EarthCare and Aeolus Aerosol and Cloud Retrievals

(or. ATLID Algorithms applied to ALADIN)

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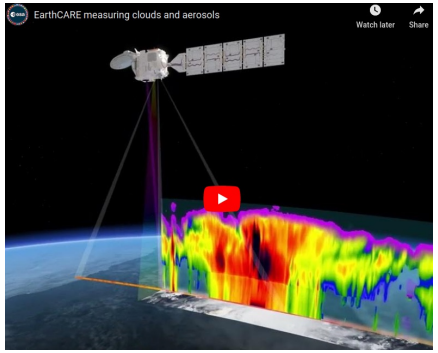
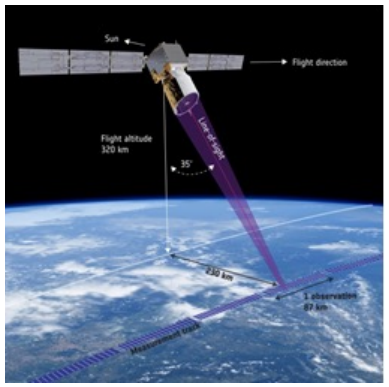
and numerous other members of the Aeolus and EarthCARE teams.



- Outline
  - Aeolus and EarthCARE
  - AEL-FM(A-FM) and AEL-PRO(A-PRO)
  - Some recent Examples
  - Outlook

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and Environment.

ALADIN and ATLID are both HSRL 355nm lidars but….



ALADIN

Optimized for winds

Large power-aperture product

But..

- Low resolution
- Low optical efficiency
- Unfavorable set of cross-talk coefficients (which acts to lower effective SNR of retrieved pure Mie and Ray attenuated backscatters)

ATLID

Optimized for aerosols and clouds

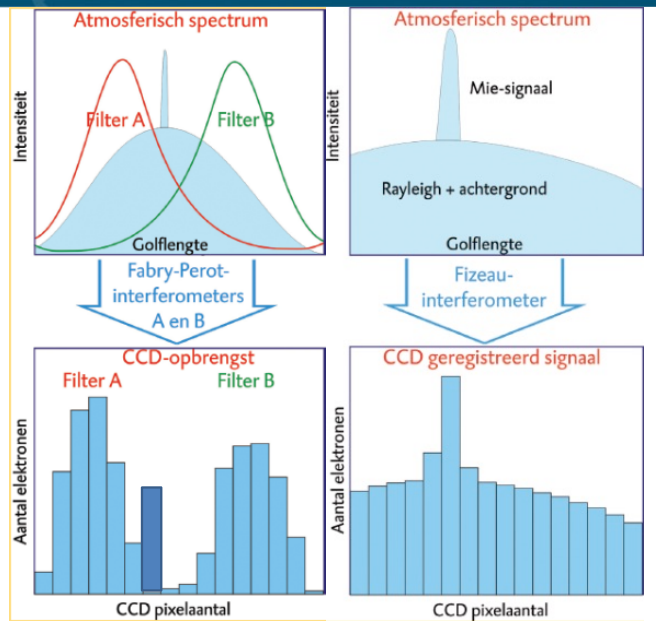
100m(Vert. res.)
385 m (Hor. res.)

- High optical efficiency
- Better cross-talk characteristics
- Launch in 2024.

ATLID is much better suited for aerosol/cloud work…but Aeolus HAS FLOWN !

aeolus DISC EARTHCARE

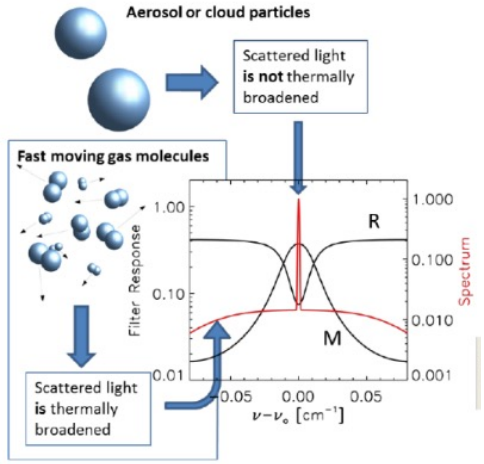
ALADIN and ATLID are HSRL Lidars but....



ALADIN has two spectrometers and 3 channels

A Dual FP (RSP)
Total signal in both channels available.

A Fizeau (MSP)
Full spectrum available.



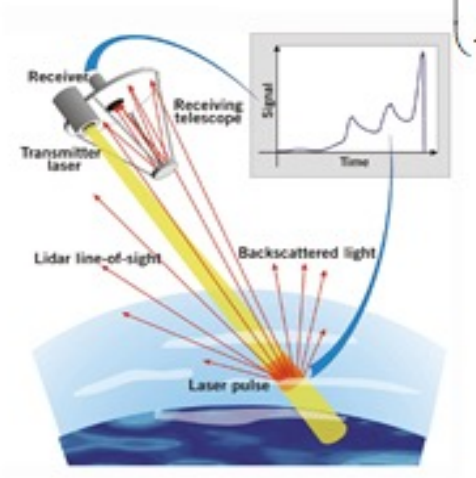
ATLID has one spectrometer and 3 channels

A single FP
separating the Mie and Ray co-polar returns and a total cross-polar channel.

Power $$P(z=\frac{ct}{2})=\frac{C}{z^2}\left(\beta_{Ray}(z)+\beta_{Mie}\right)\exp\left[-2\int_0^z\left(\alpha_{Ray}(z')+\alpha_{Mie}(z')\right)dz'\right]$$

Attenuated backscatter $$ATB=\frac{1}{C}z^2P(z)=P(z=\frac{ct}{2})=\left(\beta_{Ray}(z)+\beta_{Mie}\right)T^2(0,z)$$

$$\begin{pmatrix}ATB_{Ray,o}\\ATB_{Mie,o}\end{pmatrix}=\begin{pmatrix}K_{Ray}&0\\0&K_{Mie}\end{pmatrix}\begin{pmatrix}C_1&C_2\\C_3&C_4\end{pmatrix}\begin{pmatrix}ATB_{Ray}\\ATB_{Mie}\end{pmatrix}$$



Invert

Profiles of the "True" separate Rayleigh and Mie attenuated backscatters

IF high enough SNR extinction and backscatter can be directly derived !

Dealing with low SNR observations

Main issue : Space-borne lidar signals are noisy !.

The standard Aeolus L2a aerosol product (the SCA) is (fundamentally) a variation of the usual direct (log derivative) approach for deriving extinction. **As such, it requires high SNR signals !**

Along-track averaging to increase the SNR is one solution. However, one can not mix “strong” (e.g. cloud) and “weak”(e.g. aerosols) returns and hope to obtain anything quantitatively useful ! The Aeolus standard approach does not screen before averaging.

A strategy (based on ideas taken from ATLID developments) is to:

1) Separate the `strong’ and `weak’ features at as high a horizontal resolution as possible.
2) Separately process and merge the strong and weak fields at different resolutions.

This requires:

1) A high resolution mask
2) A quantitative retrieval approach than can be applied at difference scales which is robust to noise.

AEL-FM/AEL-PRO and A-FM/A-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)

