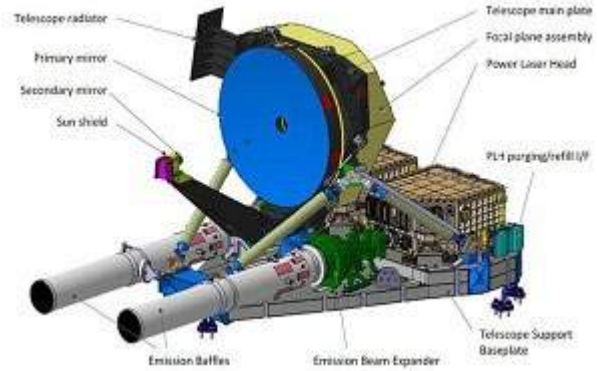
ATLID: Evolution and status of the L1 processor

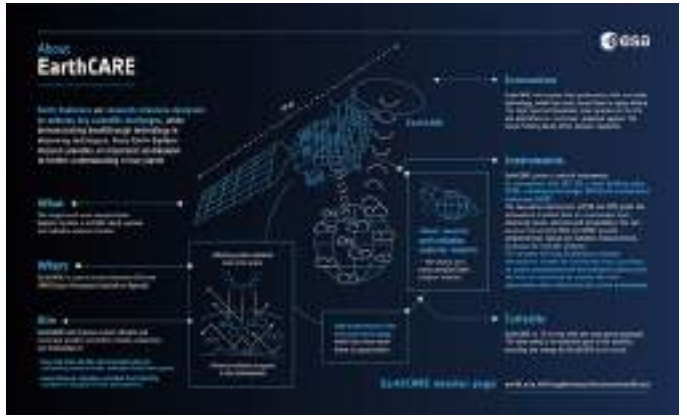


D.P. Donovan, G-J van Zadelhoff, J. De Kloe (KNMI)

M. Haarig, U. Wandinger (Tropos)

F. Marnas, A. Chantry (ESTEC)

And the much larger EarthCARE (ATLID) community !



Outline

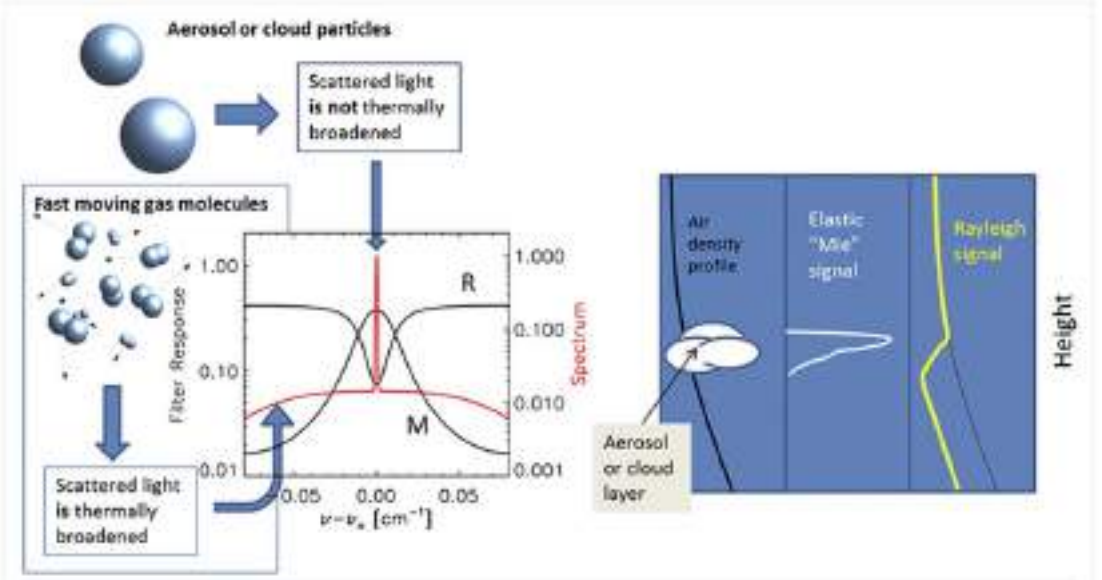
- Quick overview of ATLID
- Main issues and how they are being addressed.
- Status and Summary

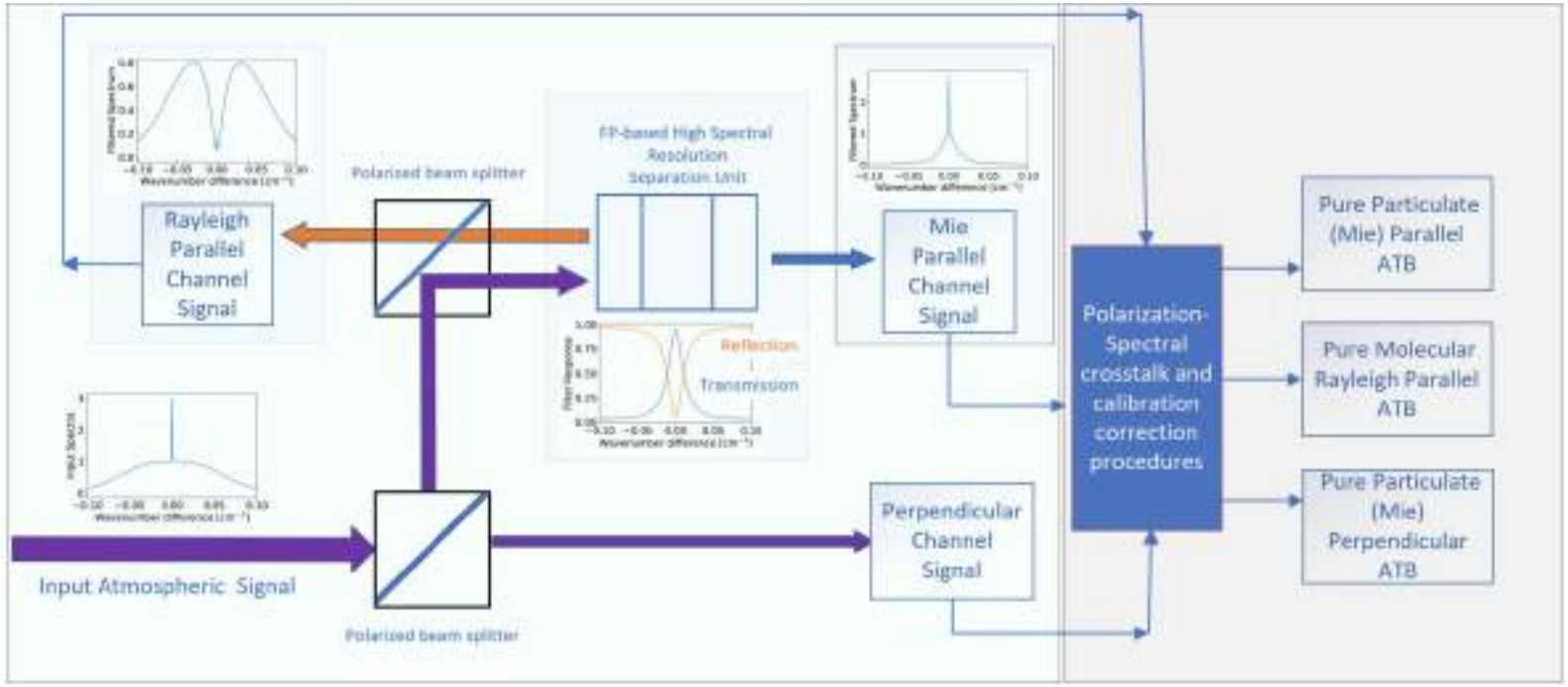
ATLID (ATmospheric LIDar)

Orbit	Routine operations
Orbit Type	Sun-synchronous
Mean Solar Local Time	14:00 (descending node)
Mean Spherical Altitude	393.14 km
Inclination	97.05°
Repeat Cycle	25 days/389 orbits
Orbital Duration	5552.7 seconds

Parameter	
Operating Wavelength	354.8 nm
Emitted Energy	38 mJ
Receiver Footprint Diameter	≤ 30 m
PRF	51 Hz
Transmit Pulse Width	20 ns
Altitude Range	-0.5 to +40 km
Vertical Sampling Interval	103 m (up to 20.2 km) 500 m (20.2 km - 40 km)
Along Track Sampling Interval	285 m (2 shots accumulated onboard)
Channels	HSRL particulate HSRL Molecular Depolarization channel

ATLID (ATmospheric LIDar)
UV HSRL with Linear Depolarization channel





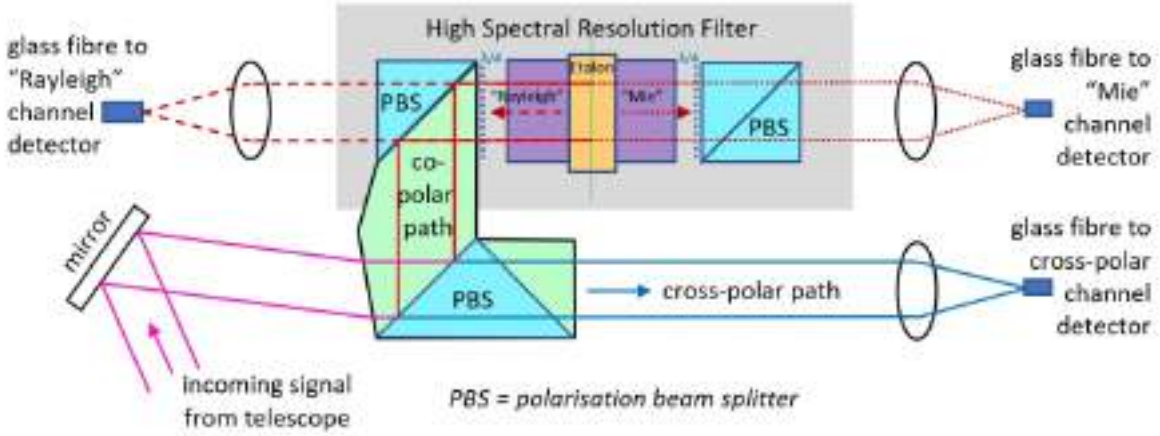
HSRL

⇒ Good daylight performance
⇒ More accurate retrievals
⇒ Extinction + Backscatter are retrieved.
⇒ More info. content.

ATLID transfer function

$$\begin{pmatrix} N_{Ray} \\ N_{Mie} \\ N_{Cro} \end{pmatrix} = \begin{pmatrix} C_{1,1} & 0 & 0 \\ 0 & C_{2,2} & 0 \\ 0 & 0 & C_{3,3} \end{pmatrix} \begin{pmatrix} B_{Ray} \\ B_{Mie,\parallel} \\ B_{Mie,\perp} \end{pmatrix}$$

This would be the idea case !



$$\begin{pmatrix} N_{Ray} \\ N_{Mie} \\ N_{Cro} \end{pmatrix} = \begin{pmatrix} C_{1,1} & C_{1,2} & C_{1,3} \\ C_{2,1} & C_{2,2} & C_{2,3} \\ C_{3,1} & C_{3,2} & C_{3,3} \end{pmatrix} \begin{pmatrix} B_{Ray} \\ B_{Mie,\parallel} \\ B_{Mie,\perp} \end{pmatrix}$$

But it is more like this !

