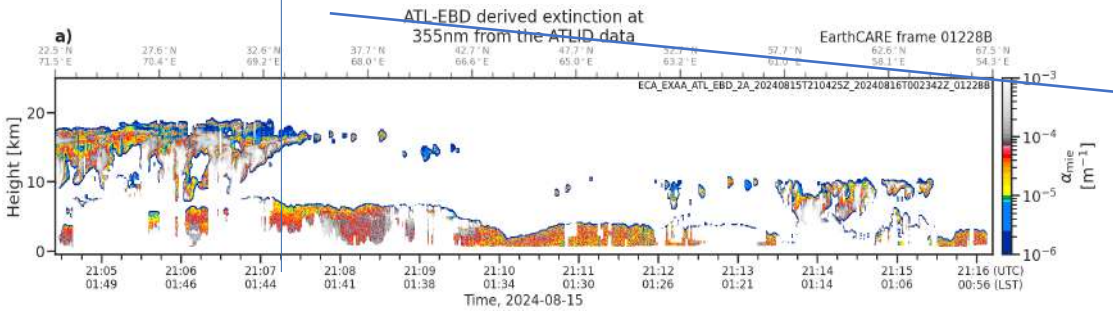
A-FM and A-PRO preliminary comparison with EARLINET data :A example

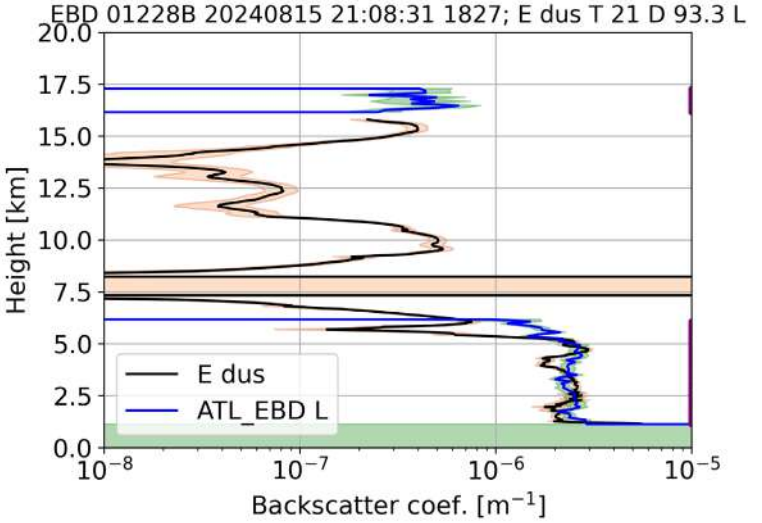


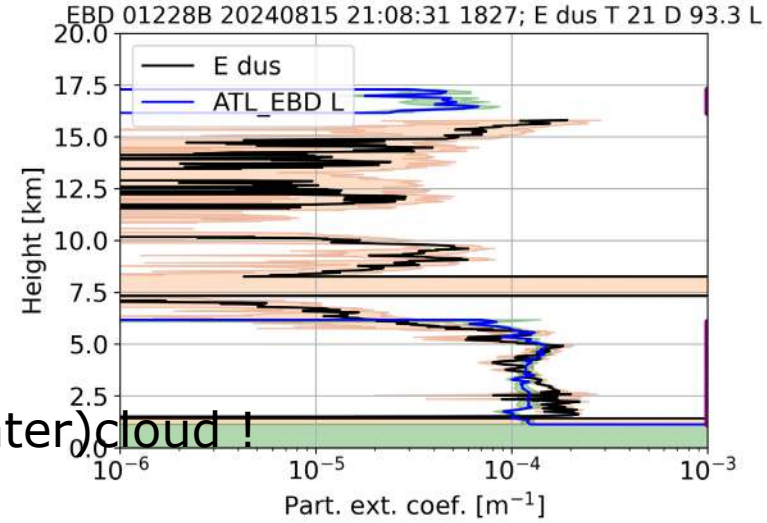
Dushanbe, Tajikistan, DUS or du











Comparisons for nighttime conditions are reasonable.
Daylight retrievals are bad ! (BB Bug)

Other known issues: Thick aerosol is misidentified as (water)cloud !