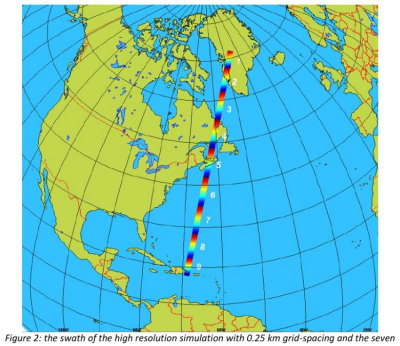
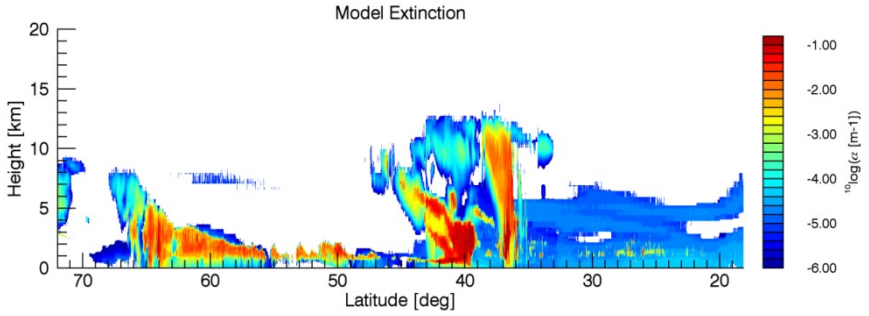
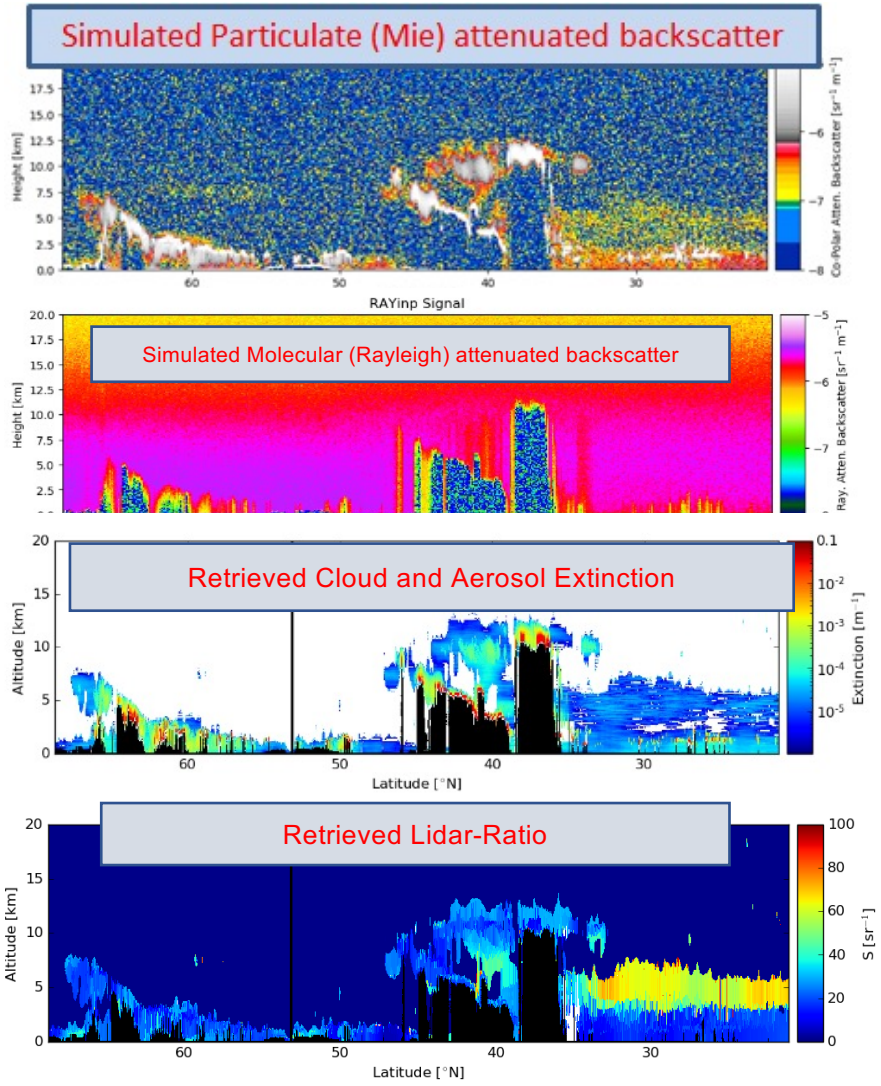
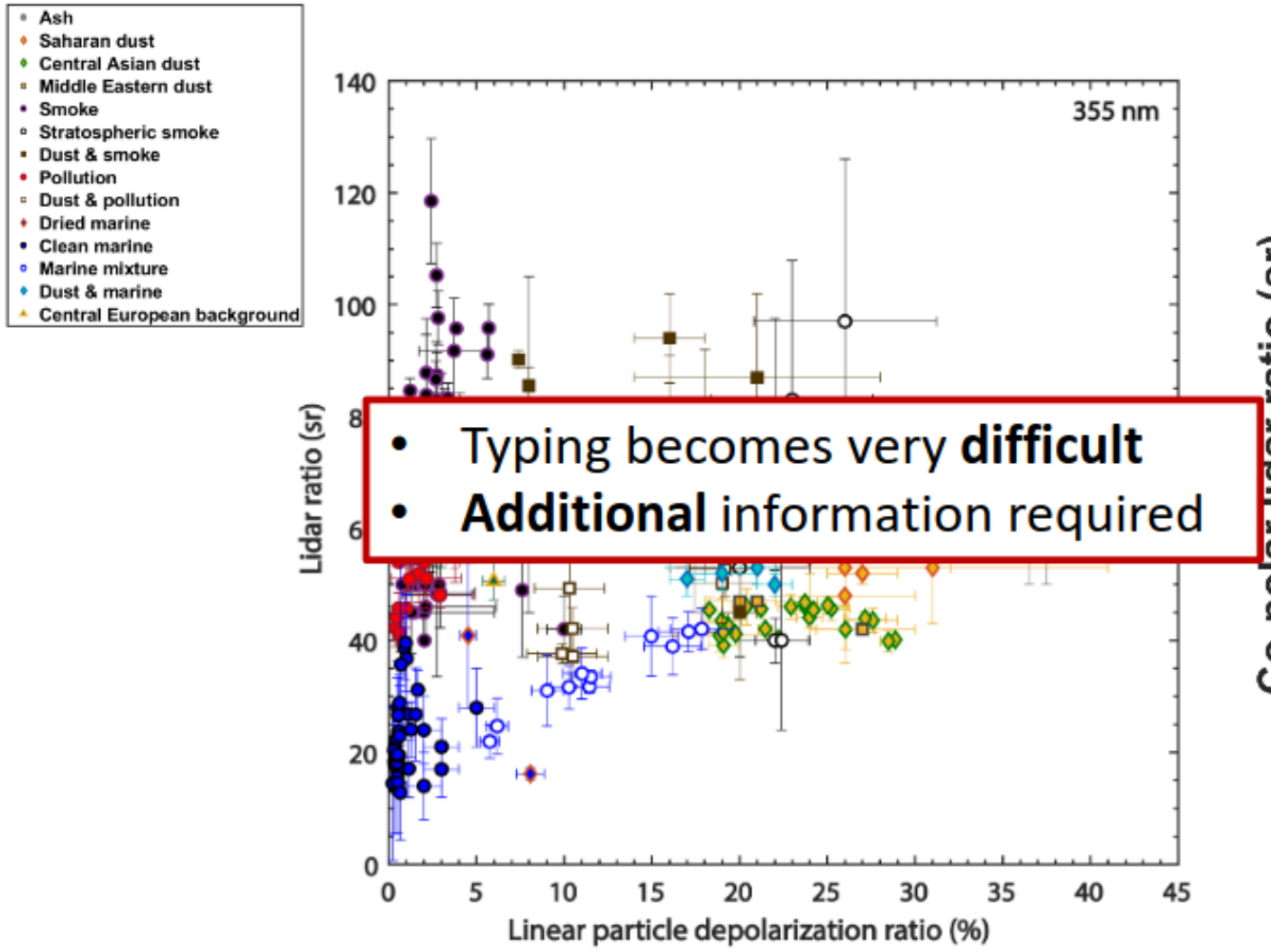


Figure 2: the swath of the high resolution simulation with 0.25 km grid-spacing and the seven section of the separated simulation.