Of Particular important are:

(Ray➔Mie x-talk)

$$\grave{o} = \frac{R_{Ray} T^{\parallel}_{Ray} (1 - T_p^{HSR})}{R_{Mie} T^{\parallel}_{Mie} T_p^{HSR}}$$

$$\psi^{\parallel} = \frac{T^{\perp}_{Mie} T_p^{HSR} R_{Mie}}{T^{\perp}_{Cro} R_{Cro}}$$

(Mie➔Ray x-talk)

$$\chi = \frac{R_{Mie} T^{\parallel}_{Mie} (1 - \tau_{Ray})}{R_{Ray} T^{\parallel}_{Ray} \tau_{Ray}}$$

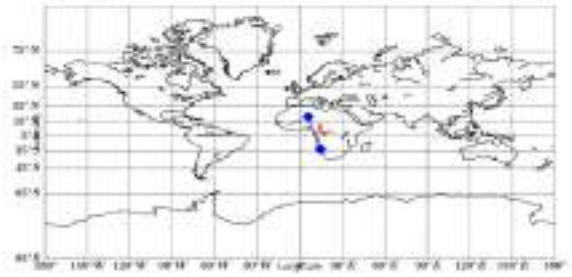
$$\psi^{\perp} = \frac{T^{\parallel}_{Cro} R_{Cro}}{T^{\parallel}_{Mie} R_{Mie} T_p^{HSR}}$$

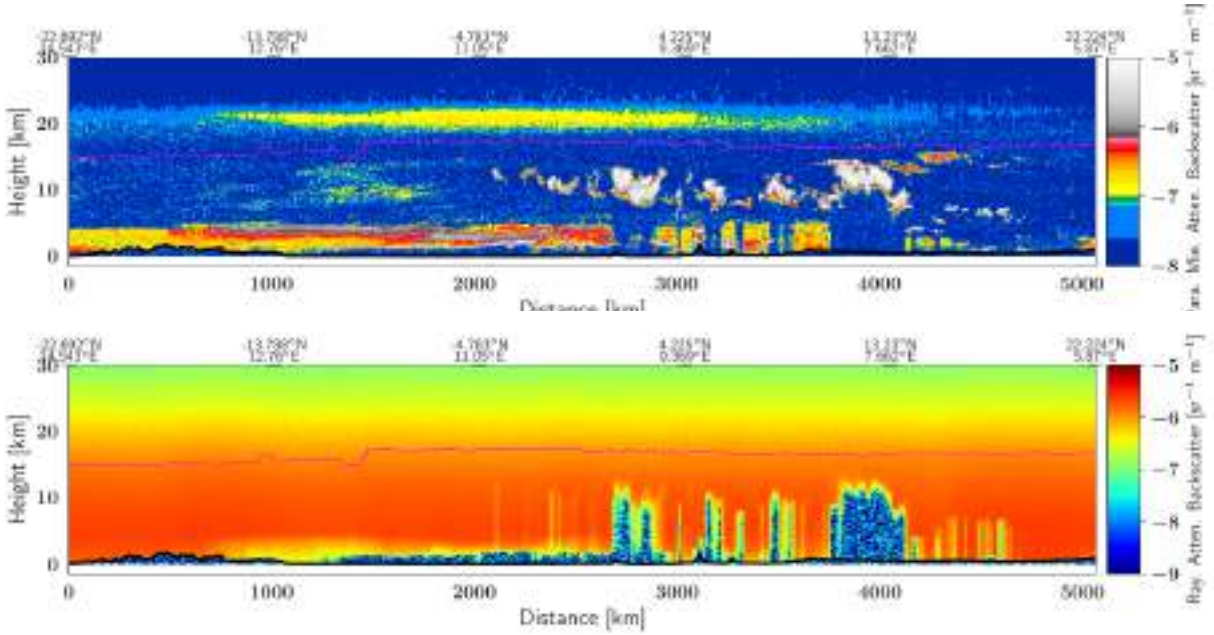
Characterization/monitoring depends heavily on using Mie-free returns (mainly above 25-30 km)

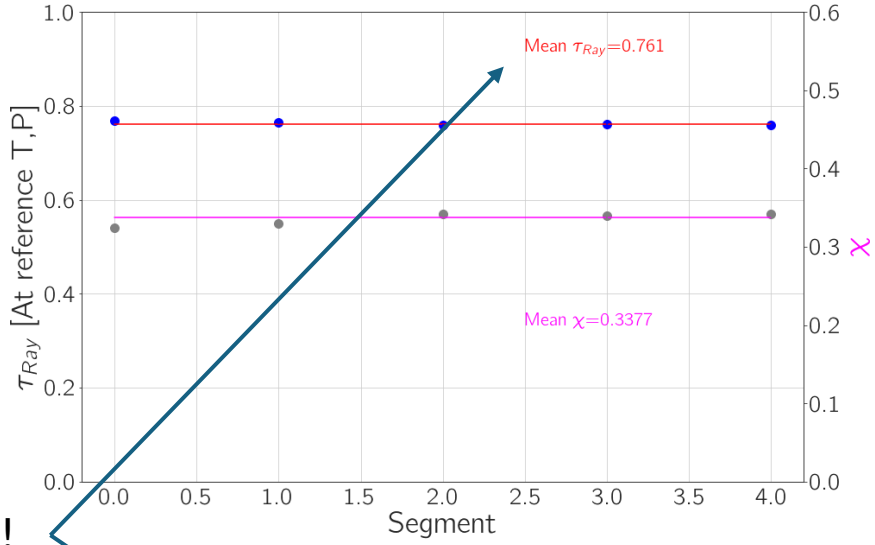
Ray➔ Mie x-talk

- Land surface returns
- Clouds (but in a novel manner)

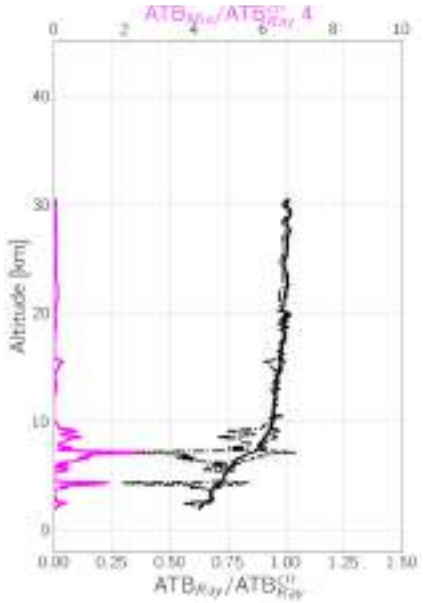
Cross-talk update 01542A: Sept 09

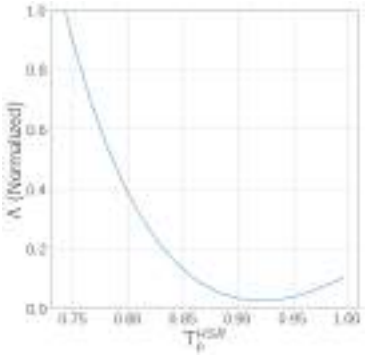


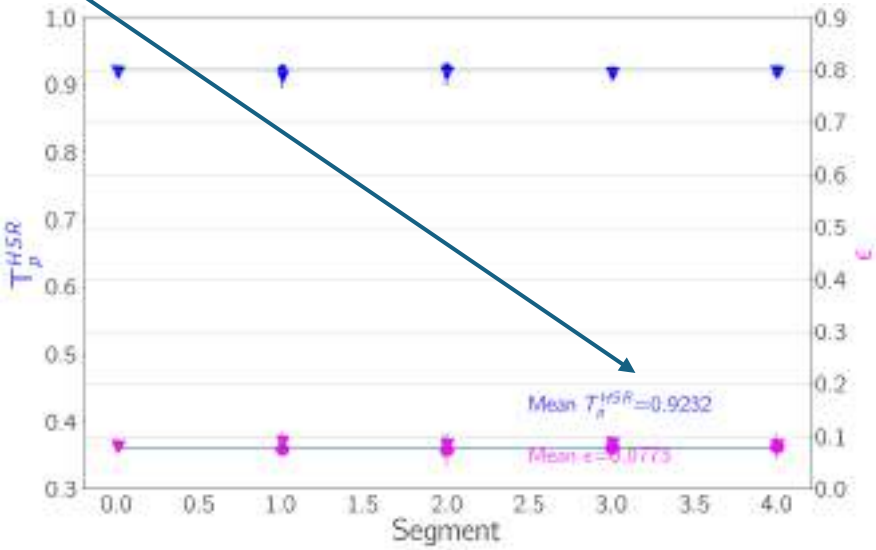




Very close to expected values !



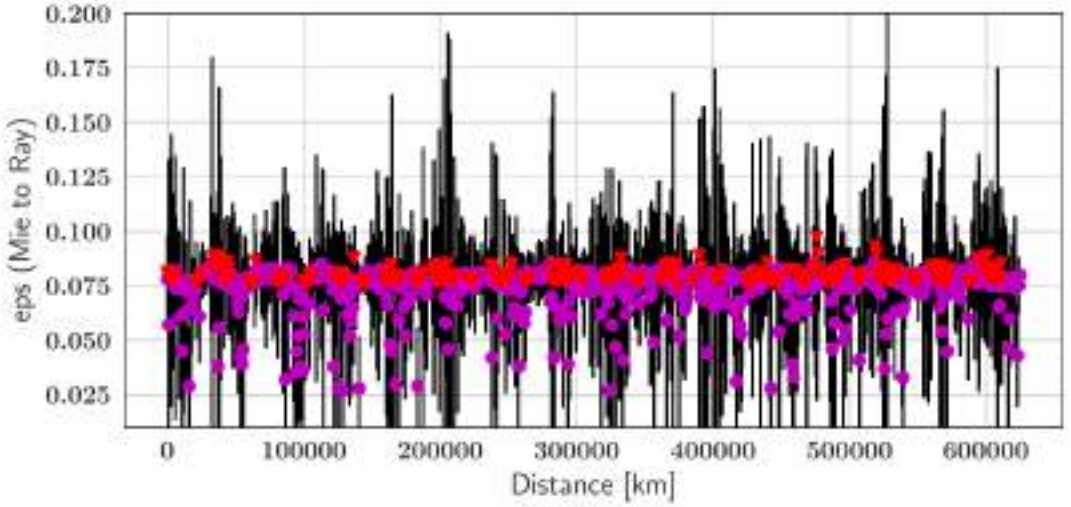




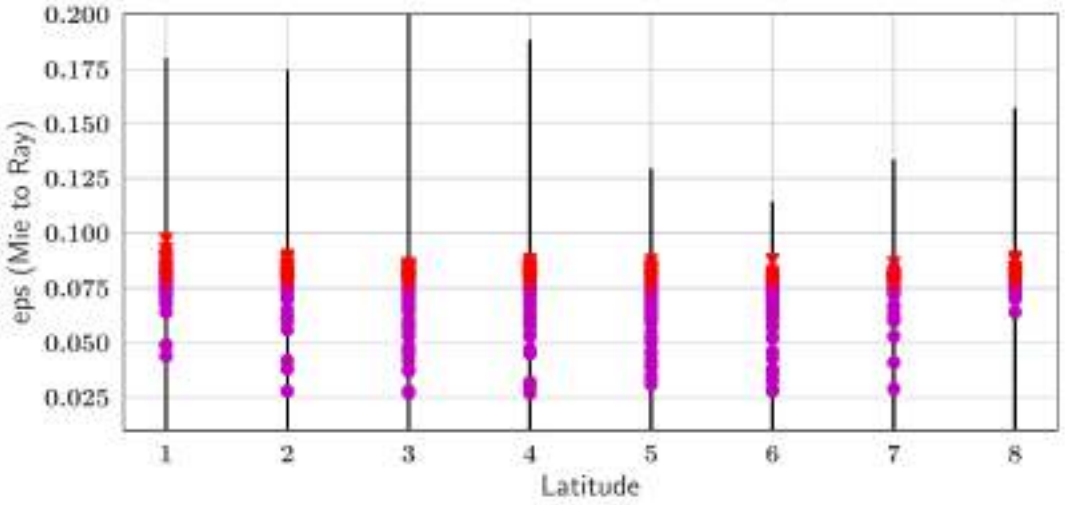
Cross-talk coefficient monitoring example