Working on a fix now.

Summary

A-PRO will be released to the Cal/Val teams soon.
L1 issues are taking more time than expected to be fixed in the operational processor.

Based on Aeolus experience we have high expectations.

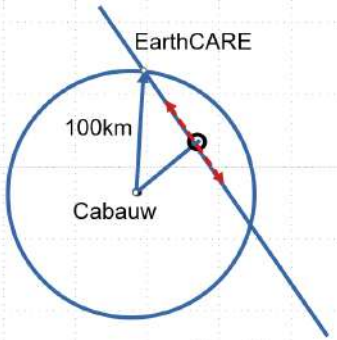
Important that it is validated against a range of different conditions.

Already there are some “known-issues” that will be fixed hopefully before release.

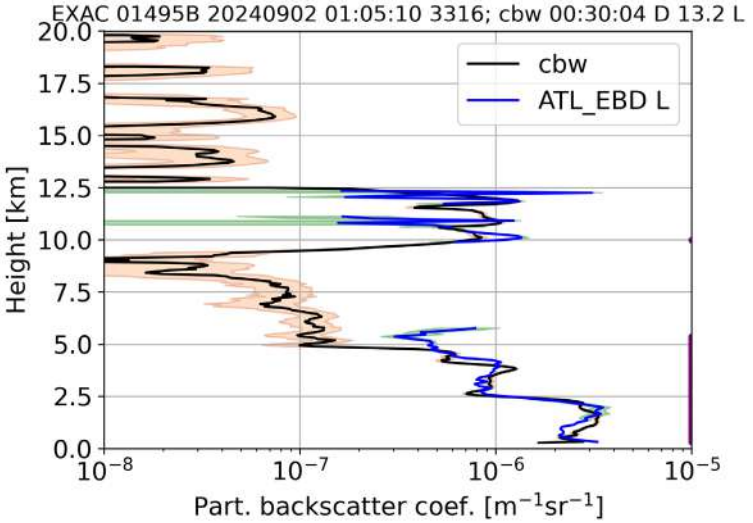
Data taken during commissioning phase will be re-processed.

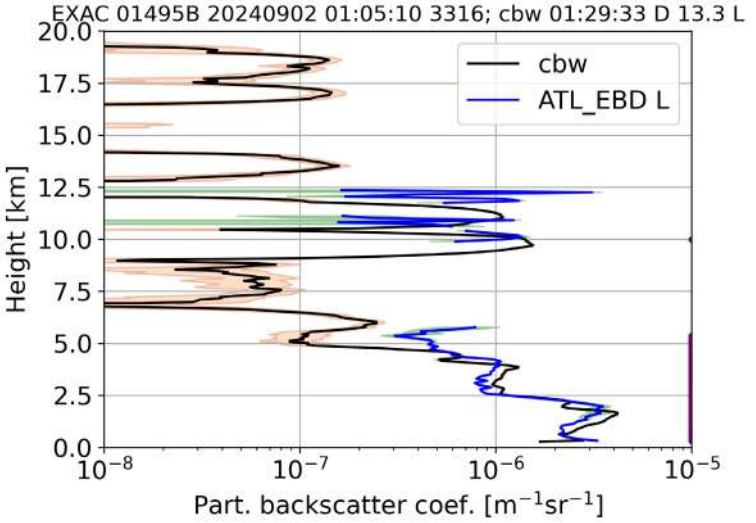
L2 Earlinet Example Comparison (using Cabauw 355 Raman data)