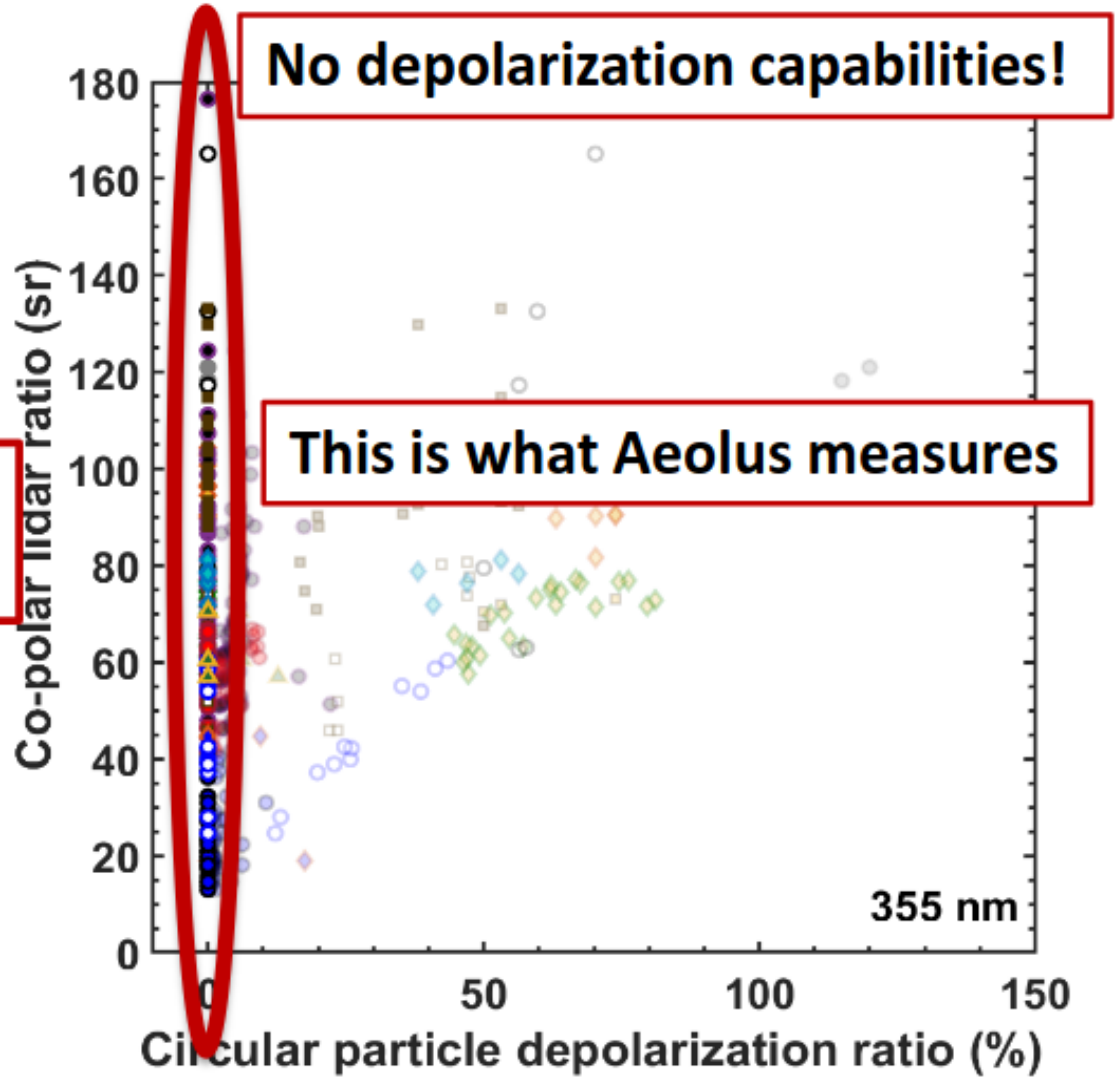




Aeolus & aerosol typing



- Typing becomes very **difficult**
- **Additional** information required



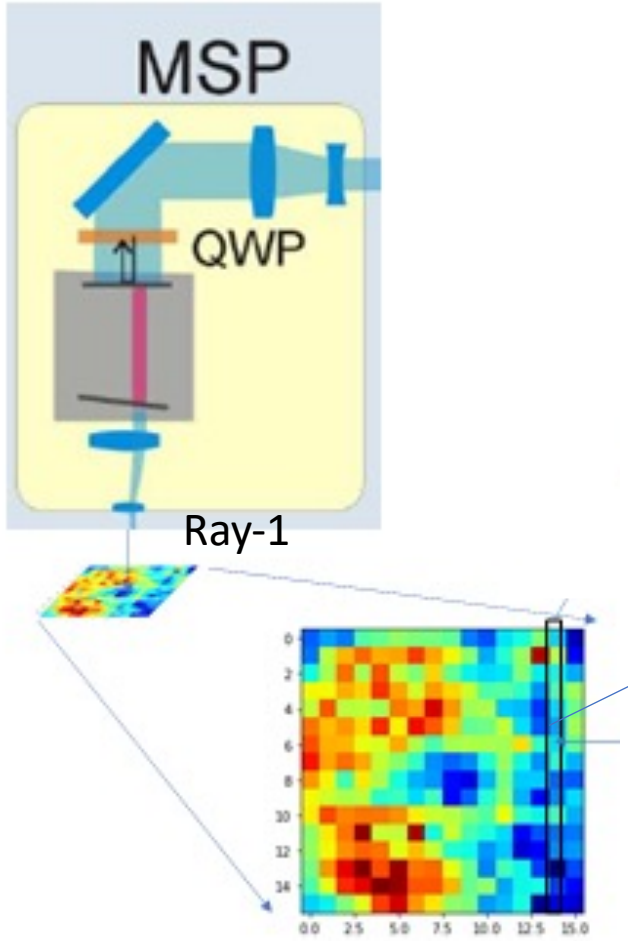
EarthCARE-like → Aeolus

Testing ATLID(-like) approaches using ALADIN observations

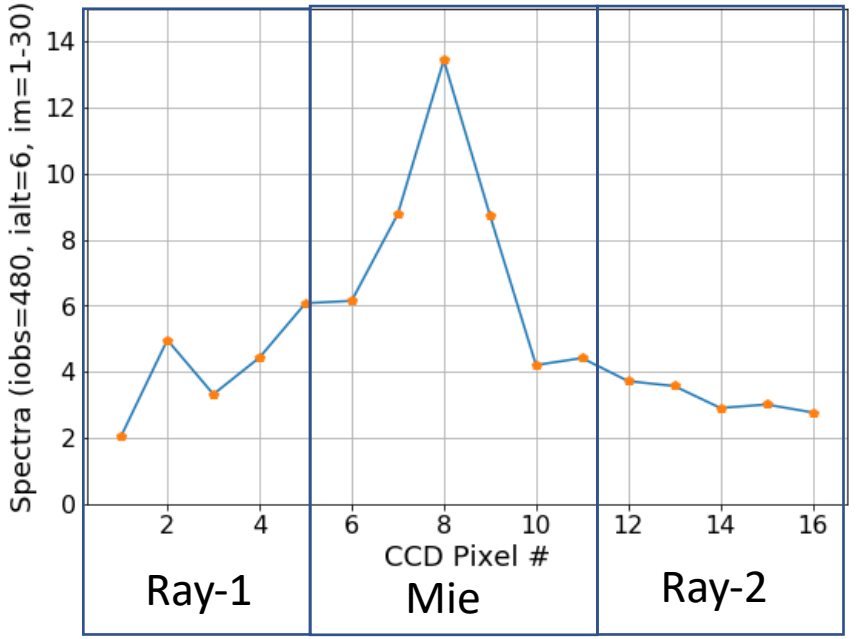
- AEL-FM and AEL-PRO have been adapted to ALADIN measurements !
  - Being implemented in the operational processor.
  - AEL-FM resembles A-FM more completely than AEL-PRO resembles A-PRO
    - E.g. Aeolus lacks depol. Measurements ➔ Aerosol type determination is problematic and and simplified ice/water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

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

First step: Create accurate pure "Rayleigh" and Pure "Mie" Calibrated attenuated backscatter profiles using MSP spectra only



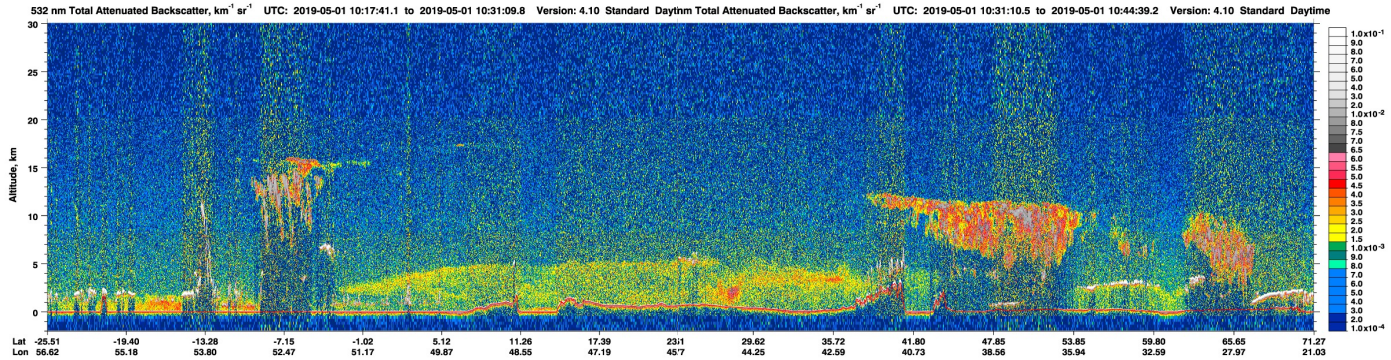
Sample CCD spectrum



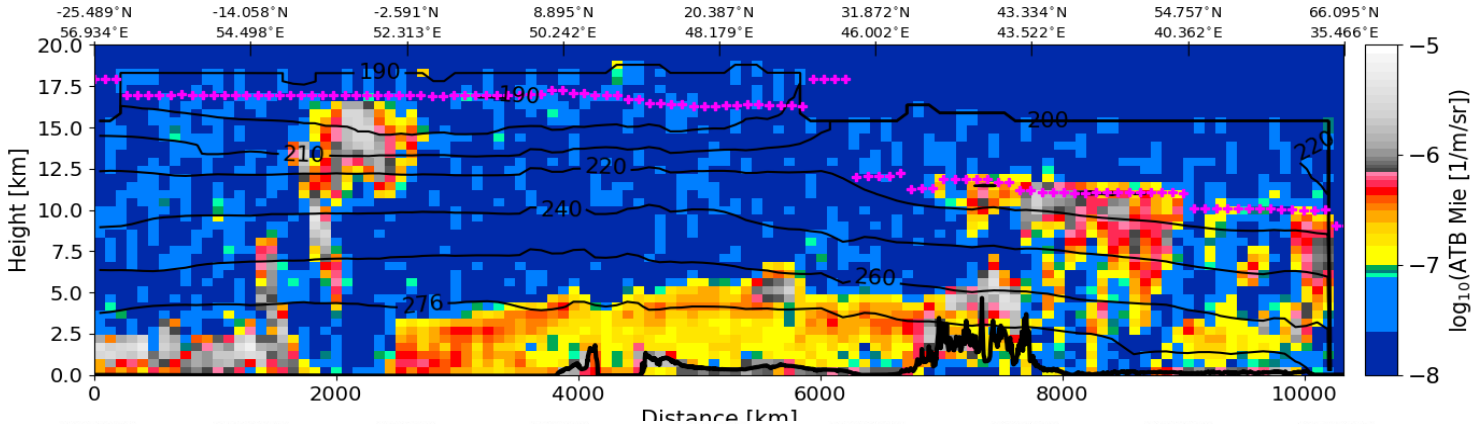
Using the MSP signals only gives better Mie SNR than using RSP+MSP !
(Ray ATB SNR is somewhat degraded though, but still more accurate)!

Reason is due to more favorable cross-talk characteristics !

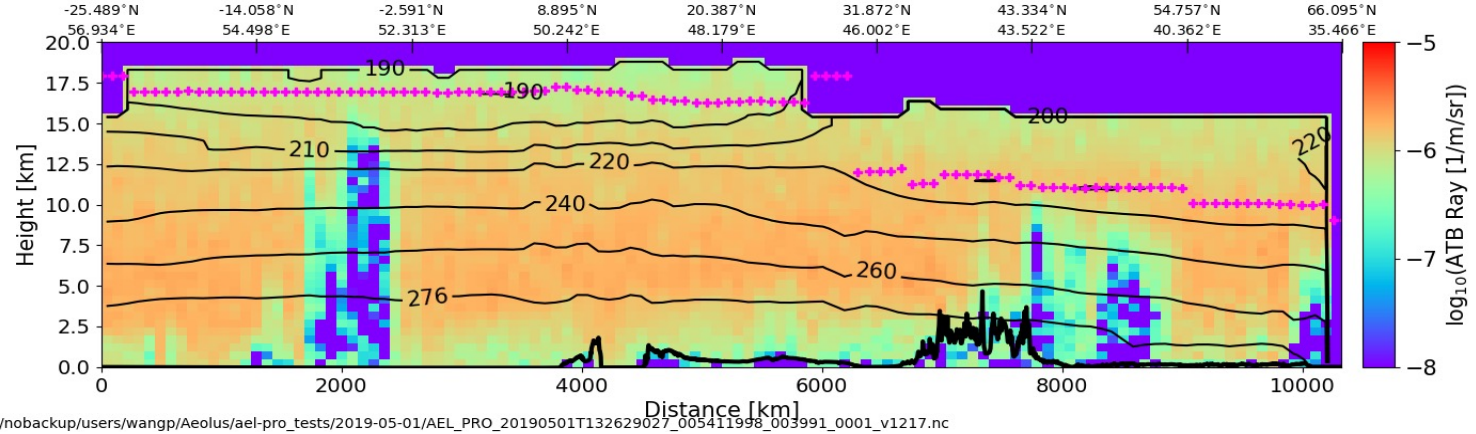
AEL-PRO PP orbit 3991 on 2019-05-01 vs Calipso total ATB at 532 nm



Calipso ATB at 532 nm



Aeolus ATB Mie at 355 nm



Aeolus ATB Ray at 355 nm

/nobackup/users/wangp/Aeolus/ael-pro_tests/2019-05-01/AEL_PRO_20190501T132629027_005411998_003991_0001_v1217.nc

Featuremask (AEL-FM)