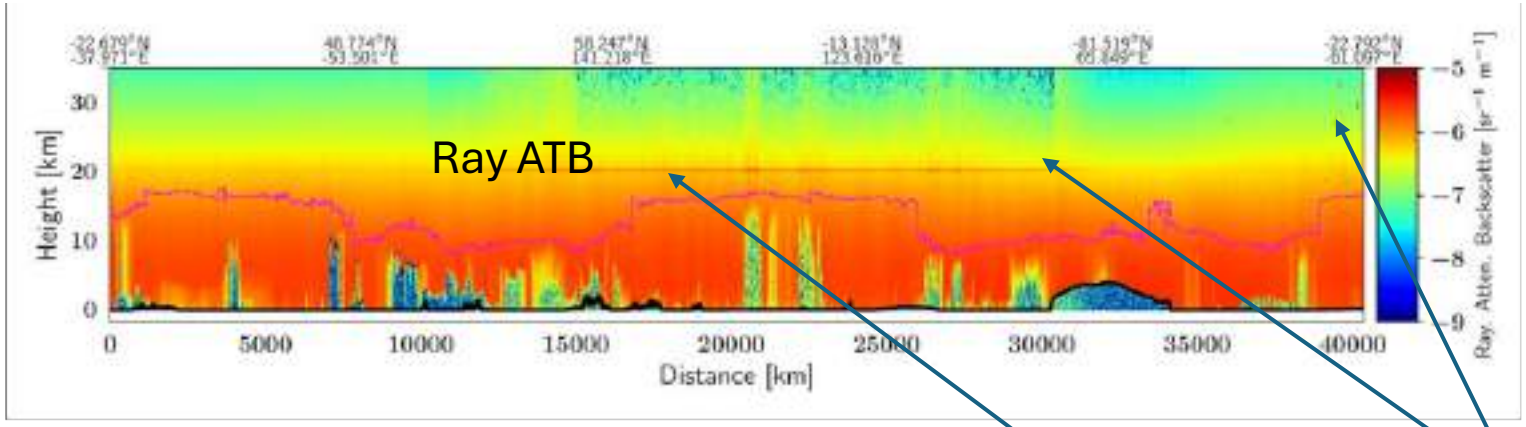
Eps: Mie ➔ Ray

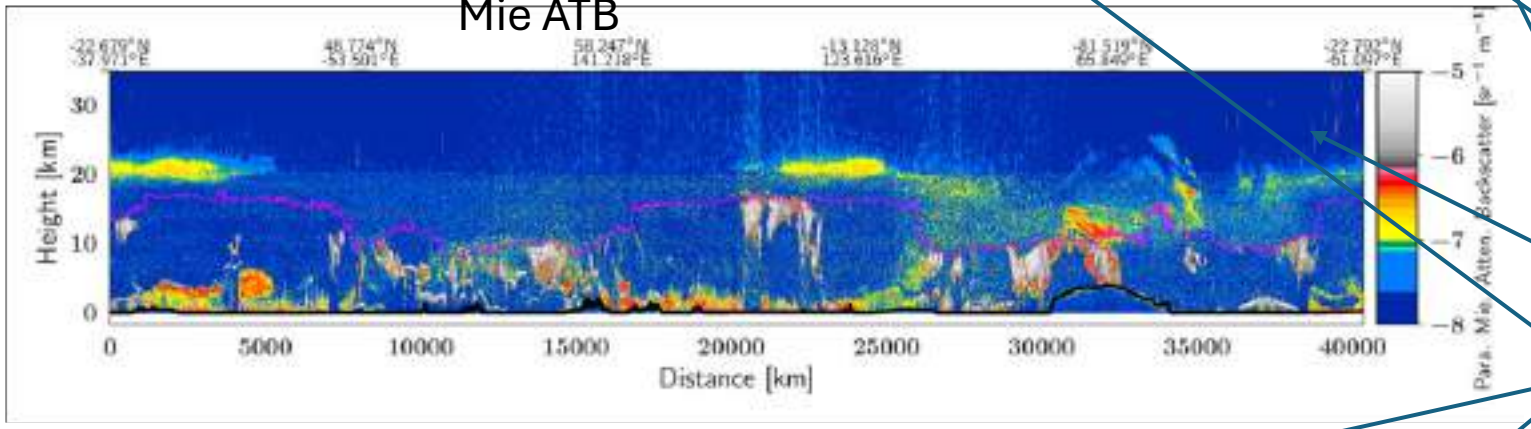
Jan 15

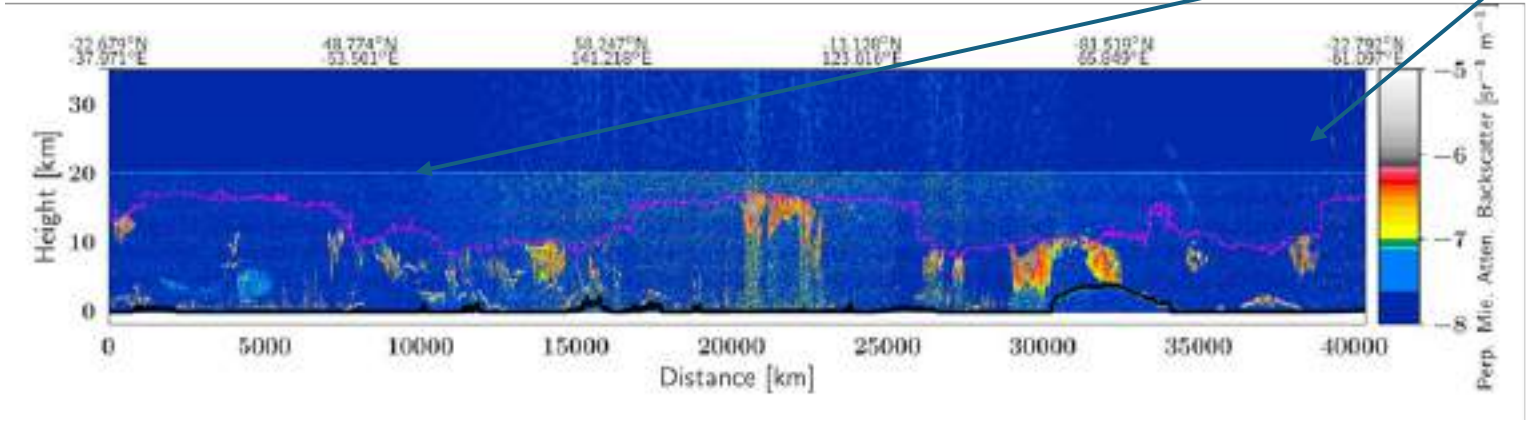


Jan 15









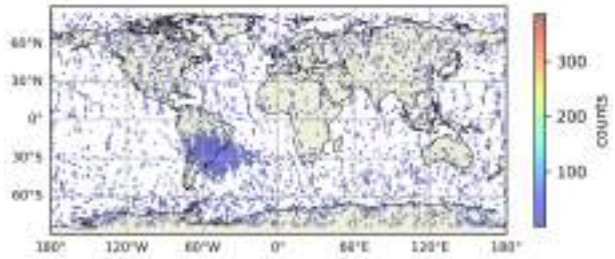
Sample output from the operational processor for one orbit.

Aug 14 Example.

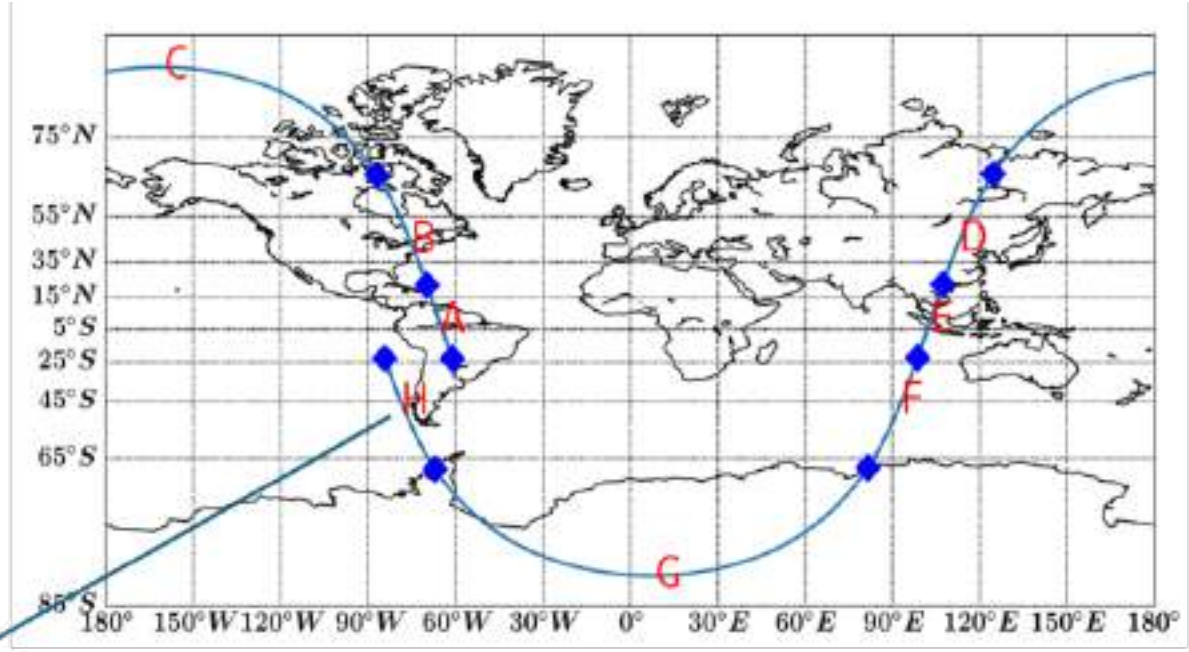
1. **Discontinuities due to faulty background removal.**
2. **Radiation speckle noise**
3. **Hot Pixels**
4. **20km feature in the Ray and Mie**
5. **Cold Pixel**
6. **Jumps between HR and LR**
7. **Offset Bug**
8. **Depolarization issues**

Main Problems encountered and solutions/mitigation.

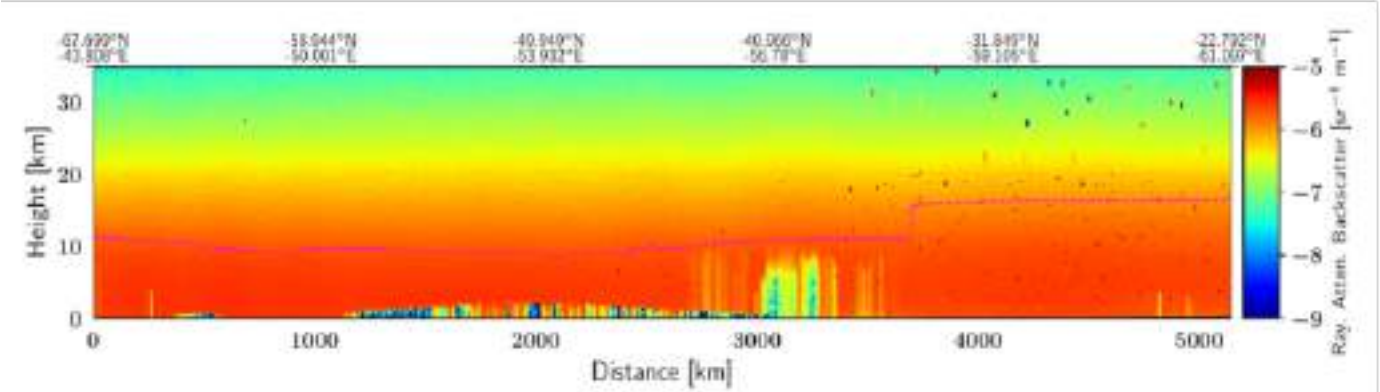
- Hot pixels
  - Frequent dark count measurements + software detection/correction for between periods.
- Radiation noise spikes
  - Software filtering
- Bugs in L1 processor
  - E.g. Detection chain DC offset removal
- Background removal and `20km features'
  - Effective, but Ad-Hoc fixes implemented but
    - Likely same root cause (non-ideal charge transfer in the CCD array) and a more fundamental fix is being investigated.
- Depol ratio was too low, but cause has been identified and should be fixed(improved) now?
  - Inconstancies in parameter definitions and implementation within the L1 processor.