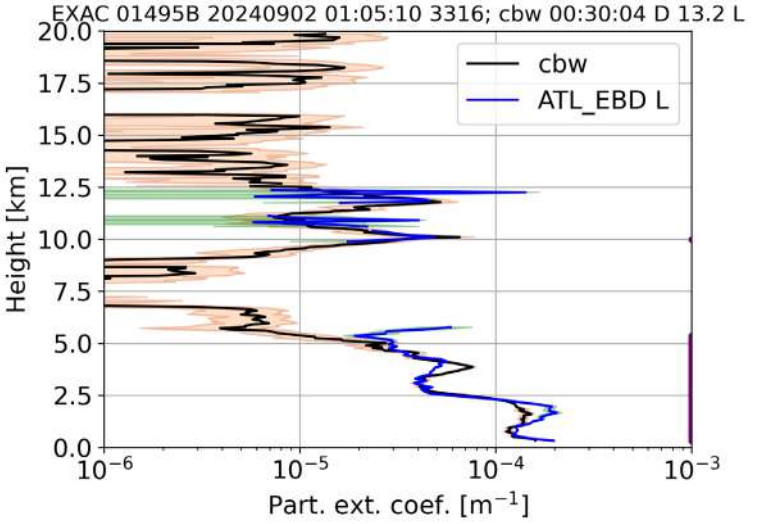
https://www.earlinet.org/

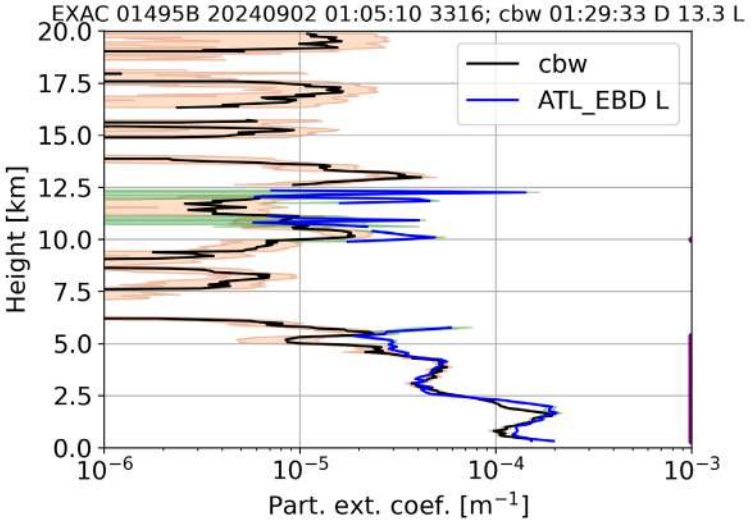


1) Select ATLID measurements within 100 km to Cabauw, time difference < 1.5 hour.
2) Select the measurement closest to Cabauw.
3) Average the measurements along track for 100 km around the closest point, can be less than 100 km if the orbit is far away.