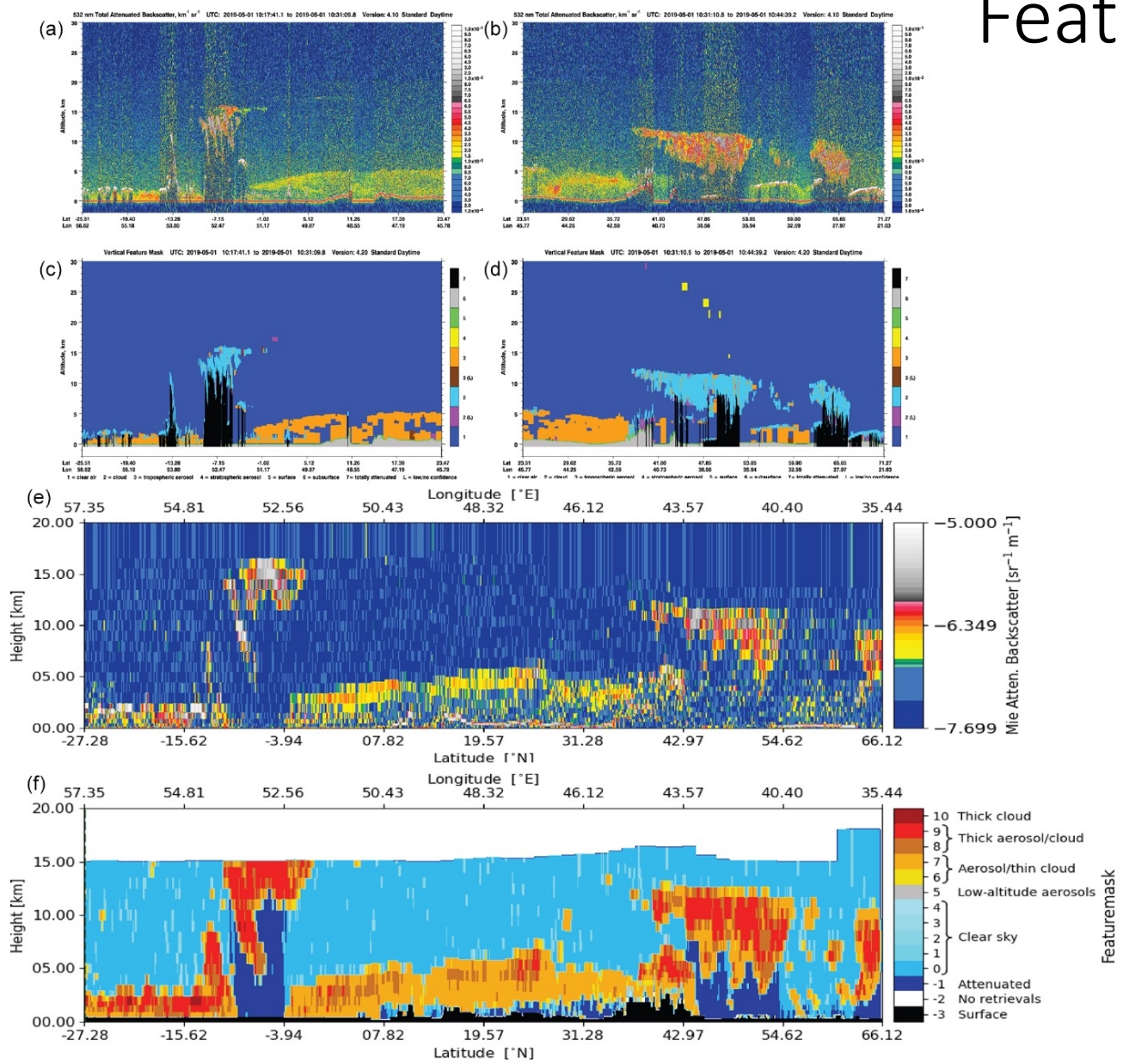


Figure 11. Comparison of a CALIPSO and Aeolus overpass (Orbit 3991) on 1 May 2019 over the tip of Somalia (east Africa) towards Yemen. Panels **(a)**–**(d)** show the CALIPSO 532 nm backscatter quick looks, with the second row being the corresponding VFM mask. Panels **(e)** and **(f)** show the 355 nm Aeolus backscatter and AEL-FM results for the overpass a few hours later. Both the dust layer and ice clouds are clearly visible in both instruments' L1 data and retrieved by their respective feature finders.

- Provides a mask on the highest resolution available.
- Uses image processing ideas to identify features in the signals.
  - Edge preserving filter (Hybrid median) to detect strong features.
  - Iterative smoothing together with signal probability histogram analysis in order to detect weak signal areas.
- Dynamic determination of noise thresholds.
  - Achieved by examining the signal+noise probability histograms

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

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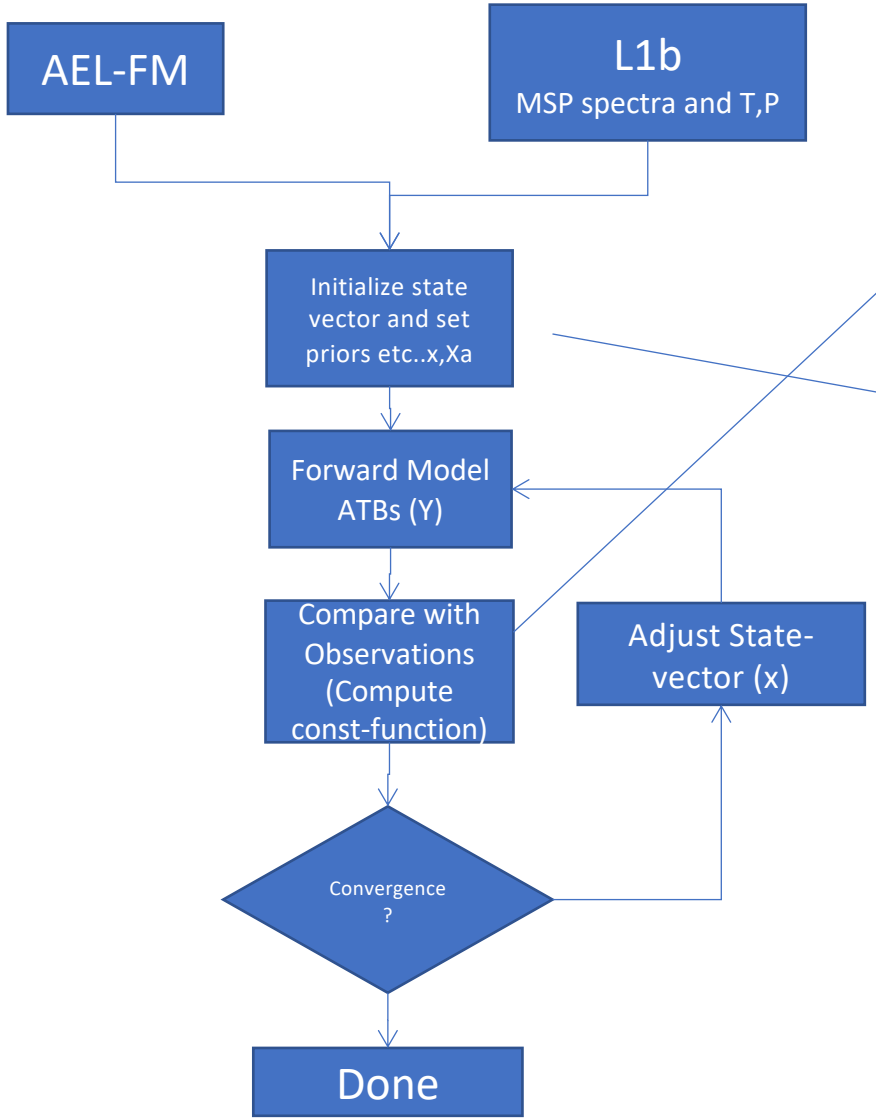
https://doi.org/10.5194/amt-16-3631-2023

Atmospheric Measurement Techniques
Open Access
EGU

AEL-PRO (simplified structure)



$$\chi^2 = [(Y_i - y_i)]\left[C_{i,j}\right]^{-1}[(Y_i - y_i)]^t + \left[(X_{i_a} - x_{i_a})\right]\left[C_{a,i_a,j_a}\right]^{-1}\left[(X_{i_a} - x_{i,a})\right]^t$$

$$x = \log state \;\; \text{var}\, iables = \log(\alpha_1 .....\alpha_{nz}, S_1 ....S_{nz}, Ra_1 .....Ra_{nz}, C_{lid})$$

$$y = observations = (ATB_{Ray_1} .....ATB_{Ray_{nz}}, ATB_{Mie_1} ....ATB_{Mie_{nz}})$$

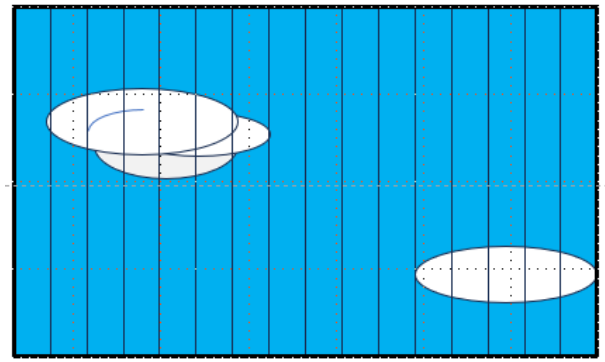
$$Y = Y(x) = forward\;\; modelled\;\; observations$$

$$X_a = apriori\;\; values = \log(S_{a,1} ....S_{a,nz}, Ra_{a,1} .....Ra_{a,nz}, C_{lid,a})$$

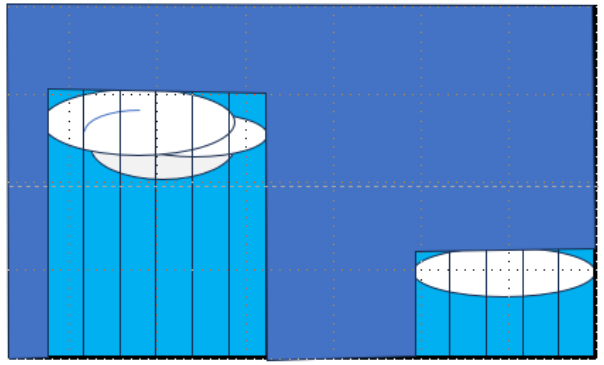
Two passes at different resolutions are performed:

-Low-res pass (aerosols + thin clouds)
-High-Res pass (clouds). Uses pass-1 results as input.