Radiation Noise



Rate is about 20- 30 per 1e+5 profiles per day.



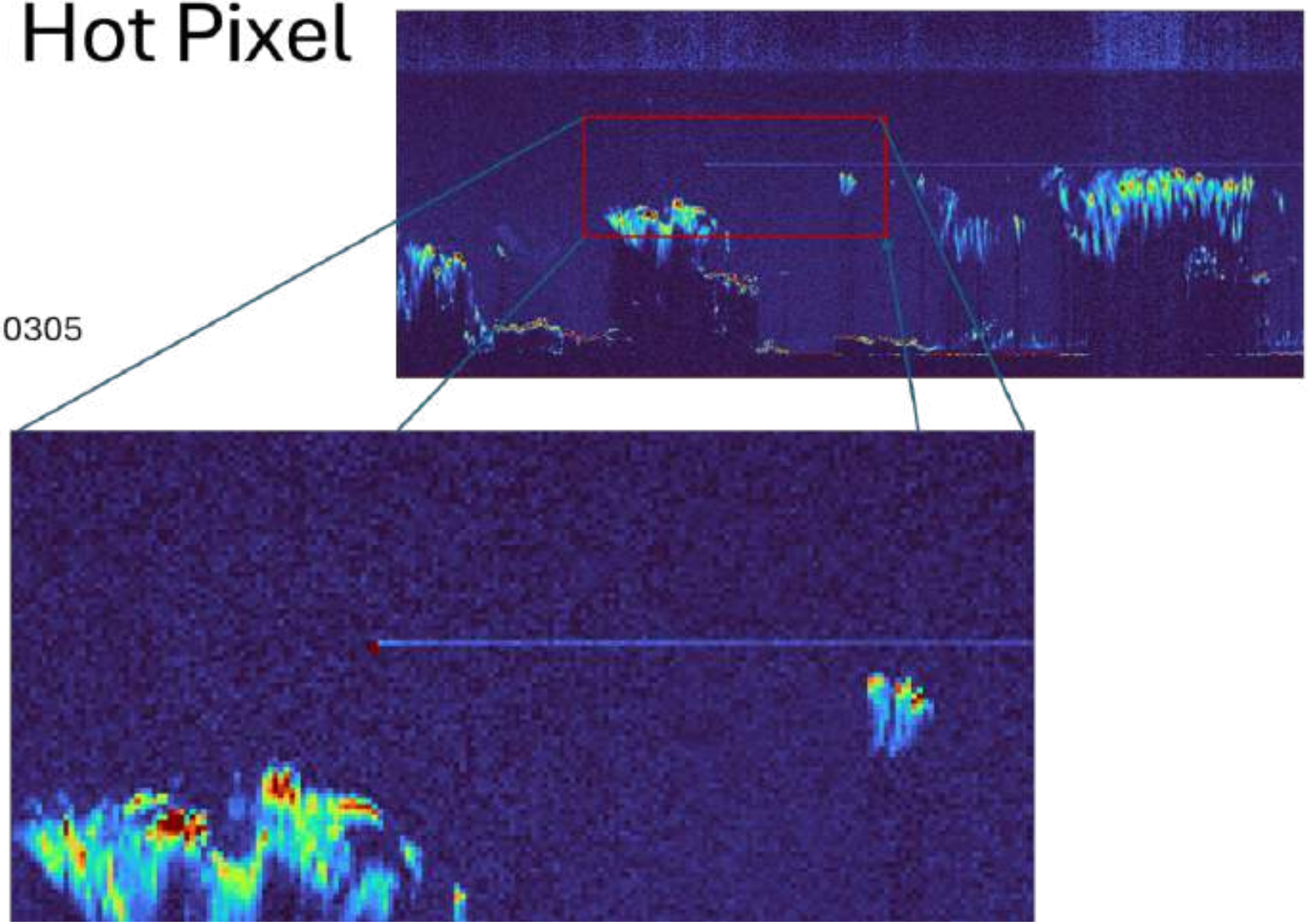
Can be detected by

1) Finding the e.g. 99 percentile level
2) Flagging pixels e.g. 10x higher than this level
3) Checking for false positives by comparing to other channels

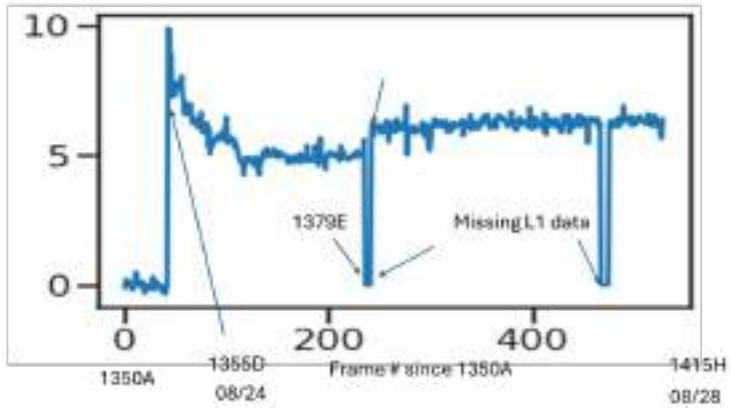
Birth of a Hot Pixel

Cross-Polar Channel

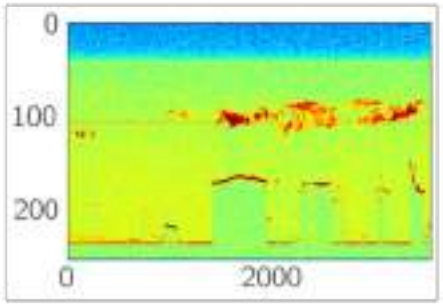
Frame 1355D 08/24 : 0305



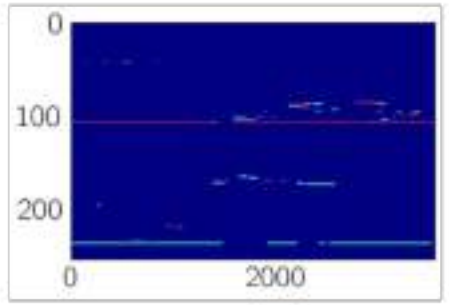
Estimated offset in Background in Cro Normalized Signals



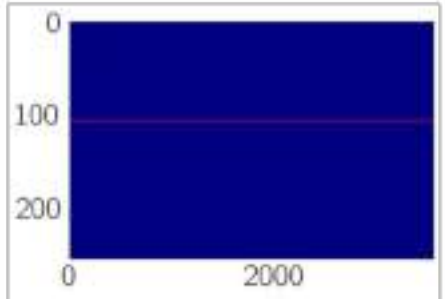
HP detection



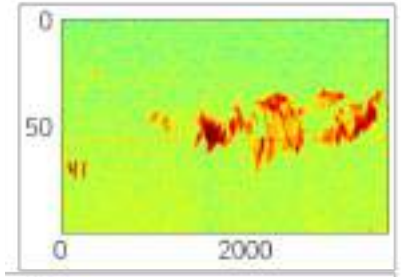
Per Frame Segment:
Apply (very) simple line finding algorithm based on the horizontal continuity of
2*S(iz)-S(iz-1)-S(iz+1)

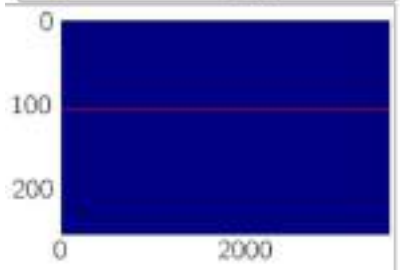


Remove the surface and filter any lines that do not span at least e.g. 80% of the interval