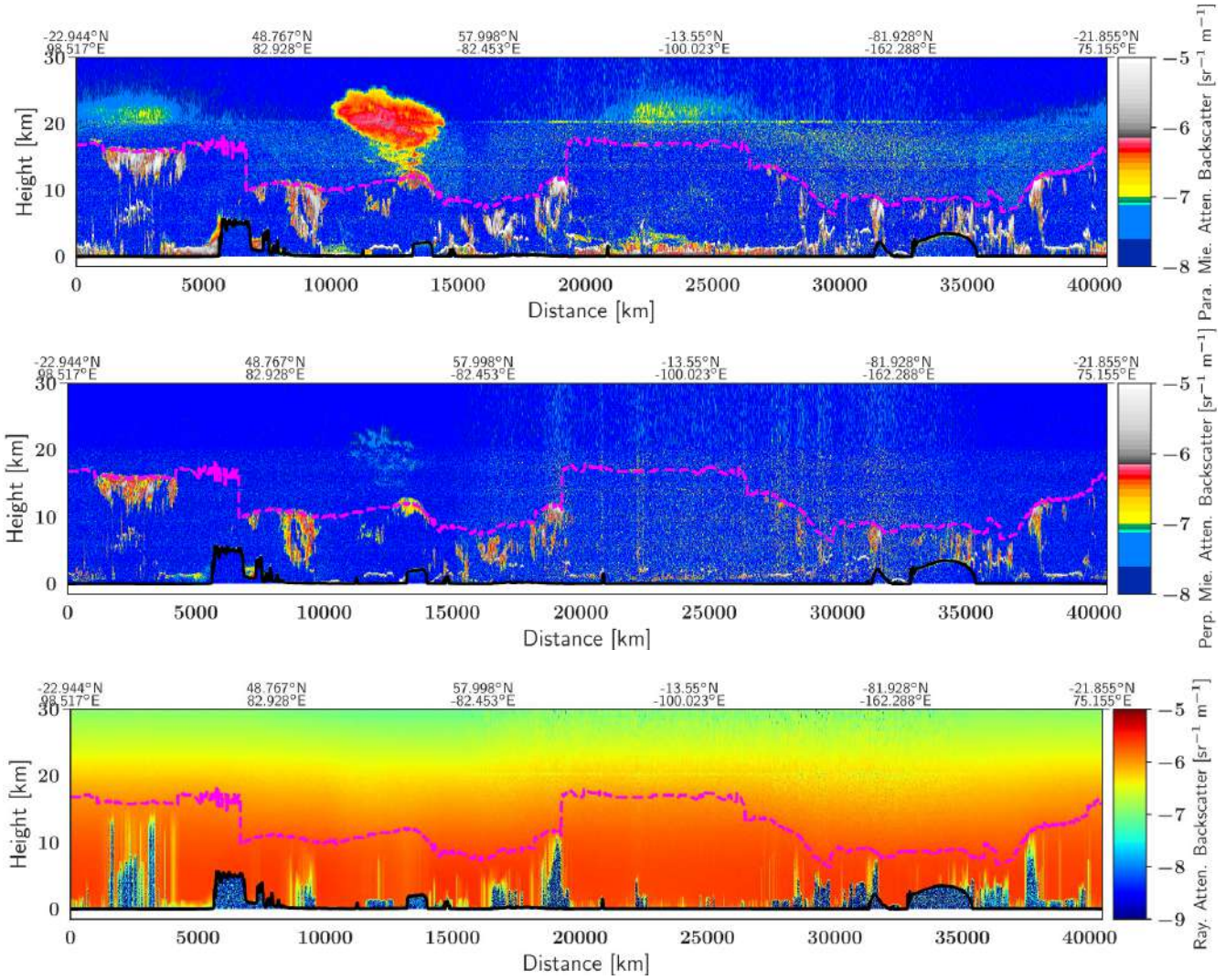


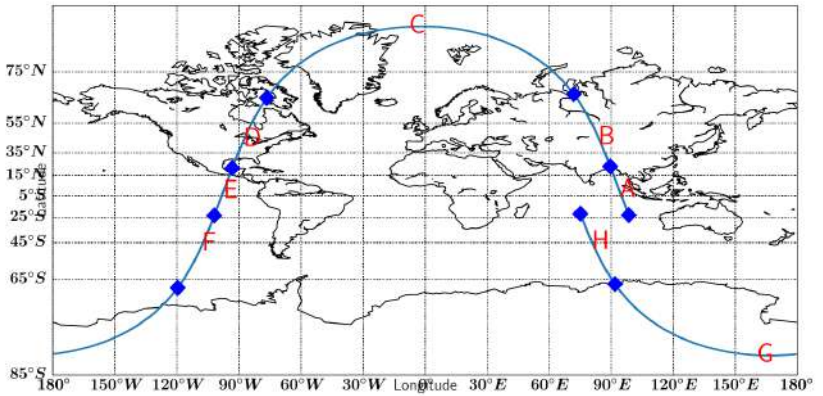