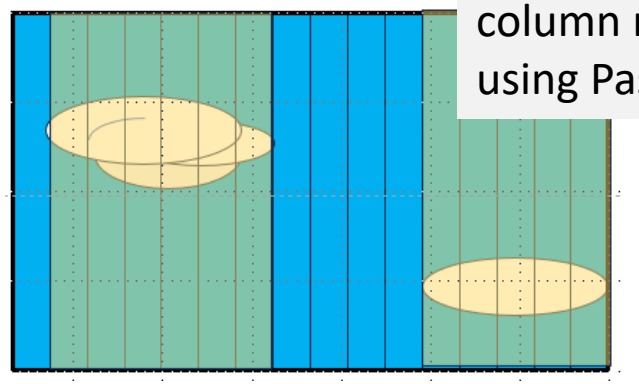
Pass-1 and Pass-2



Separate “weak” and “strong” features



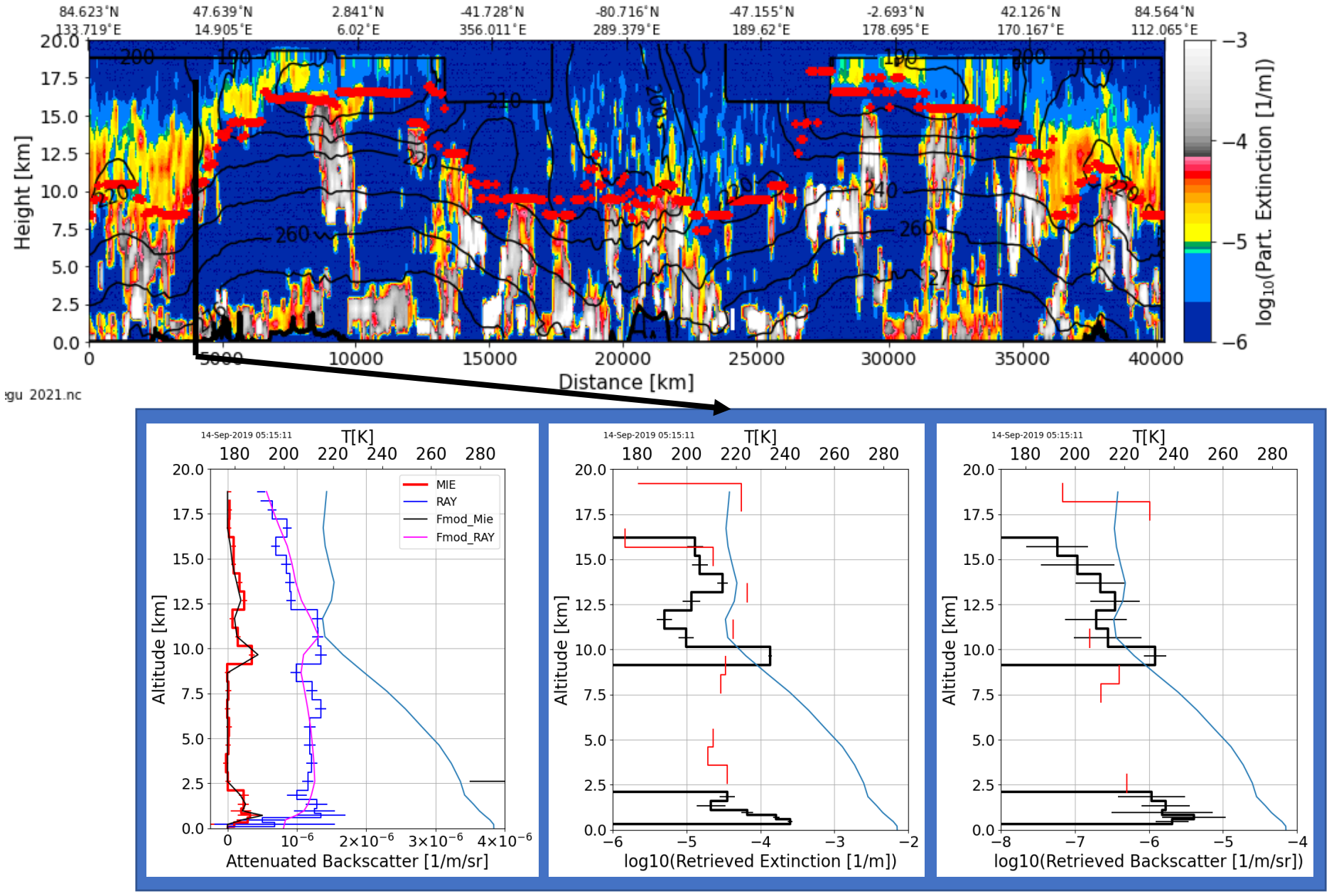
Average over “Weak-feature” areas and retrieve “background” aerosol/thin-cloud fields



Perform column-by-column retrievals using Pass-I results

Merge Pass-1 and Pass-II results

AEL-PRO Example



Example Comparison with CALIPSO

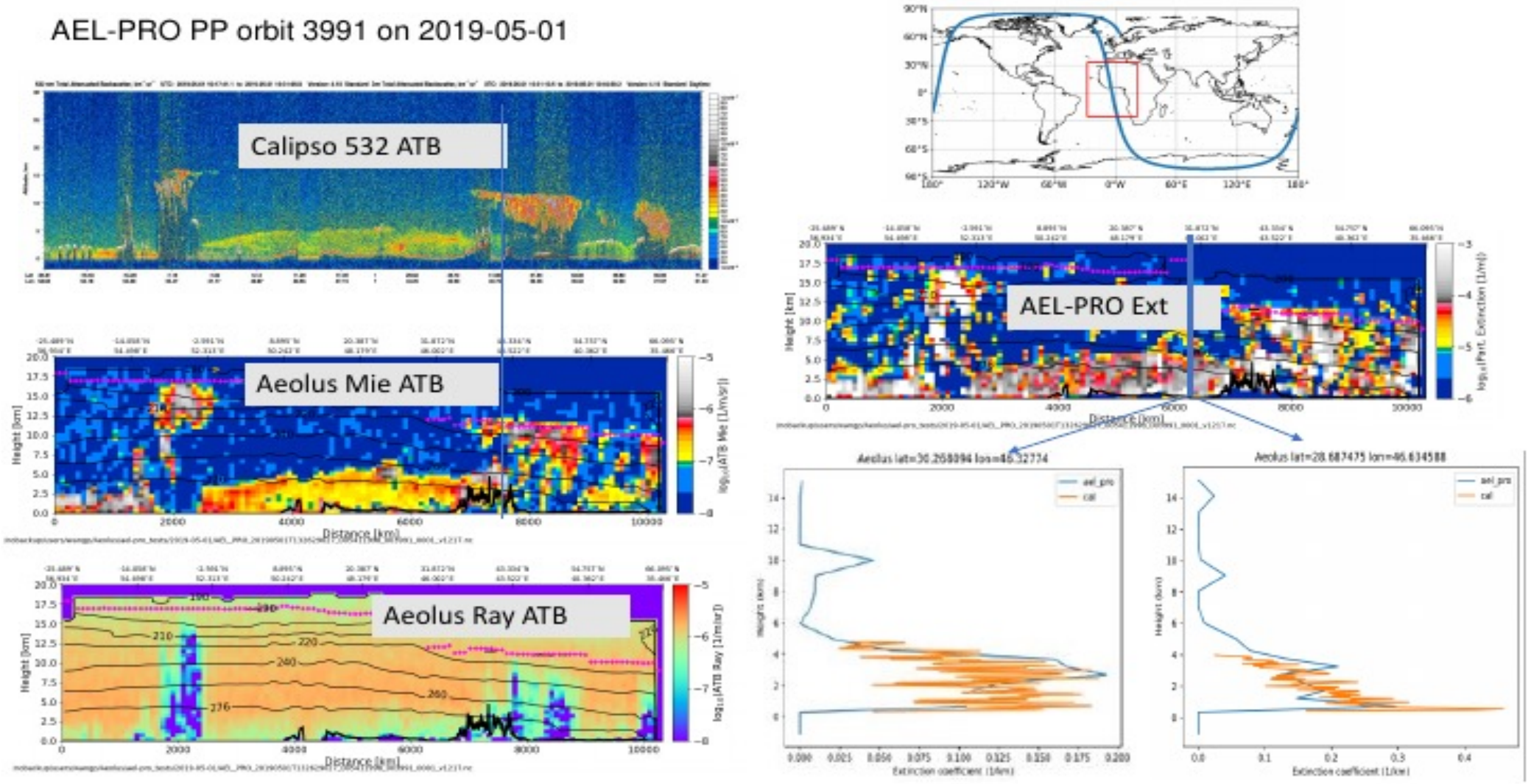
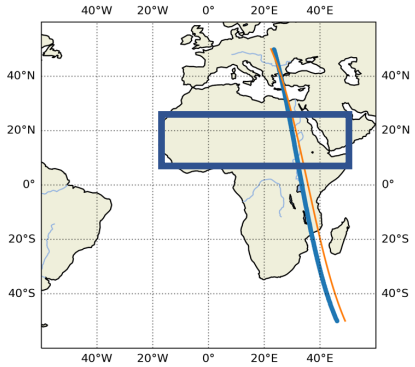
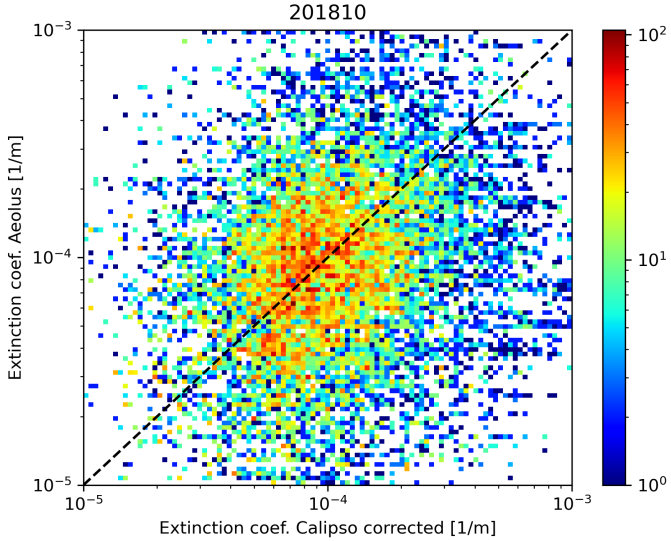


Fig. 4. CALIPSO and ALADIN ATBs and extinction retrieval within an orbit section within a few 10s of km and 3.5 hrs on May 01, 2019.