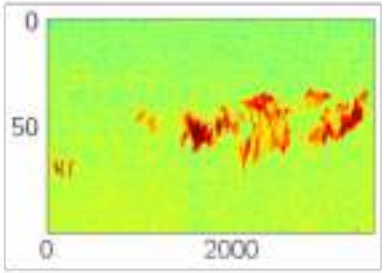


HP replacement





Estimate offset using Pixels adjacent in height and subtract

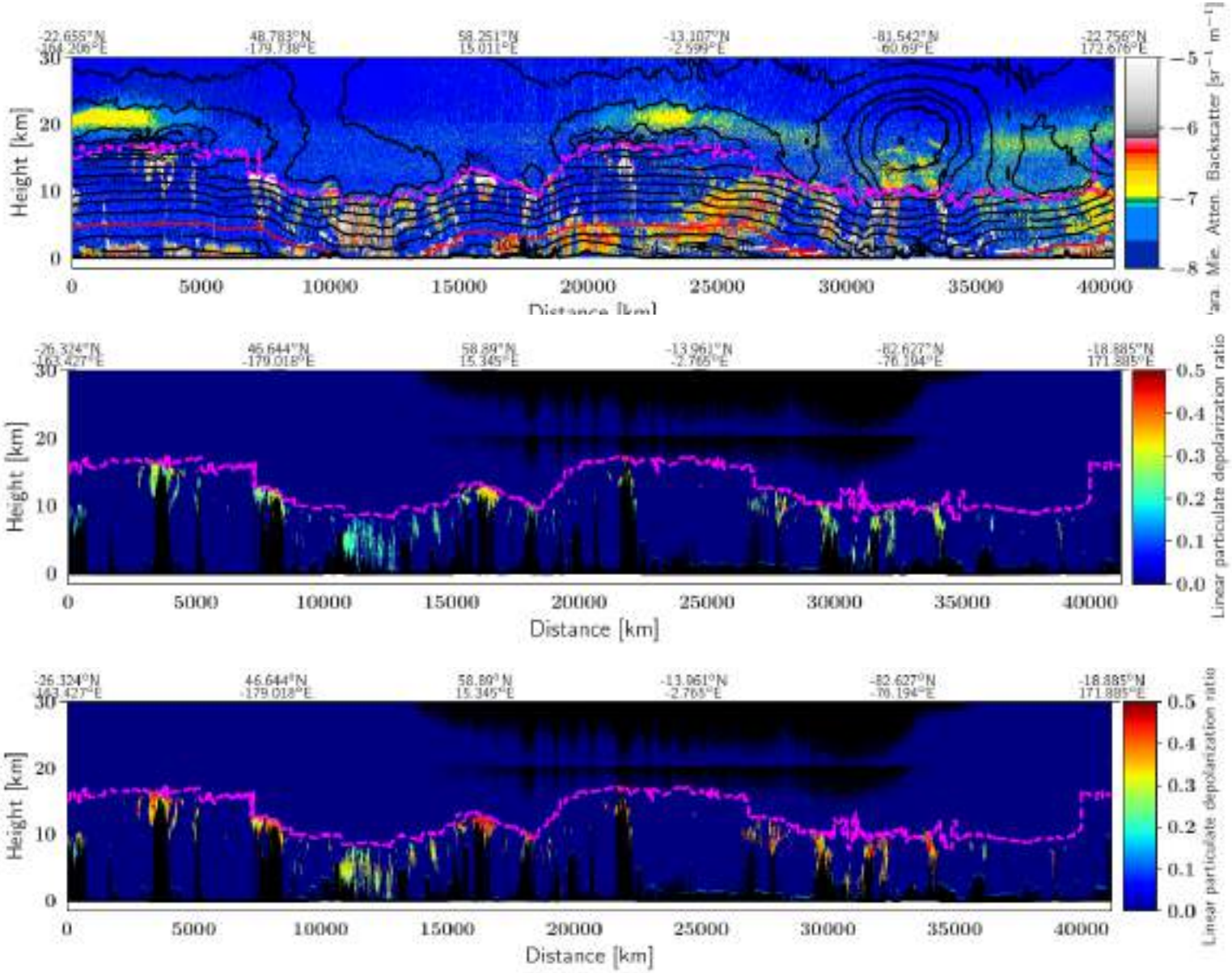


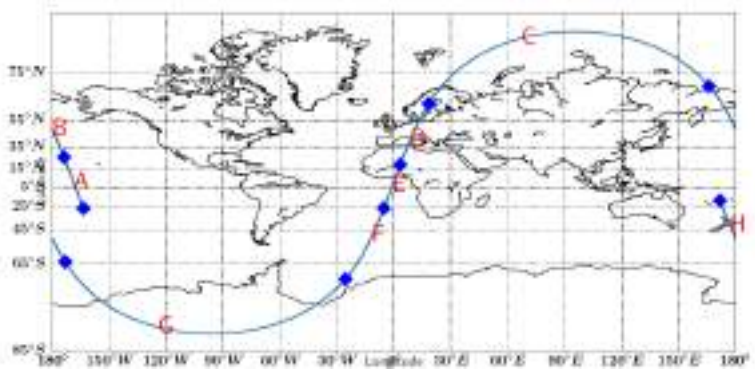
Add to output detection mask and deduced offsets !

A detection and correction algorithm has been developed and is being deployed.

Does not replace dark count map acquisitions but helps improve data quality between the map acquisitions and contributes to the overall HP tracking.

Depolarization Ratio: Example Orbit (01752)





Before

After

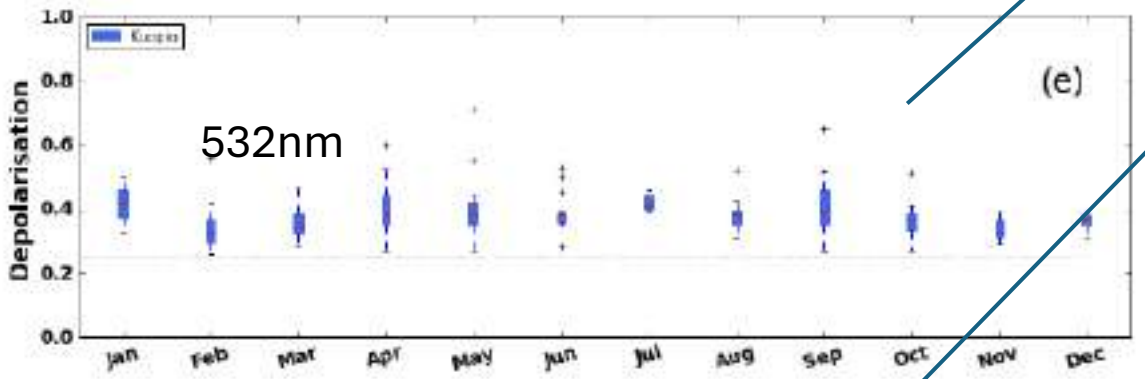
Could only be really investigated in depth after the background and offset issues were sorted out.

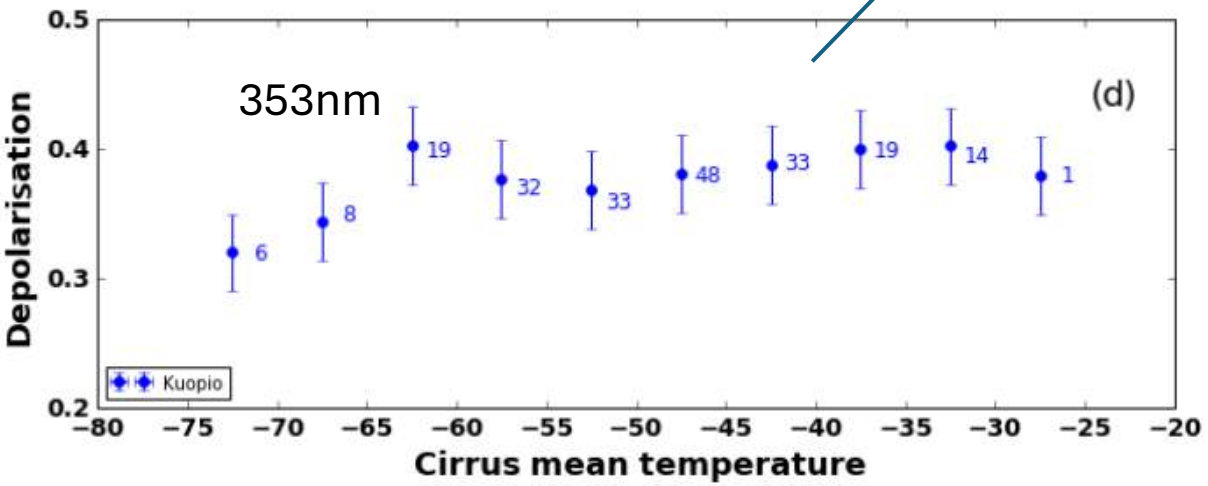
- Recently a lot of progress has been made though.
  - Most recently inconsistencies between the calibration database definitions of a few relevant factors and the definitions used in the processor were identified.

Comparison with results in

Variability in cirrus cloud properties using a Polly^{XT} Raman lidar over high and tropical latitudes

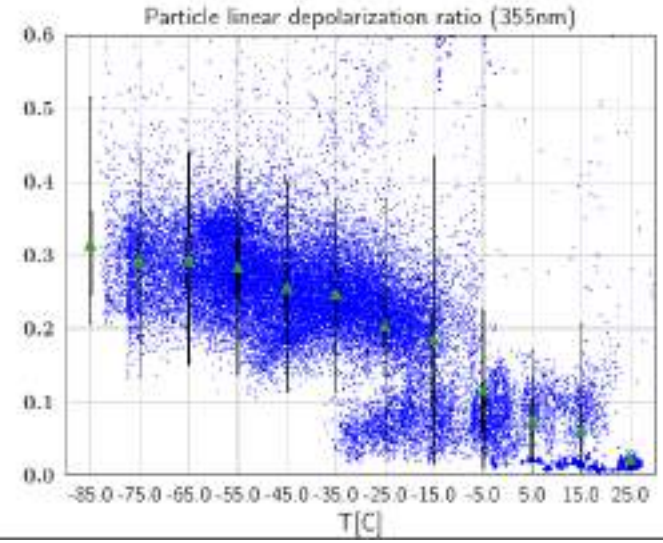
Kalliopi Artemis Voudouri[1], Elina Giannakaki[2,3], Mika Komppula[3], and Dimitris Balis[1]



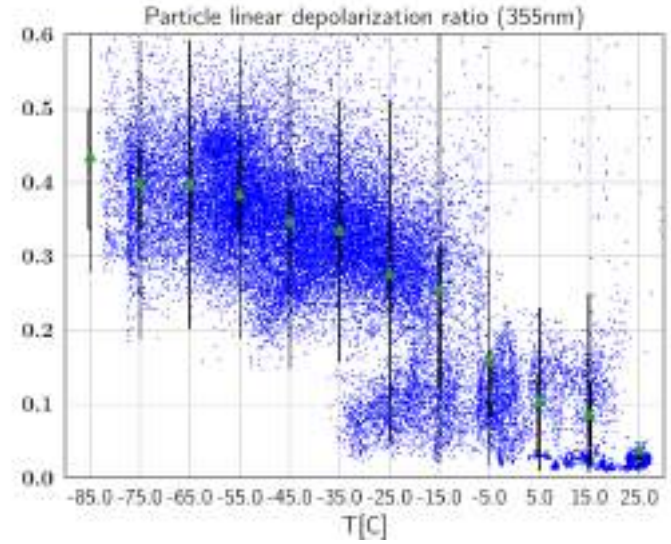


Cirrus properties	Gwal Pahari
N	11 (7 d, 4 n)
% subvisible	0
% thin	20
% opaque	80
LR 355	27 ± 12 23 ± 8 d 31 ± 15 n
LR 532	28 ± 22 23 ± 3 d 33 ± 11 n
COD 355	0.60 ± 0.25 0.40 ± 0.30 d 0.80 ± 0.20 n
COD 532	0.45 ± 0.30 0.30 ± 0.40 d 0.60 ± 0.20 n
CR (355/532)	1.50 ± 0.80

