PERCUSION – Airborne HSRL measurements for ATLID validation

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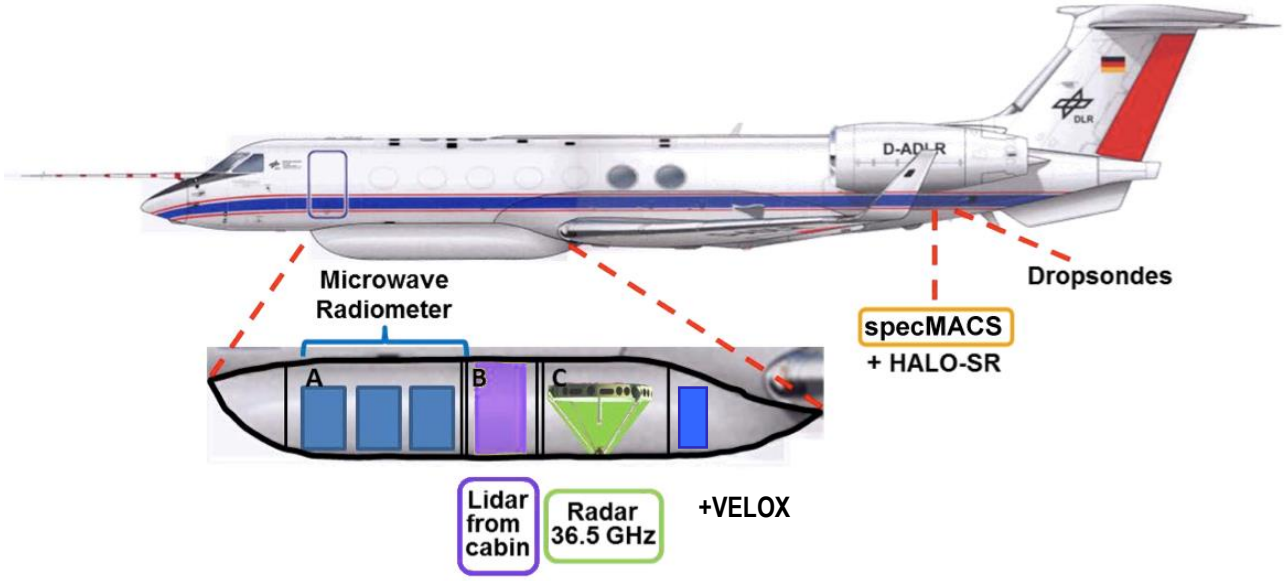
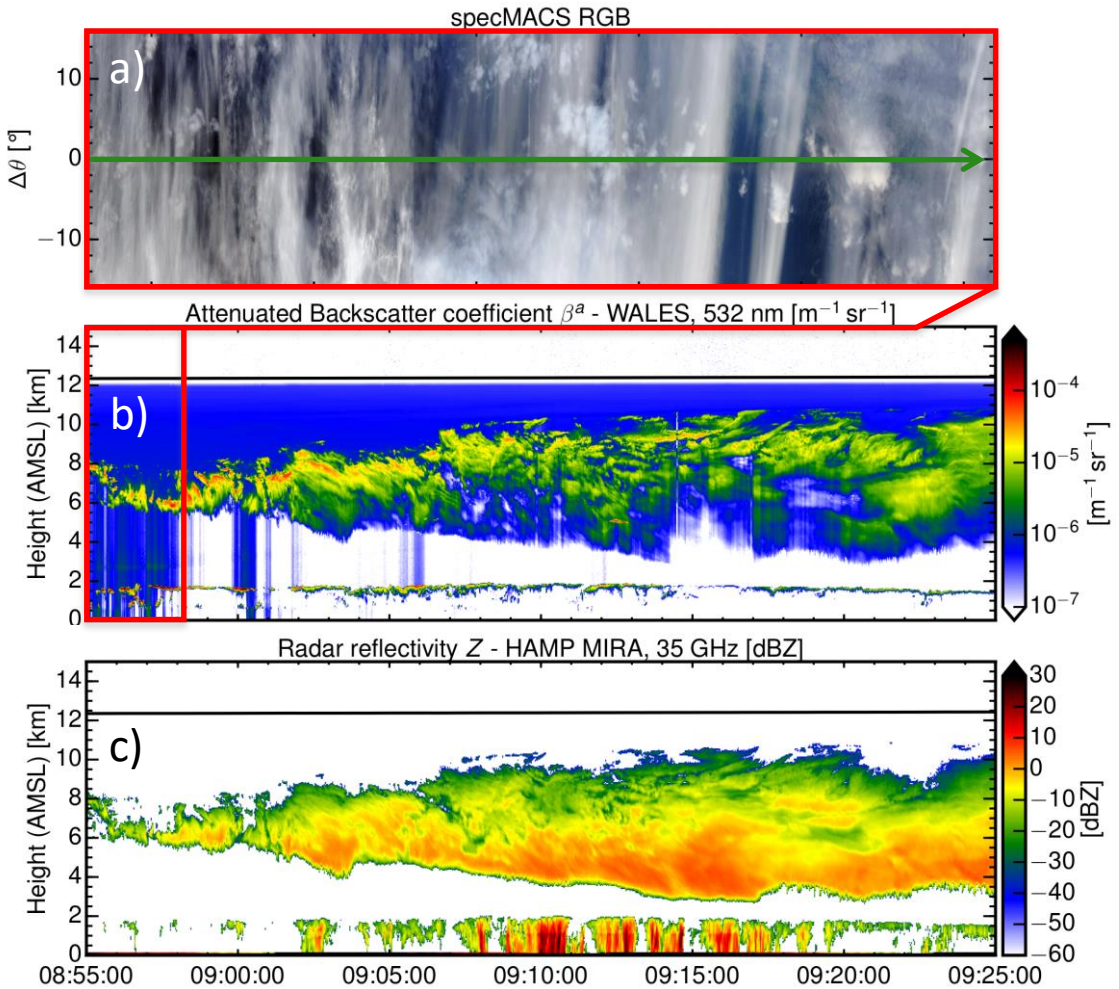
and the PERCUSION team