Calipso and Aeolus aerosol extinction coefficients 2018-10

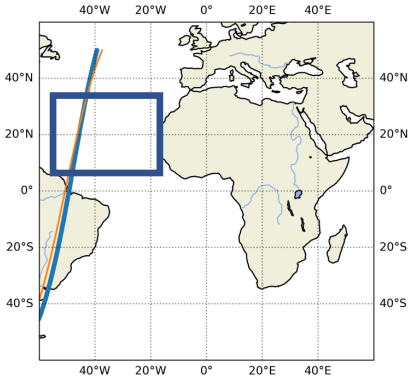
Dust

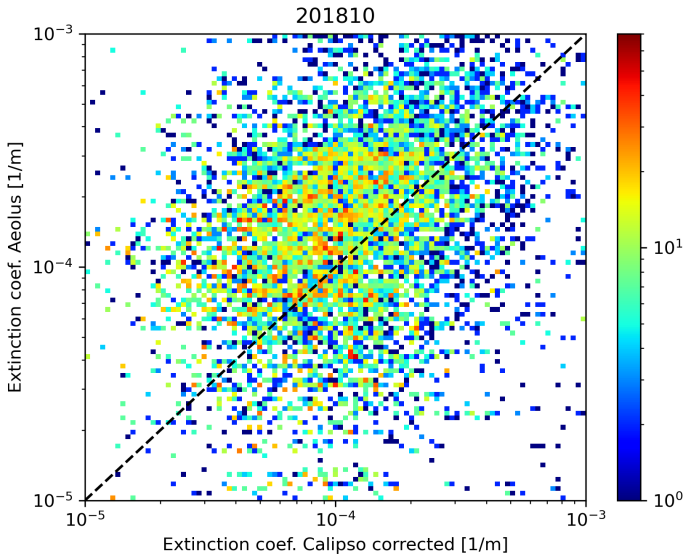




Region 1

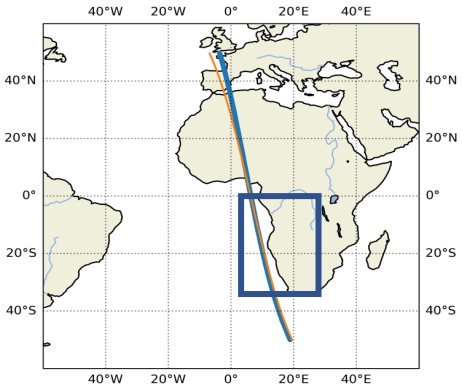
Dust over ocean

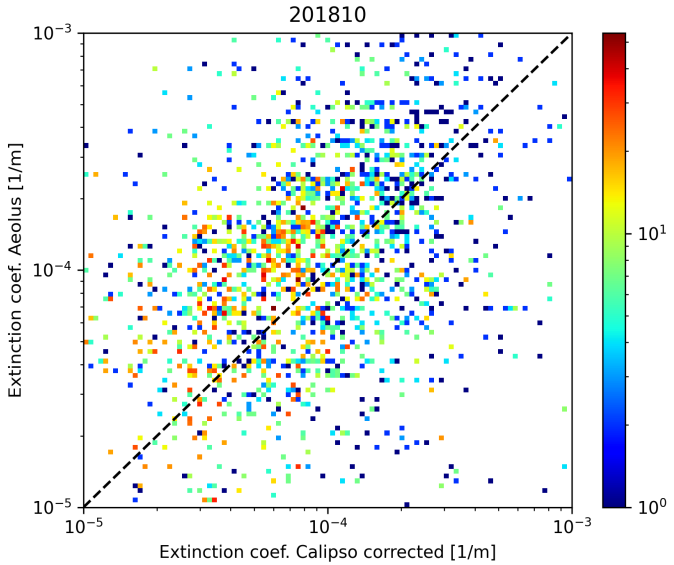




Region 2

Smoke

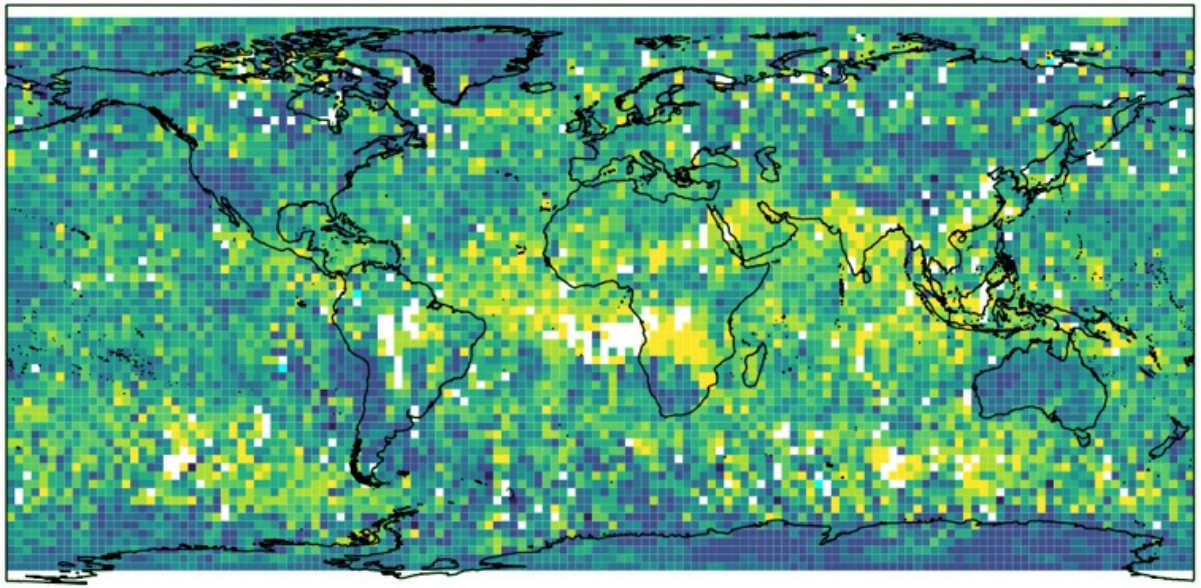




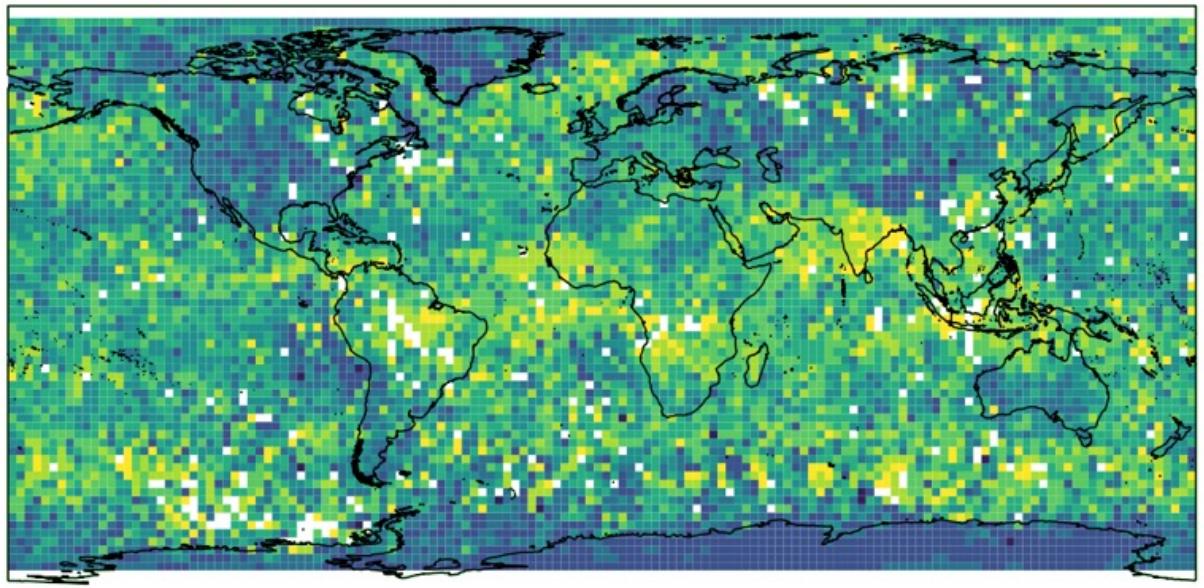
Region 3

MONTHLY MEAN ESTIMATES

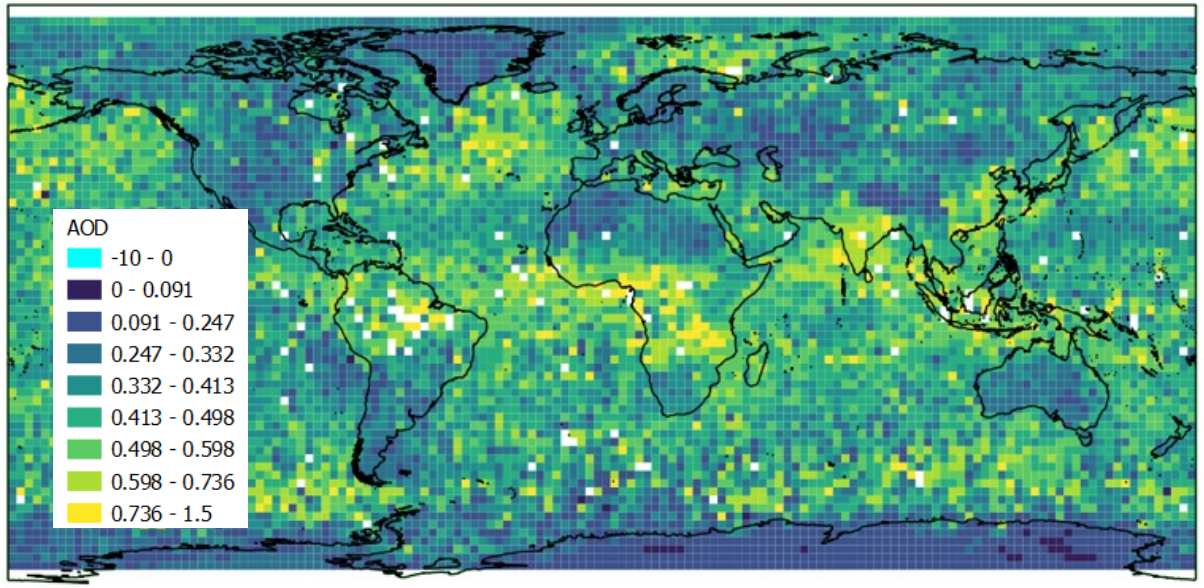
AOD | HIGHEST QUALITY FLAG APPLIED | 2018 - 09