Before



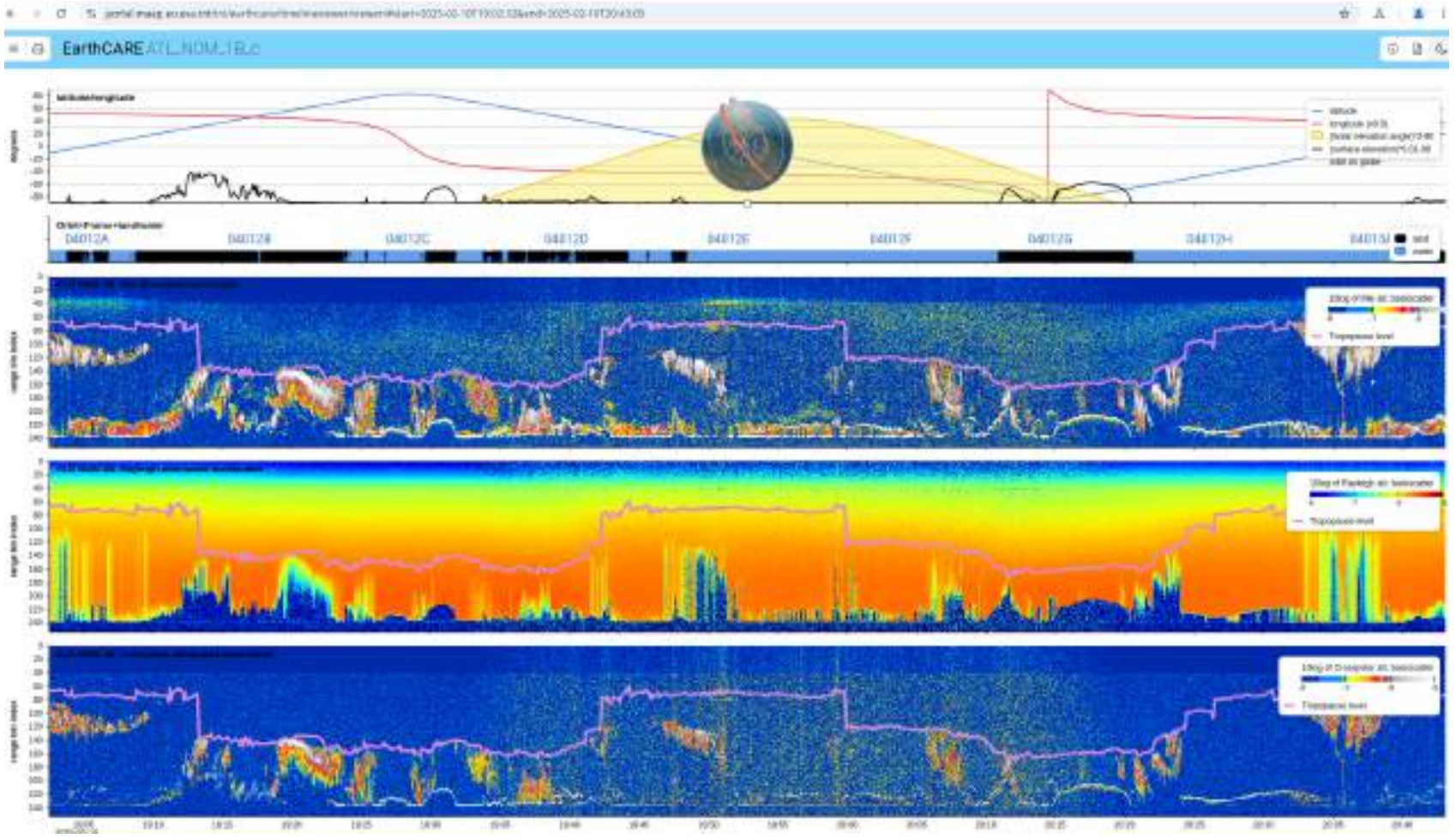
Now



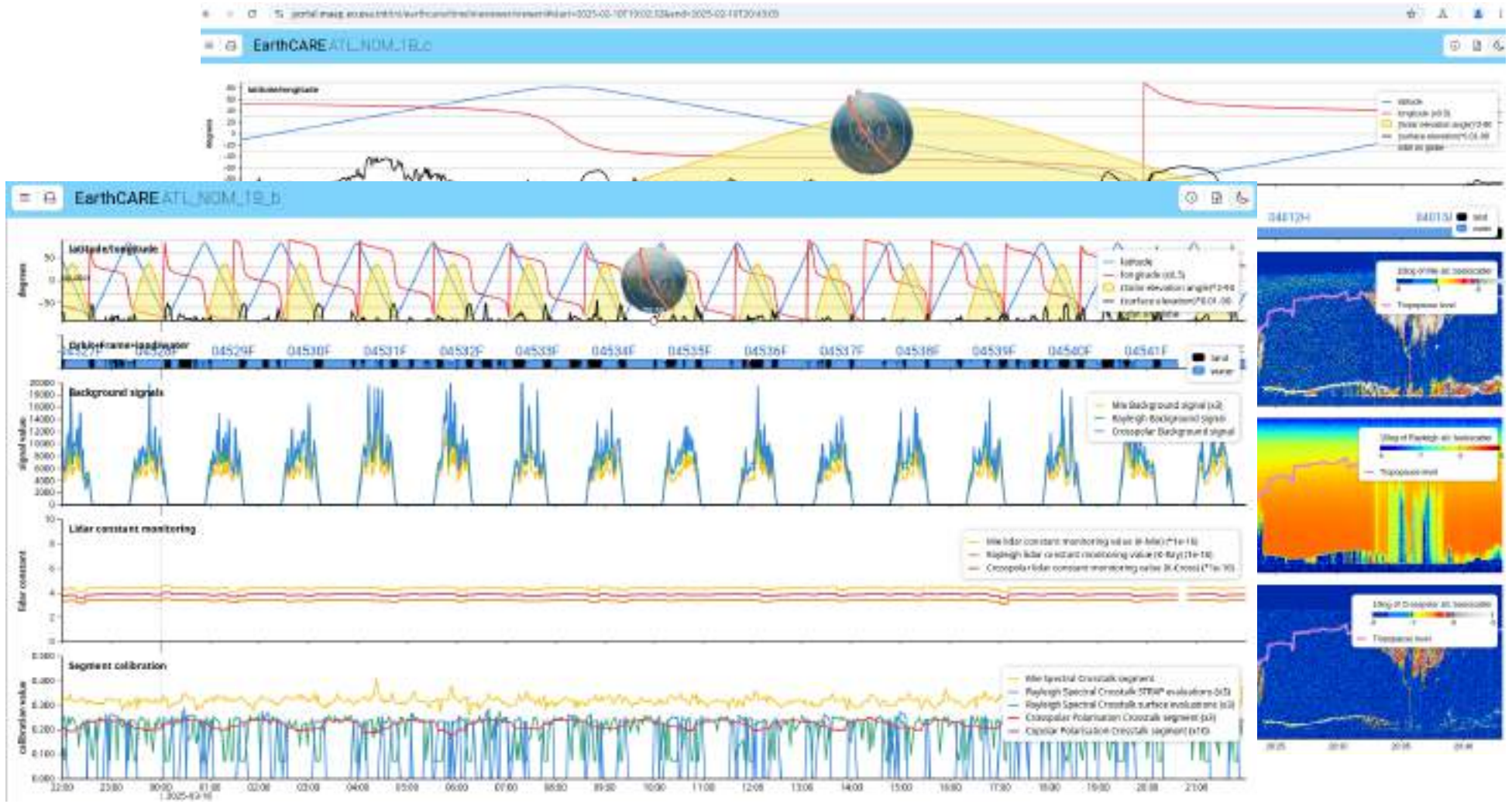
Summary

- L1 data is of good quality !
  - In the first public release
    - Offset fix has been implemented.
    - Background fix has been implemented.
    - Spurious (protonic) noise spikes filtering.
    - Update of the transmission factors.
- Since the first public release:
  - 20km spike correction.
  - Missed Hot / Cold Pixel correction / filtering
  - Update of the detector sensitivity values ➔ better depol.
  - Beter calibration (filtering of altitudes where PSCs may be present).
  - Beter energy normalization.
  - Etc..

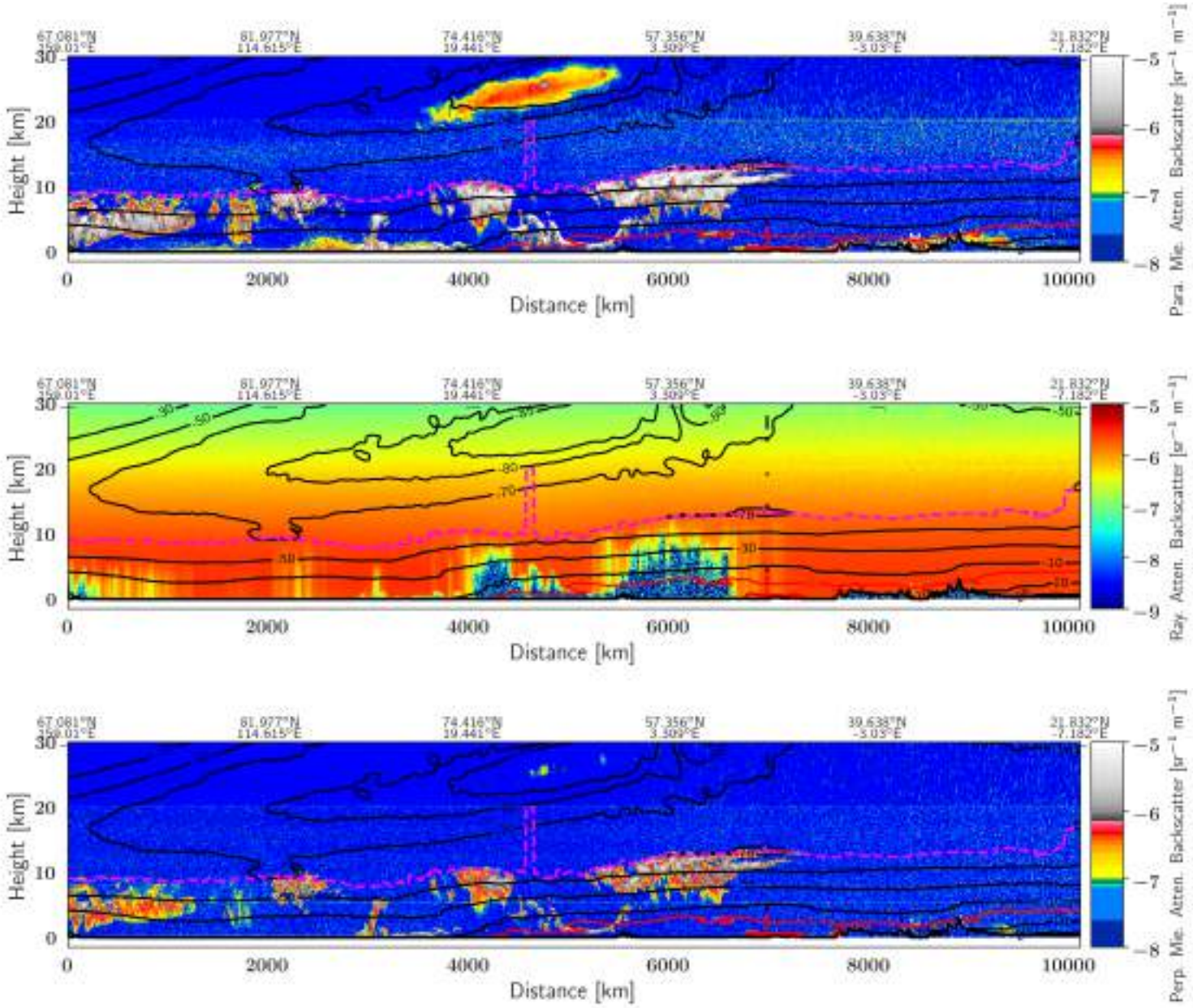
https://portal.maap.eo.esa.int/ini/earthcare/timelineviewer/viewer/.

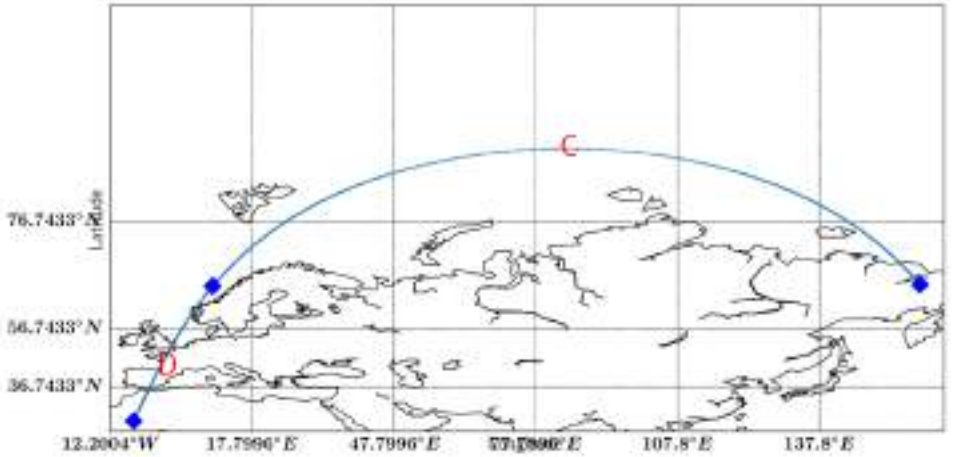


https://portal.maap.eo.esa.int/ini/earthcare/timelineviewer/viewer/.