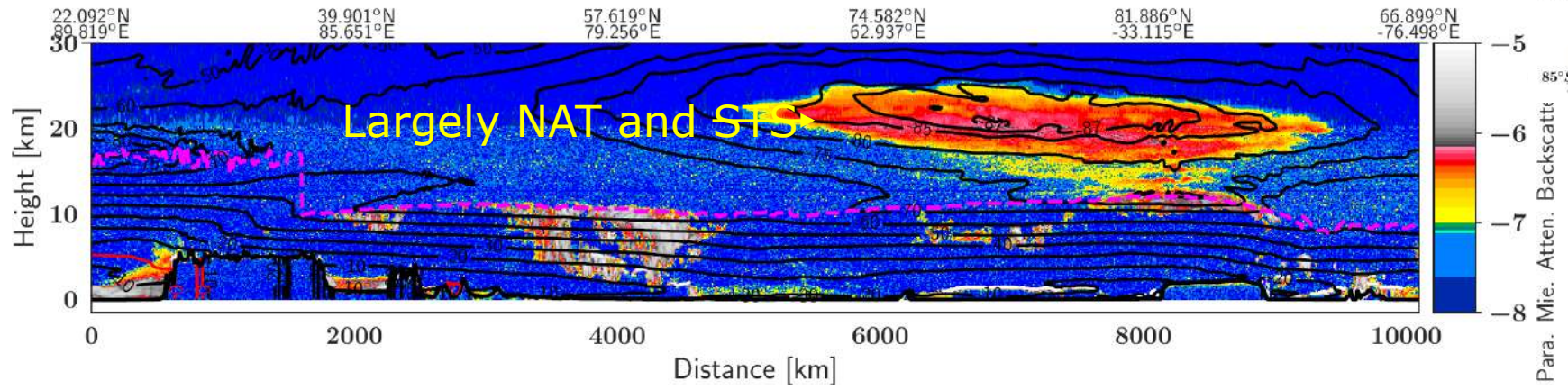


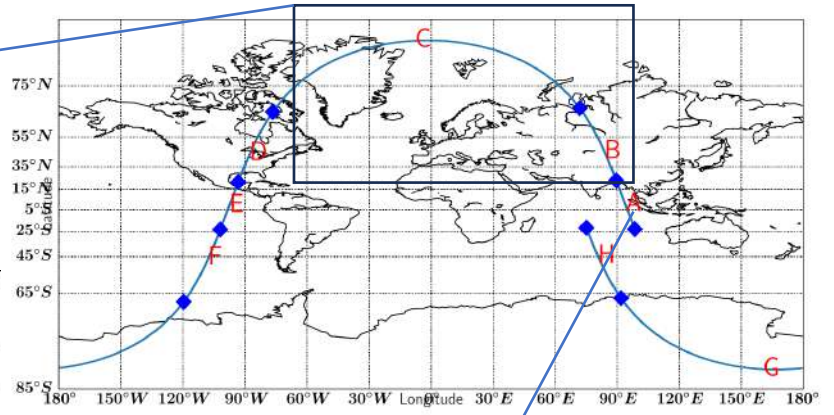


PSCs and Vol Aerosol observations