AOD | HIGHEST QUALITY FLAG APPLIED | 2018 - 10



AOD | HIGHEST QUALITY FLAG APPLIED | 2018 - 11



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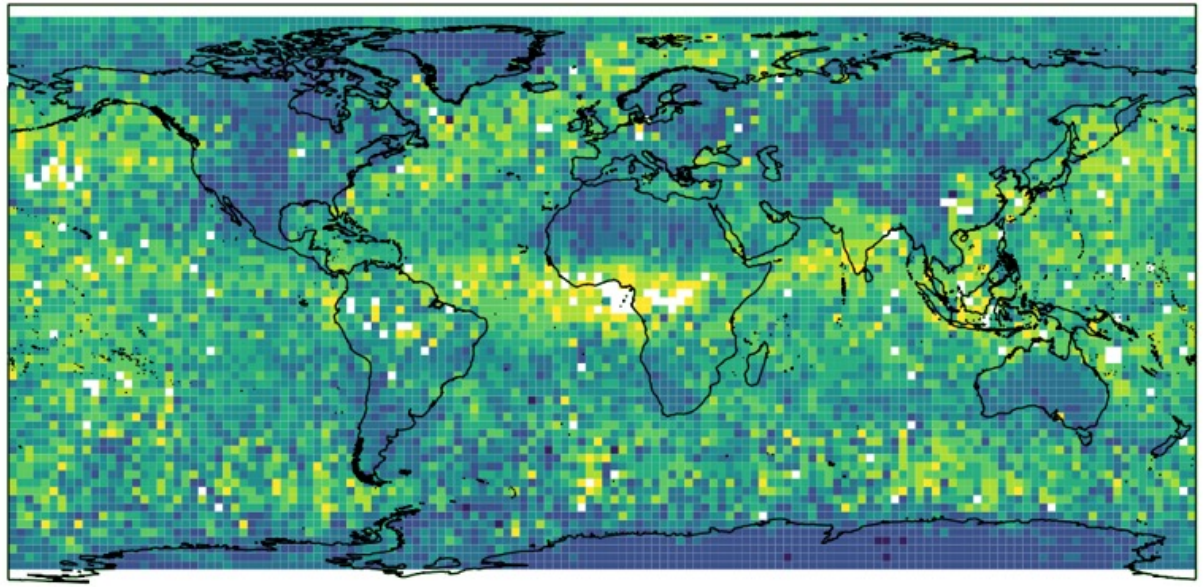
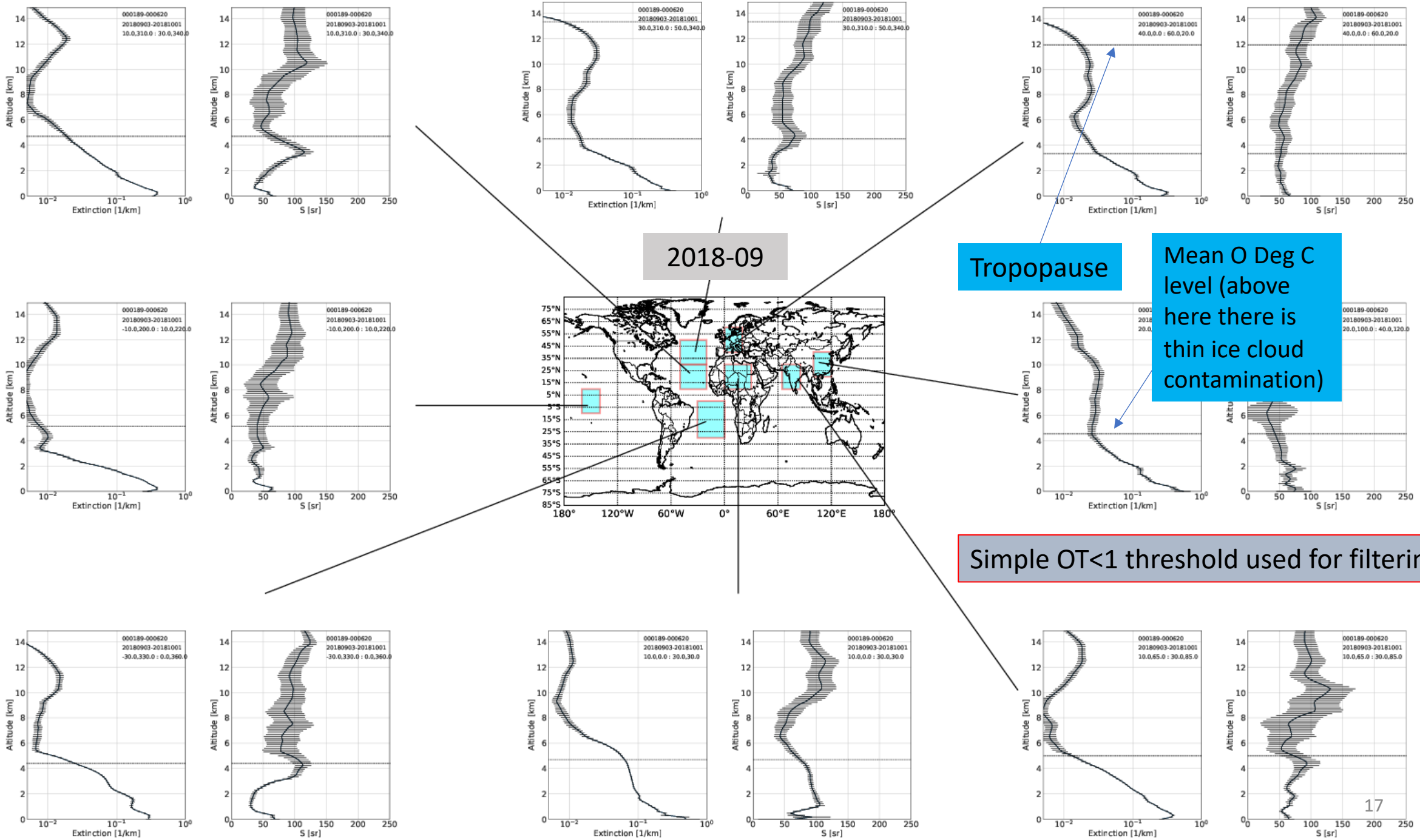
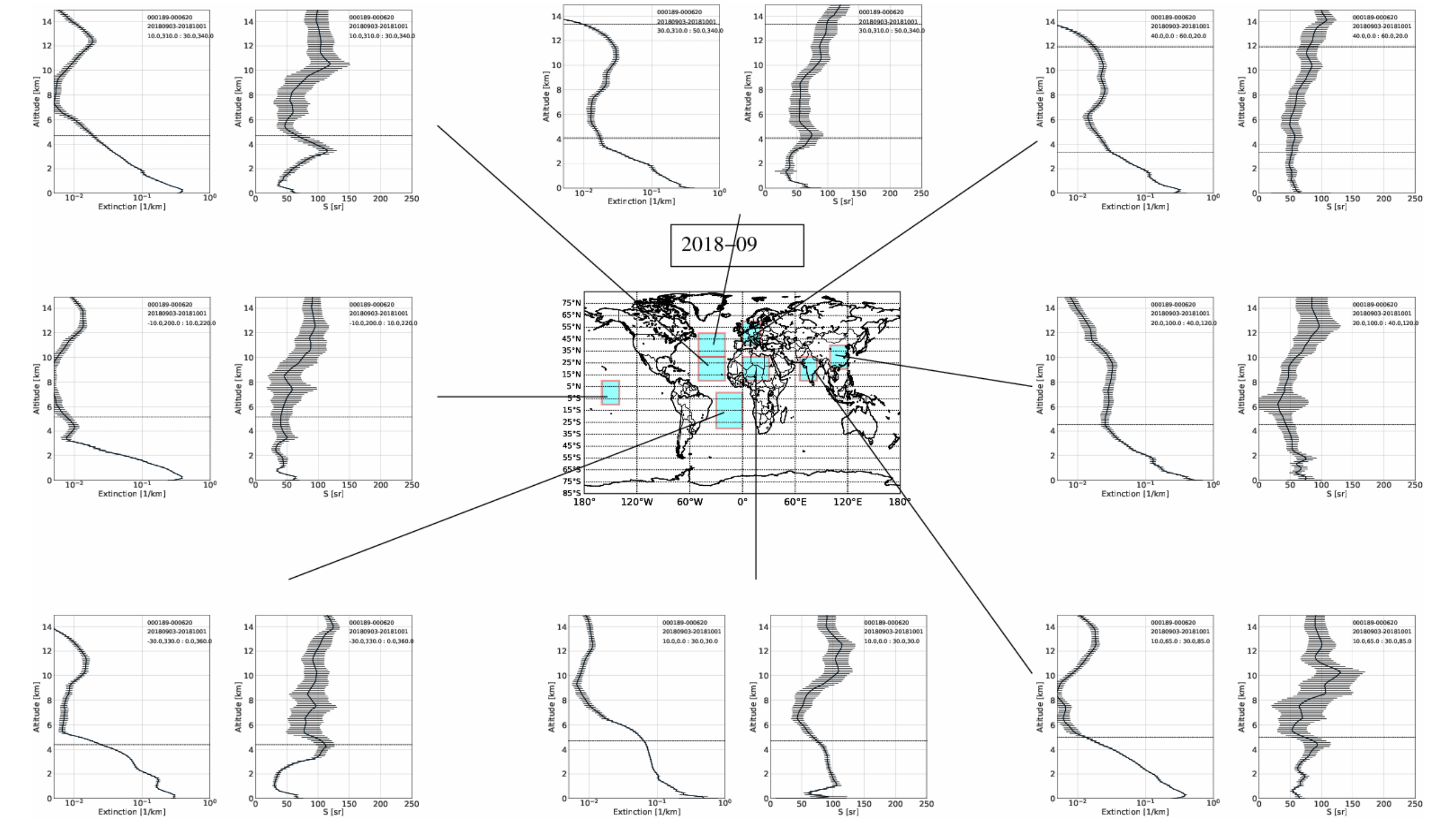
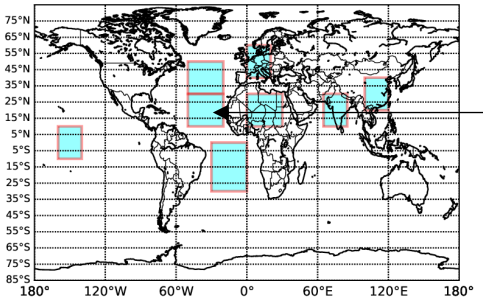


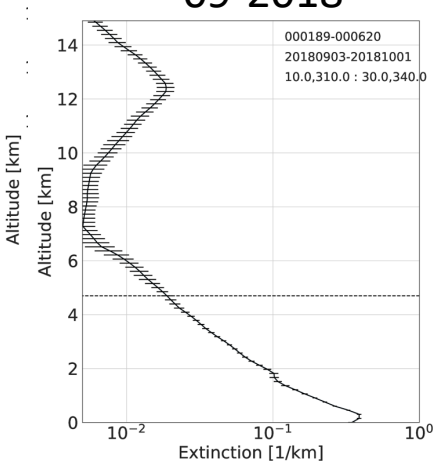

2018-09
Tropopause
Mean O Deg C level (above here there is thin ice cloud contamination)
Simple OT<1 threshold used for filtering
Altitude [km]
Extinction [1/km]
S [sr]

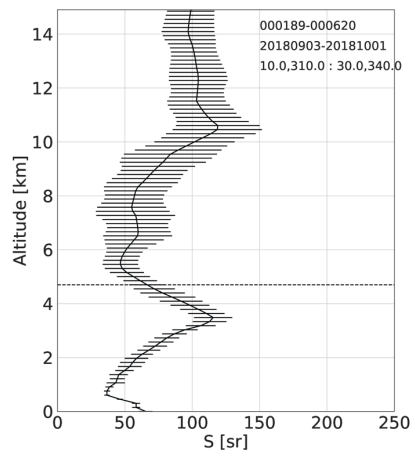

2018–09
000189-000620
20180903-20181001
10.0,310.0 : 30.0,340.0
30.0,310.0 : 50.0,340.0
40.0,0.0 : 60.0,20.0
-10.0,200.0 : 10.0,220.0
20.0,100.0 : 40.0,120.0
-30.0,330.0 : 0.0,360.0
10.0,0.0 : 30.0,30.0
10.0,65.0 : 30.0,85.0
Altitude [km]
Extinction [1/km]
S [sr]
75°N
65°N
55°N
45°N
35°N
25°N
15°N
5°N
5°S
15°S
25°S
35°S
45°S
55°S
65°S
75°S
85°S
180°
120°W
60°W
0°
60°E
120°E
180°