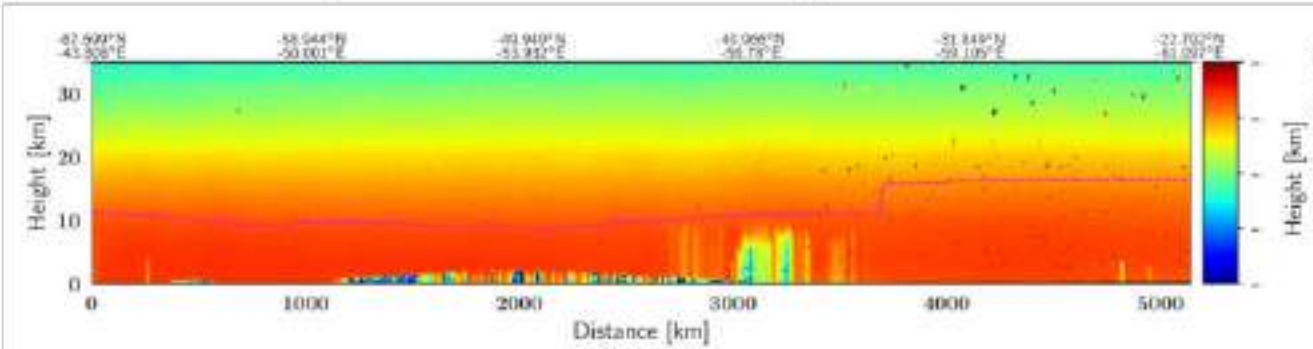
And to finish…… a nice PSC over Europe CASE !

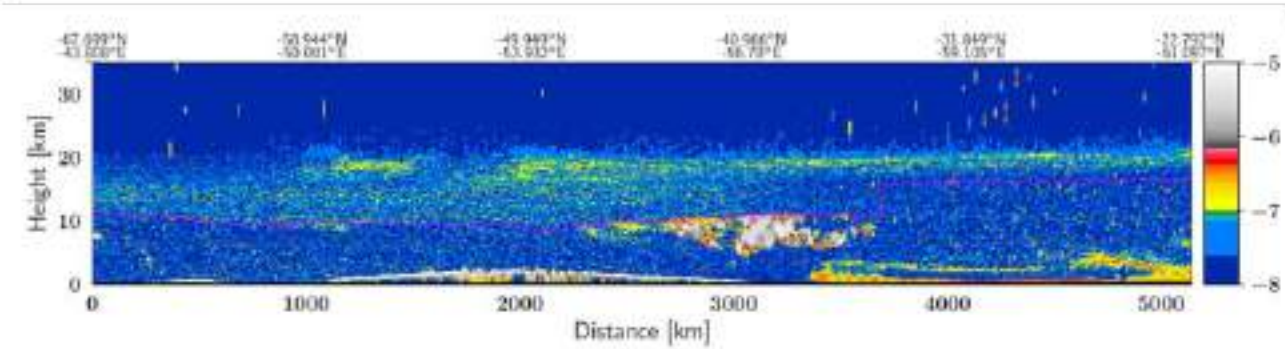


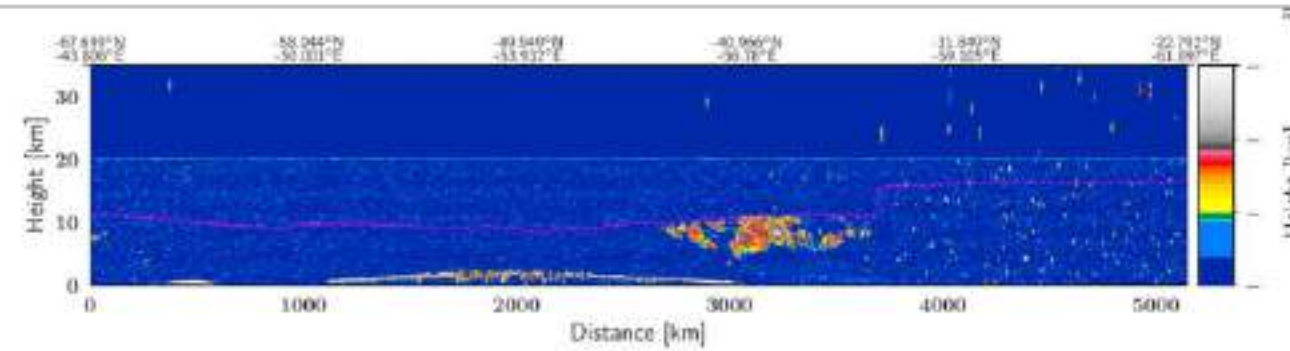


Orbit 01202 Frame H

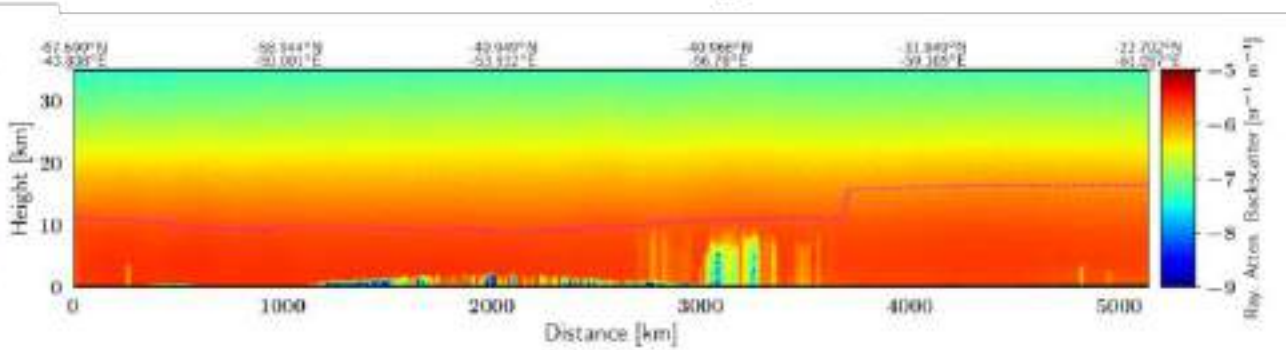
Operational Processor Aug 14 2024

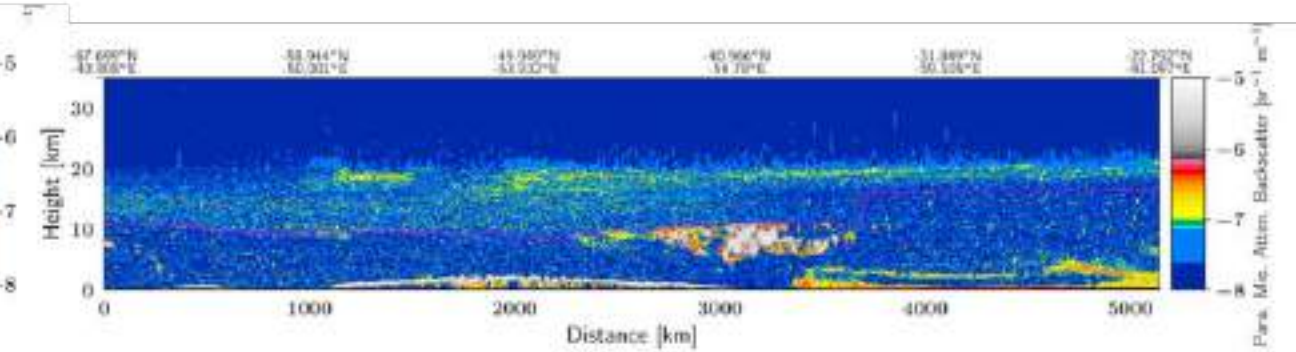


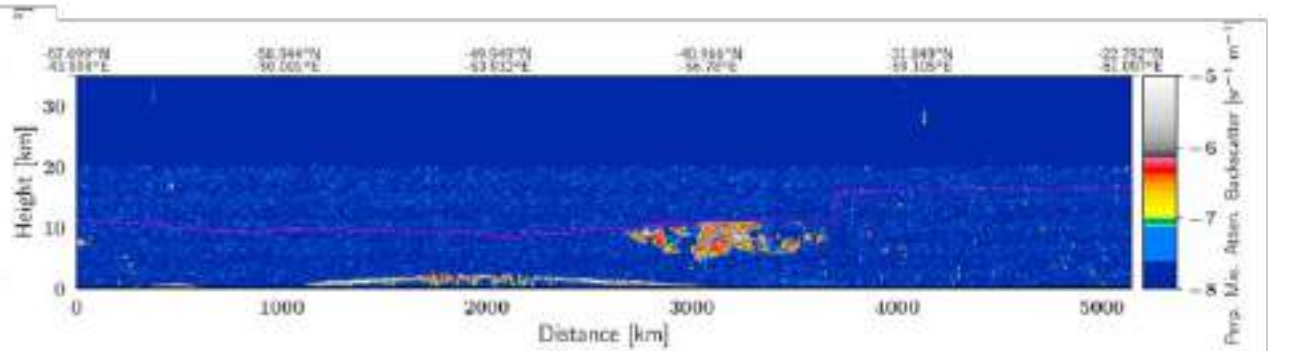




KNMI Post-Processor Aug 26 2024

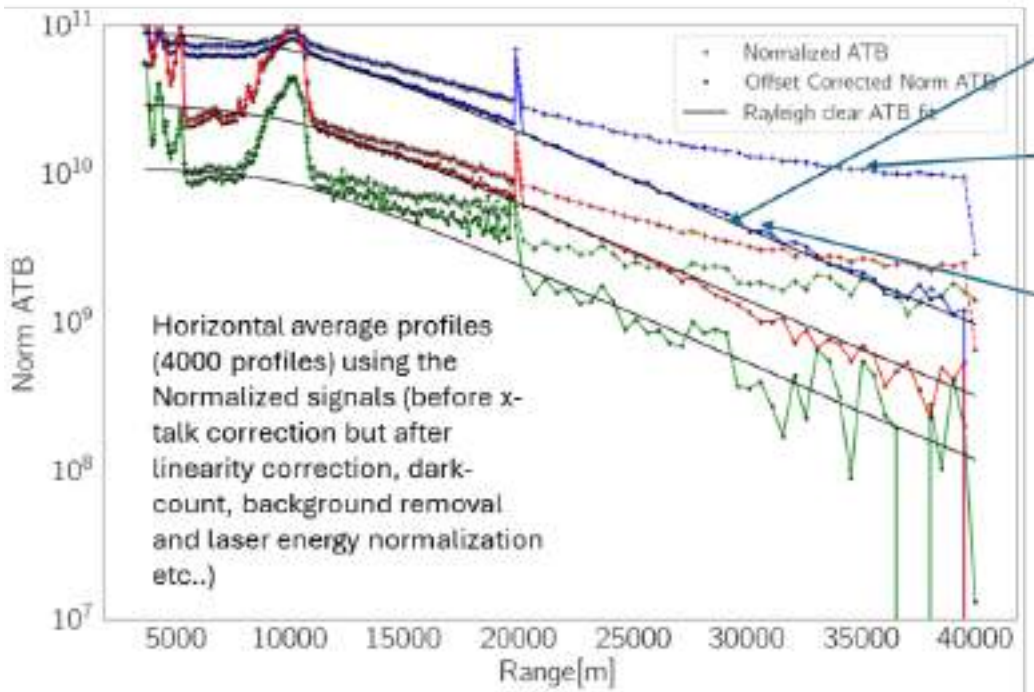






Background Removal was not working well enough: Relationship between signal acquired in the background sections of the detection CCD and the signal sections of the CCD were not accurate enough !

High background case: 01055D



Solid Lines are fits to the expected Rayleigh Clear Signal.

Using Normalized signals without an offset adjustment fits very badly !

Allowing for an offset (i.e. allowing for a small error in the background removal) results in very much better fits !