EarthCARE-like payload on HALO

- G550, max. alt 16 km / max. range: 8000 km
- In operation since 2012
- operated by DLR





Scientific Instruments

HSRL-Lidar (WALES, 532 nm – Wirth et al. 2009)

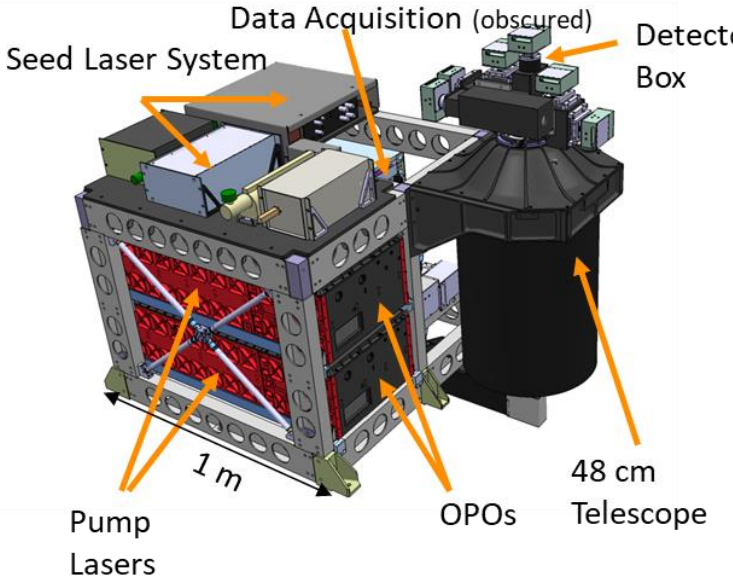
Cloud Doppler Radar (MIRA, 35 GHz – Ewald et al. 2019)

Hyper-Spektral Imager (specMACS – Ewald et al. 2016)

Thermal Infrared Imager (VELOX – Schäfer et al. 2014)

WALES Lidar system

Airborne water vapor DIAL and HSLR, developed and build at DLR-IPA



Aerosol

- Backscatter coefficient (532 nm, 1064 nm)
- Color ratio (532 nm/1064 nm)
- Aerosol **depolarization** 532 nm
- Aerosol **extinction 532 nm – I_2-cell-HSRL**
- Resolution (raw data): range 7.5 m, time = 0.2 s
  (standard products): range 15.0 m, time 1.0 s

→ **Possibility of aerosol classification**

Water Vapor

- H_2O mixing ratio (4 wavelengths ~935 nm)
- Resolution: range 250 m, time = 24 s
- Relative humidity (with external temperature data)