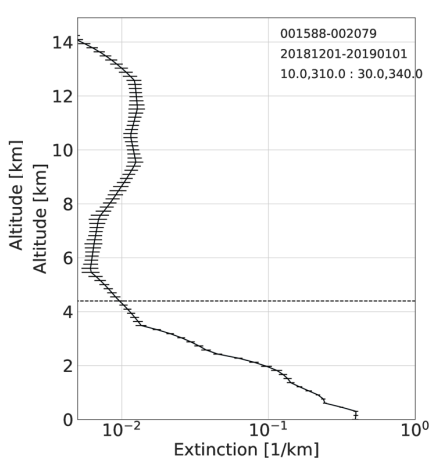
Atlantic: East of North Africa

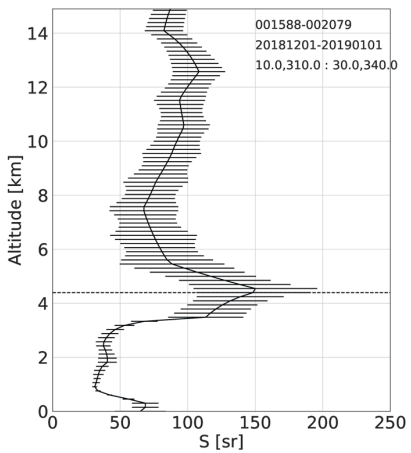
09-2018



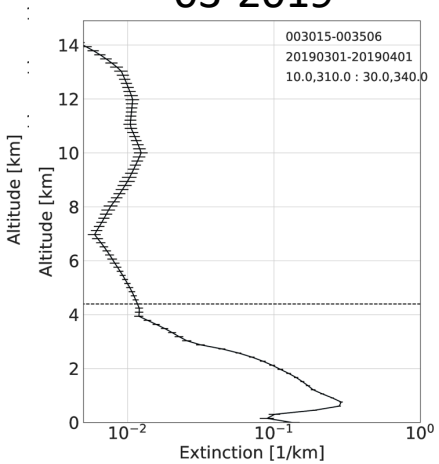


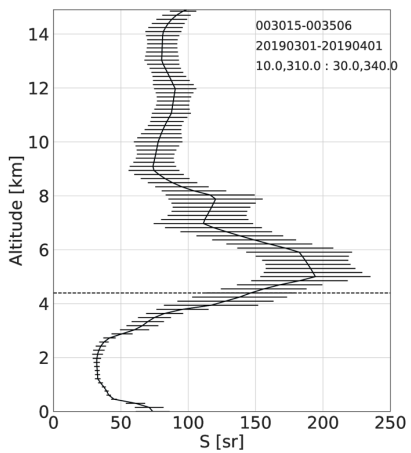
12-2018



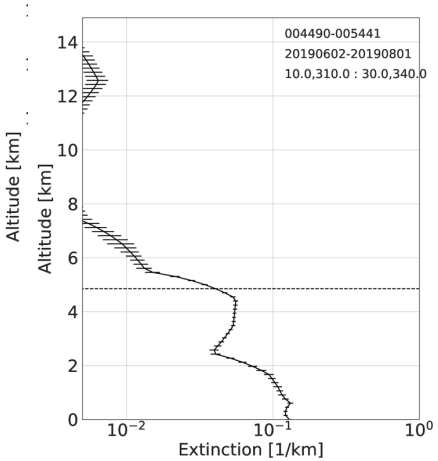


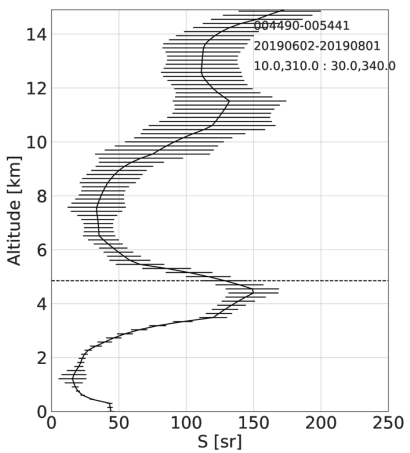
03-2019





06-2019





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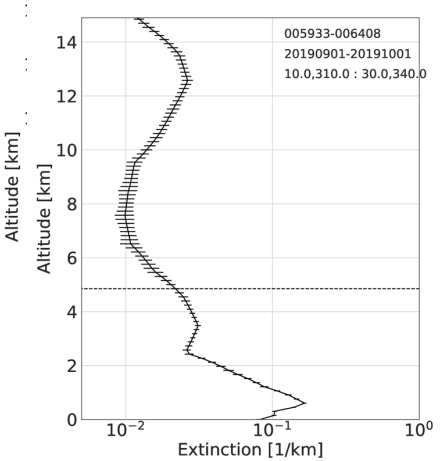

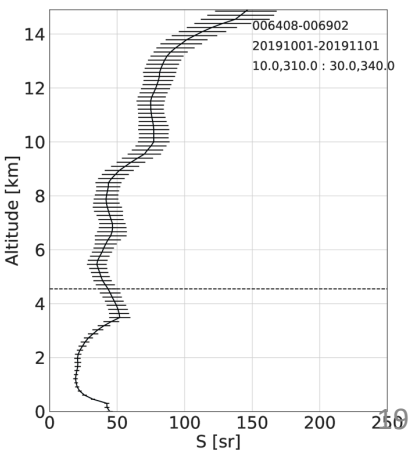

Summary and Future work-I

AEL_FM and AEL_PRO

- Data is certainly useful !
- AEL_PRO data soon to be released
  - Classification in the data is NOT reliable.
- Future Work
- Debugging Validation/Evaluation
- Better Classification product ?
  - Better cirrus-vs-aerosol discrimination.
  - Limited Aerosol typing.
- Better ATBs : Combining MSP-only Mie ATB with RSP signals ?

Summary-II

- EarthCARE (should be) much more useful for aerosols and clouds !
  - Launch target May 1st !
  - Better SNR
  - Better Resolution
  - Depol Channel ➔ Better target classification !
  - Measurements in context with Radar and Imager !
  - Provision of (best-effort) NRT data (at least L1 and (some-L2)) !
  - See AMT special issue (25+ papers) https://amt.copernicus.org/articles/special_issue1156.html
  - Sample Data: https://zenodo.org/records/7728948
- Aeolus has really helped prepare for EarthCARE !
  - Valuable example of inter-mission synergy !

https://www.esa.int/Applications/Observing_the_Earth/FutureEO/EarthCARE

Started | Most Visited | Getting Started | Mozilla Firefox | The UV-LIDAR at Cab... | Outlook | Free Content | KNMI: EARLINET | SAP Net

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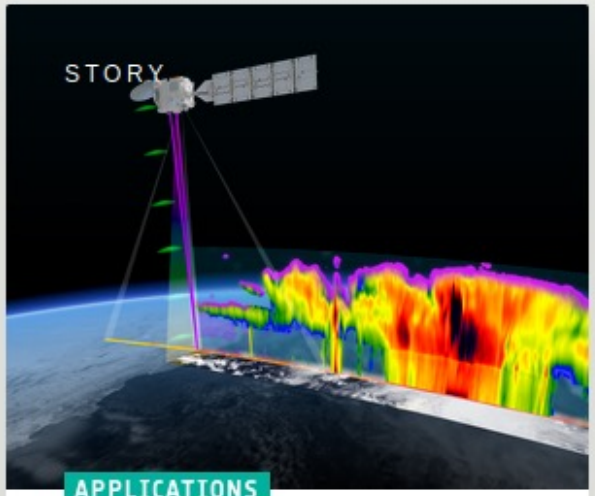
Su

Latest

- Ea



APPLICATIONS

Gearing up for EarthCARE

27/10/2023 3004 VIEWS 69 LIKES

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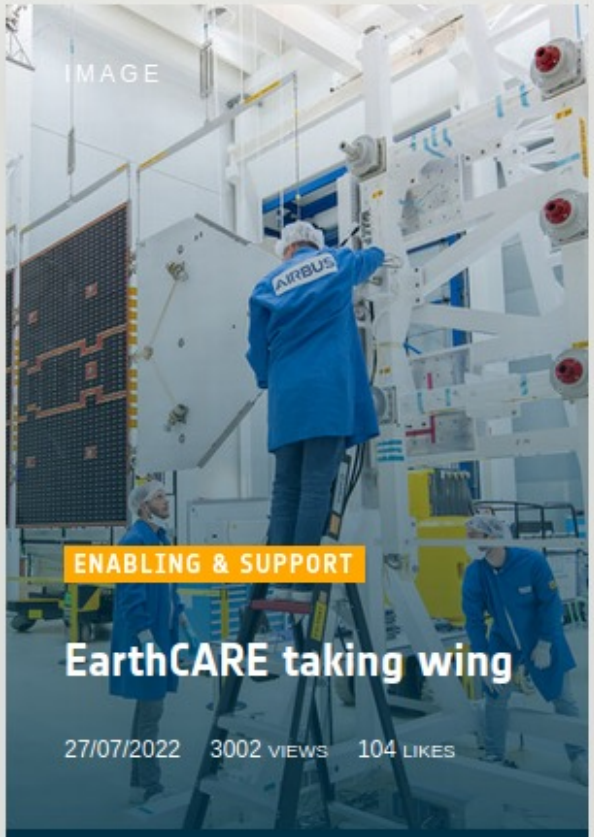
APPLICATIONS

EarthCARE science and validation workshop

13 - 17 November 2023 | ESA-ESRIN, Frascati, Italy

OPEN →



ENABLING & SUPPORT

EarthCARE taking wing

27/07/2022 3002 VIEWS 104 LIKES

VIEW →

Published March 13, 2023 | Version 10.10

Dataset | Open

EarthCARE level-2 demonstration products from simulated scenes

van Zadelhoff, Gerd-Jan[1]; Barker, Howard W.[2]; Baudrez, Edward[3]; Bley, Sebastian[4]; Clerbaux, Nicolas[3]; Cole, Jason N. S.[2]; de Kloe, Jos[1]; Docter, Nicole[5]; Domenech, Carlos[6]; Donovan, David P.[1]; Dufresne, Jean-Louis[7]; Eisinger, Michael[8]; Fischer, Juergen[5]; García-Marañón, Raquel[6]; Haarig, Moritz[4]; Hogan, Robin J.[9]; Hünerbein, Anja[4]; Kollias, Pavlos[10]; Koopman, Rob[8]; Madenach, Nils[5]; Mason, Shannon L.[9]; Preusker, Rene[5]; Puigdomènech Treserras, Bernat[11]; Qu, Zhipeng[2]; Ruiz-Saldaña, Manuel[6]; Shephard, Mark[2]; Velázquez-Blazquez, Almudena[3]; Villefranque, Najda[7]; Wandinger, Ulla[4]; Wang, Ping[1]; Wehr, Tobias[8]

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Overview

The EarthCARE satellite combines four instruments, a Cloud Profiling Radar (CPR), an Atmospheric Lidar (ATLID), a Multispectral Imager (MSI) and a Broadband Radiometer (BBR), from which many products will be generated on the properties of clouds, aerosols, precipitation and radiation. The dataset in this repository consists of test products generated from simulated 3D scenes produced by