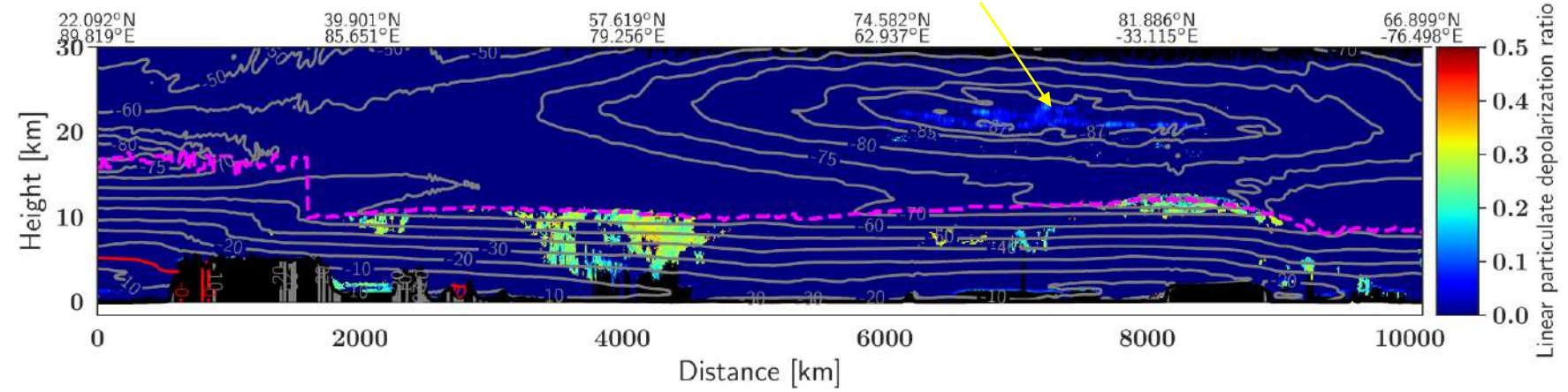


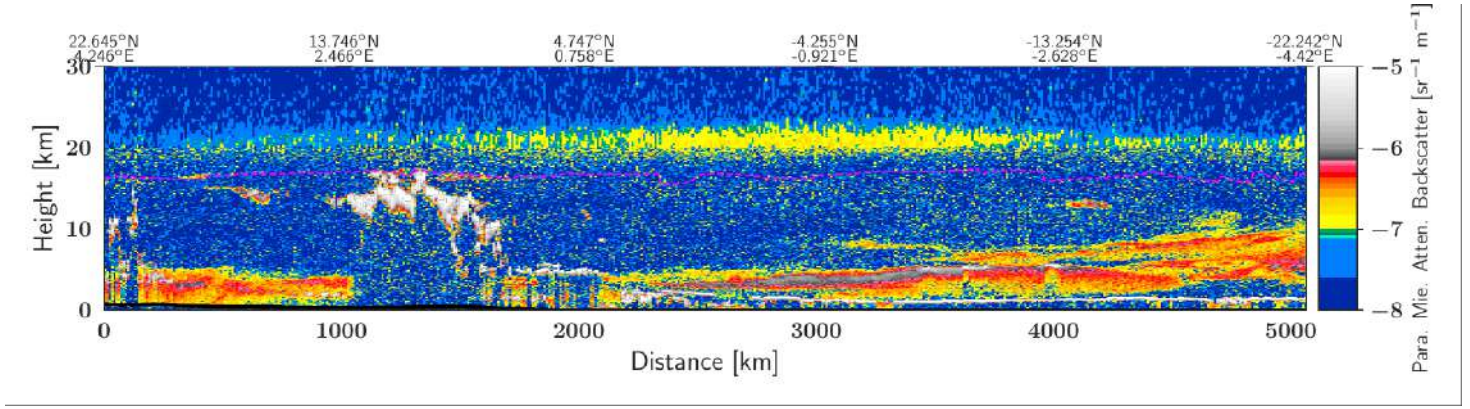


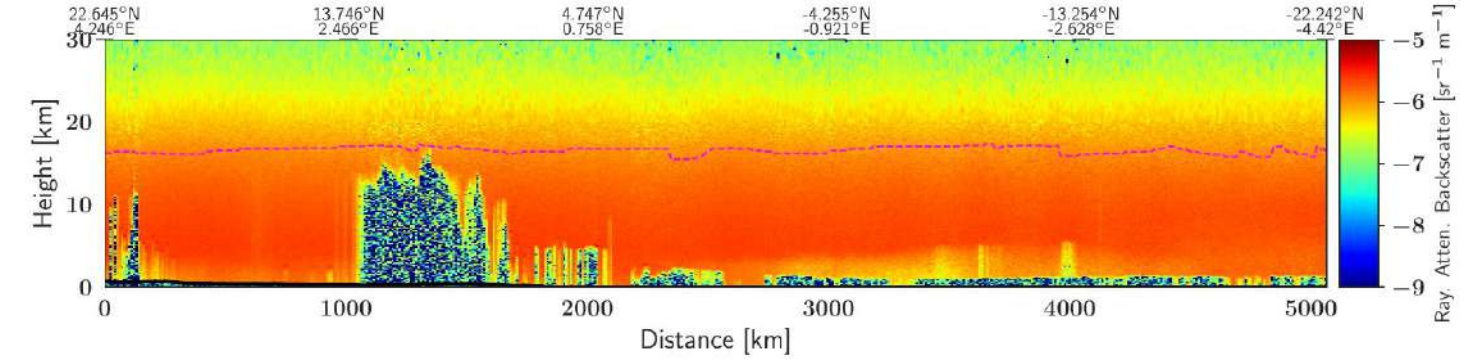