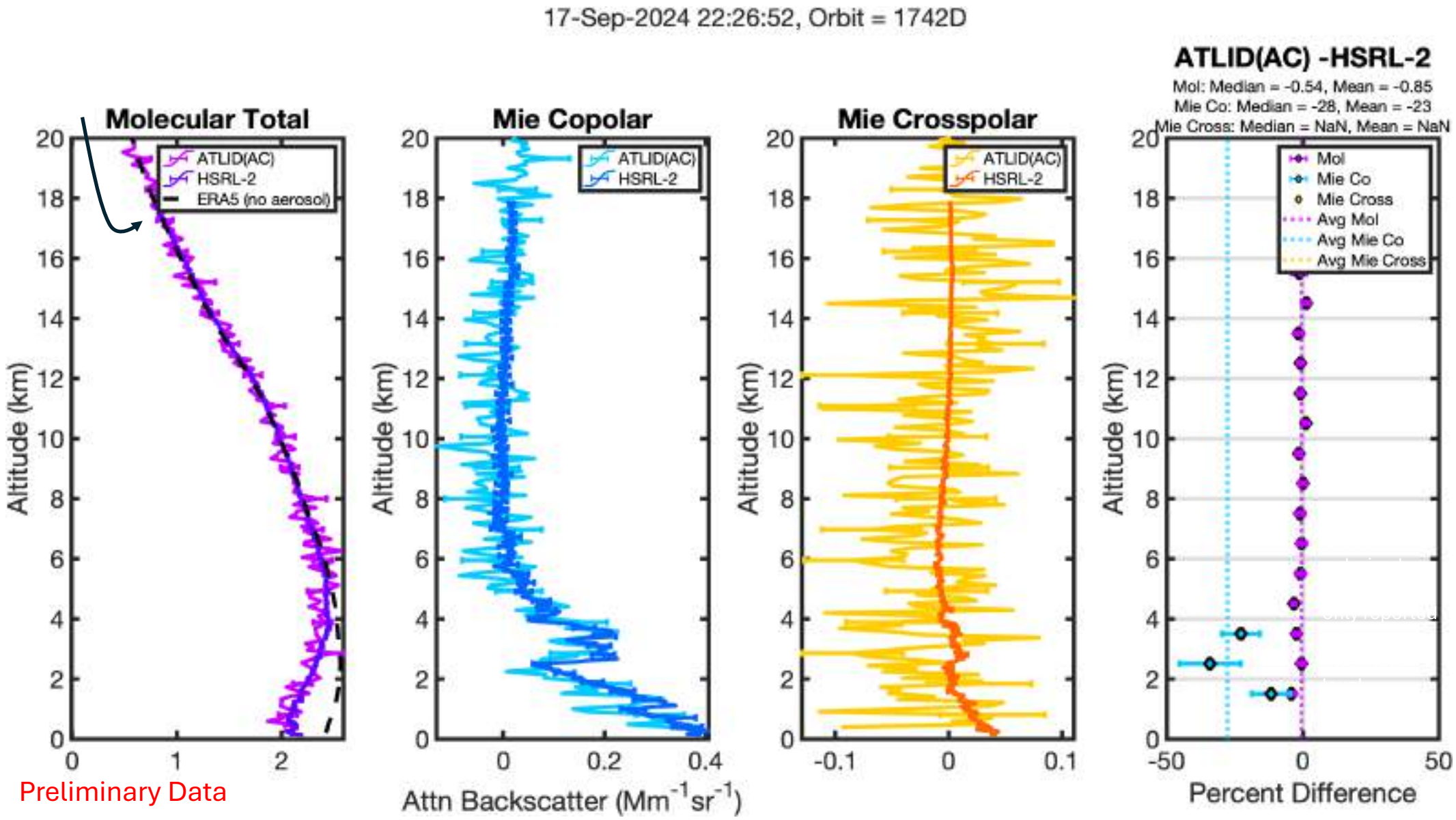
This explains why the calibration is off in daylight and other effects (but does not explain the 20km spike features).

Shape of signal is all wrong. Extinction and backscatter derived using such signals will be way off !

9.3.1 ECVT airborne campaigns overview

Level 1 Signals: Attenuated Molecular, Mie, Cross

Courtesy J. Hair

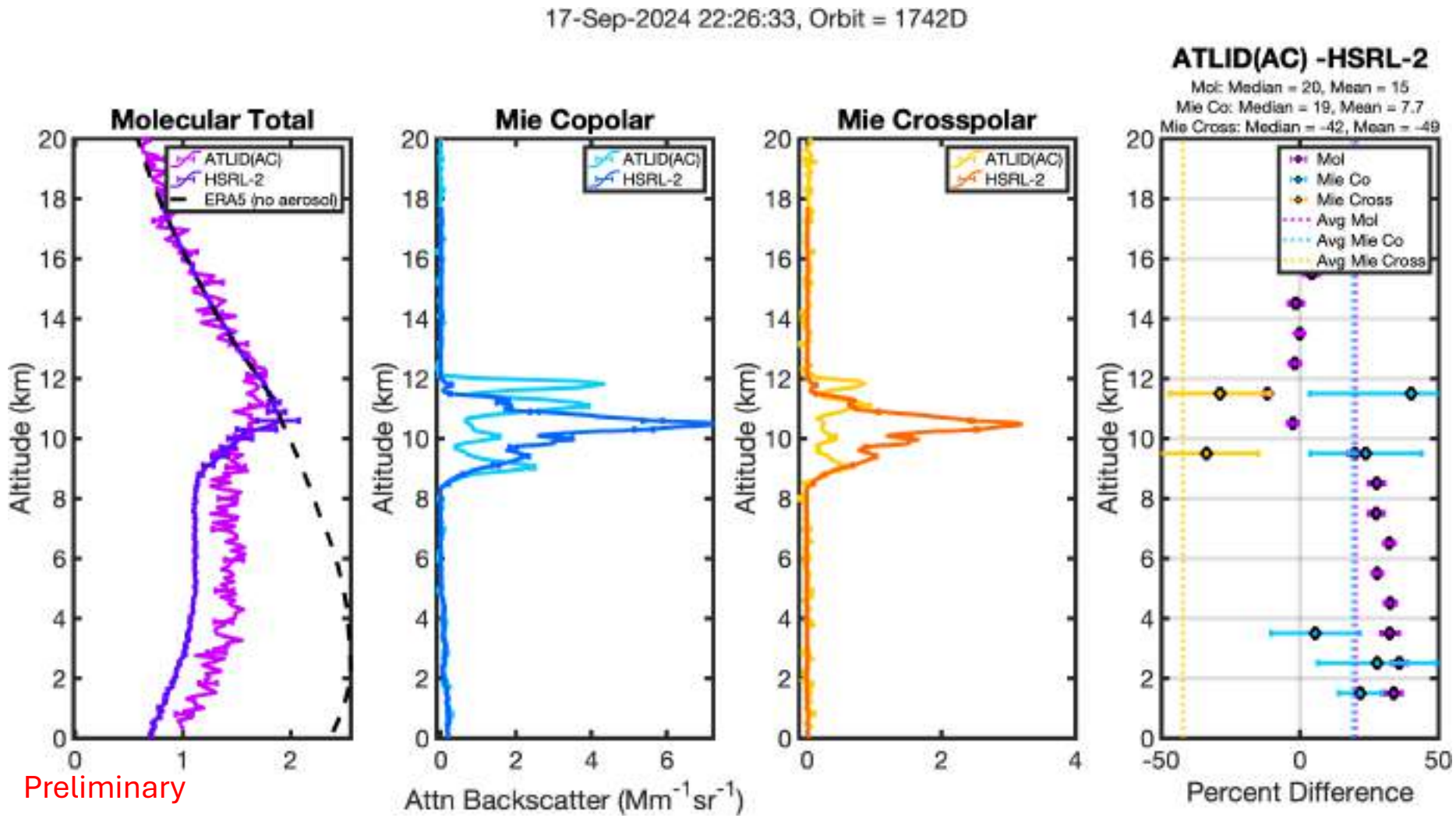


Preliminary Data

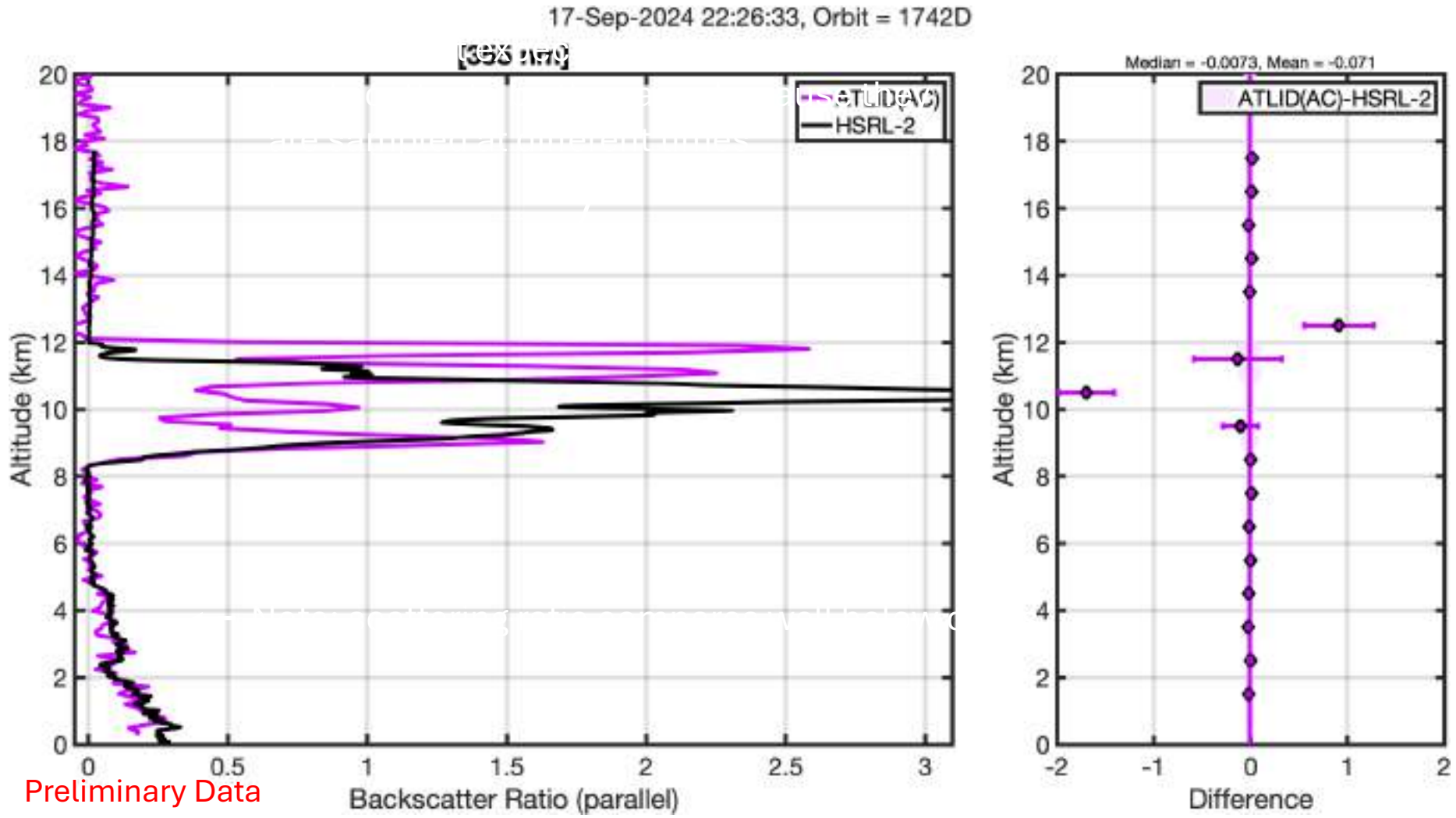
Courtesy J. Hair

Level 1 Signals: Molecular, Mie, Cross

(in cloudy conditions things are harder to compare directly)



Courtesy J. Hair

Scattering Ratio (parallel aerosol-to-molecular)

(But both being HSRL systems the scattering ratios can be directly compared !➔ very good agreement outside of the cloud))