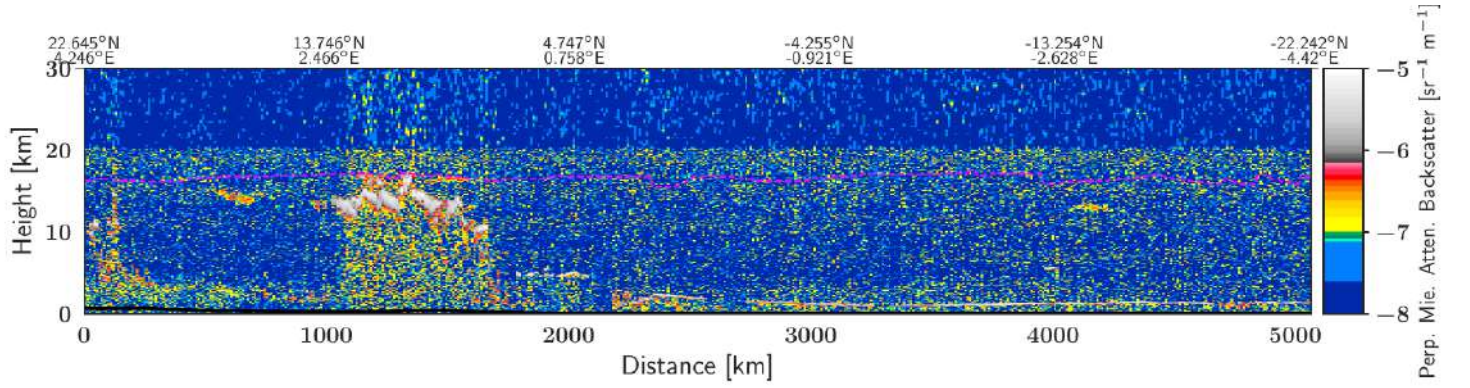


But below -87 C PSC Type-II (Water Ice)



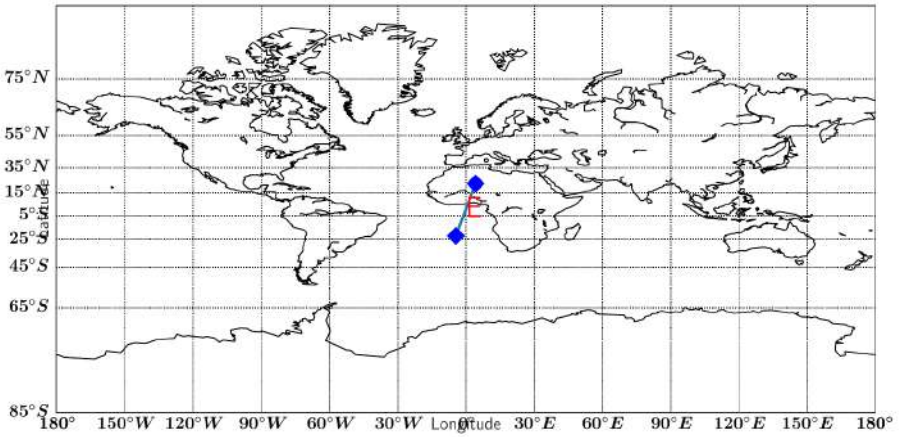




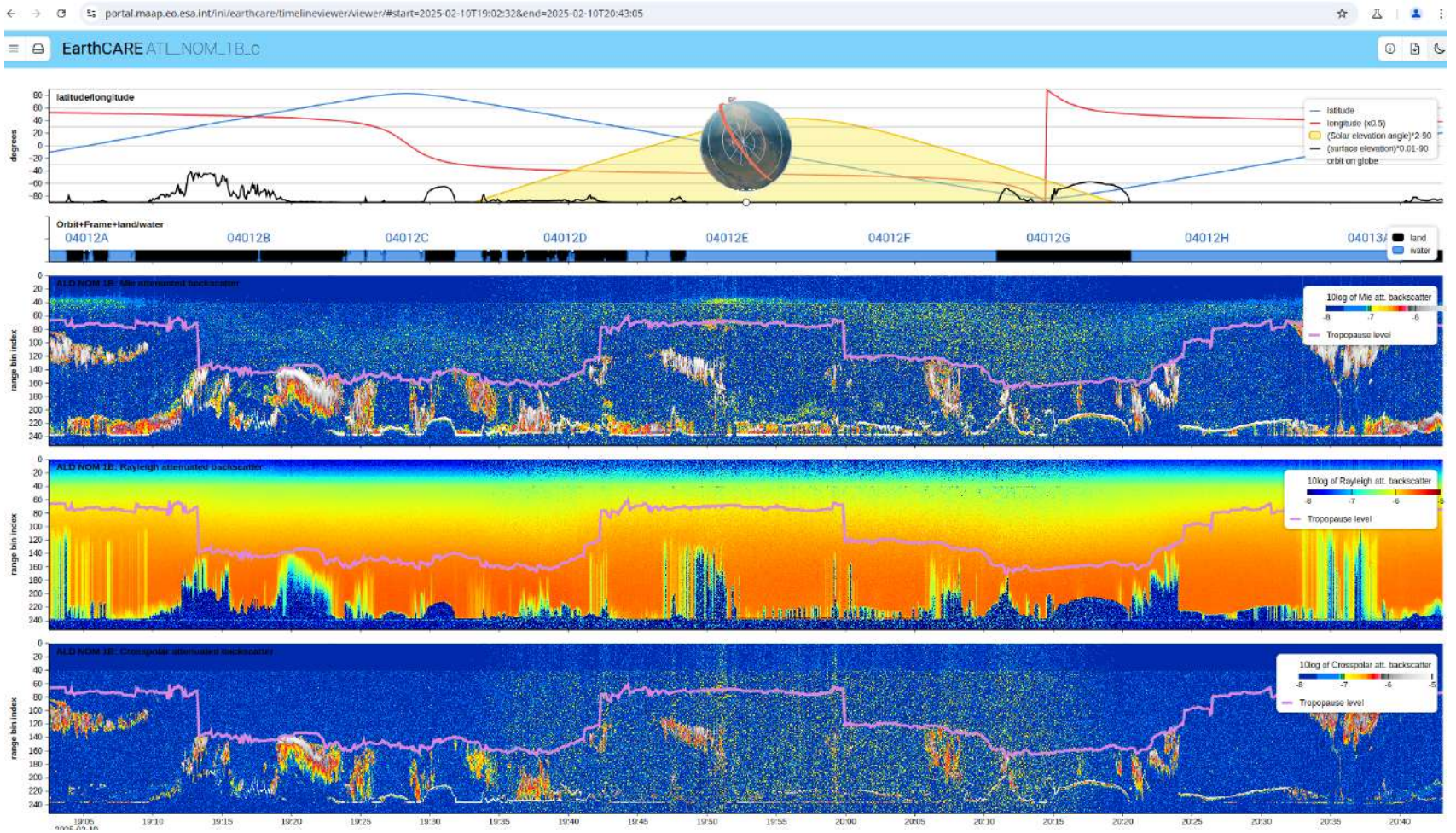


Press Release Case

Orbit: 01752:18/09/2024



https://portal.maap.eo.esa.int/ini/earthcare/timelineviewer/viewer/.



Multi-Scale A-EBD products