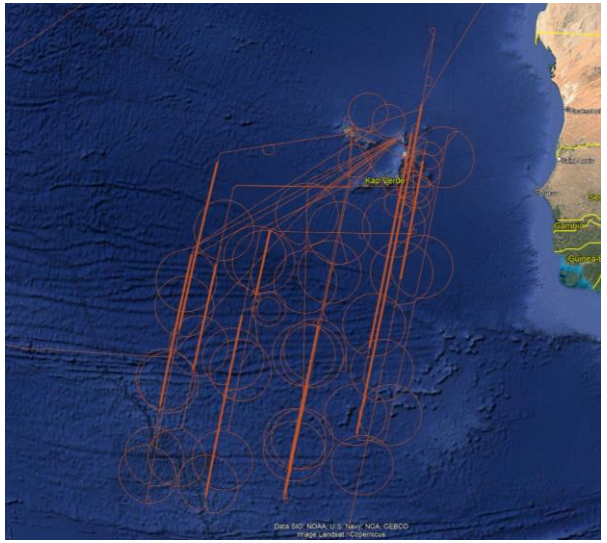
→ **In-cloud and outside cloud distribution of relative humidity and water vapor**

Parameter	WALES lidar
Number of Wavelength @ 935 nm	4
Laser pulse energy 532nm, 935nm, 1064 nm	50 mJ / 40 mJ / 150 mJ
Pulse repetition frequency	2 x 100 Hz
Mie Crosstalk HSRL channel	$< 10^{-3}$
Laser Frequency stability 935 nm	< 60 MHz
Laser Frequency stability 532 nm	< 2 MHz
Laser spectral purity	> 99.9%
Telescope diameter	0.48 m
Telescope field of view	1 mrad
Receiver bandpass filter-width (fwhm)	1 nm
Detector type 935 nm / 1064 nm	APD
Detector type 532 nm	PM
Acquisition Method	analog

Wirth et al., 2009 Appl. Phys.

Strategy – Flight tracks

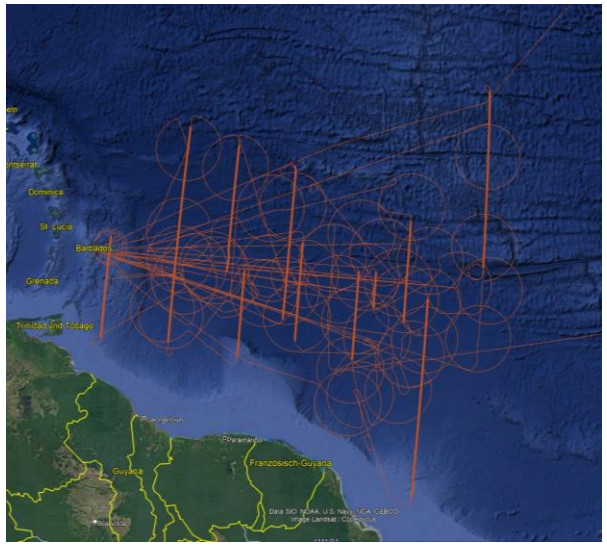
Sal, Cape Verde



8 August – 6 September 2024

- 10 EC underflights
- 4 overpasses over Mindelo ground station
- 3 coordinated flights (curtain) with ATR (2 direct EC overpass)
- 3 coordinated flights (curtain) with King Air (1 direct EC overpass)
- Coordination with METEOR

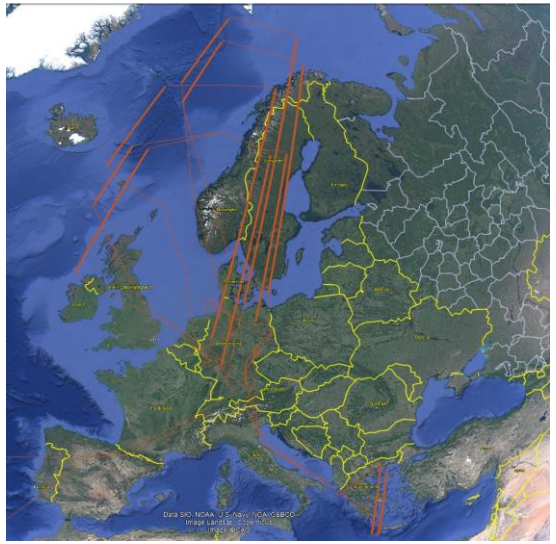
Barbados



6 – 29 September 2024

- 11 EC underflights
- Overpasses/measurements near BCO ground station
- various METEOR overpasses

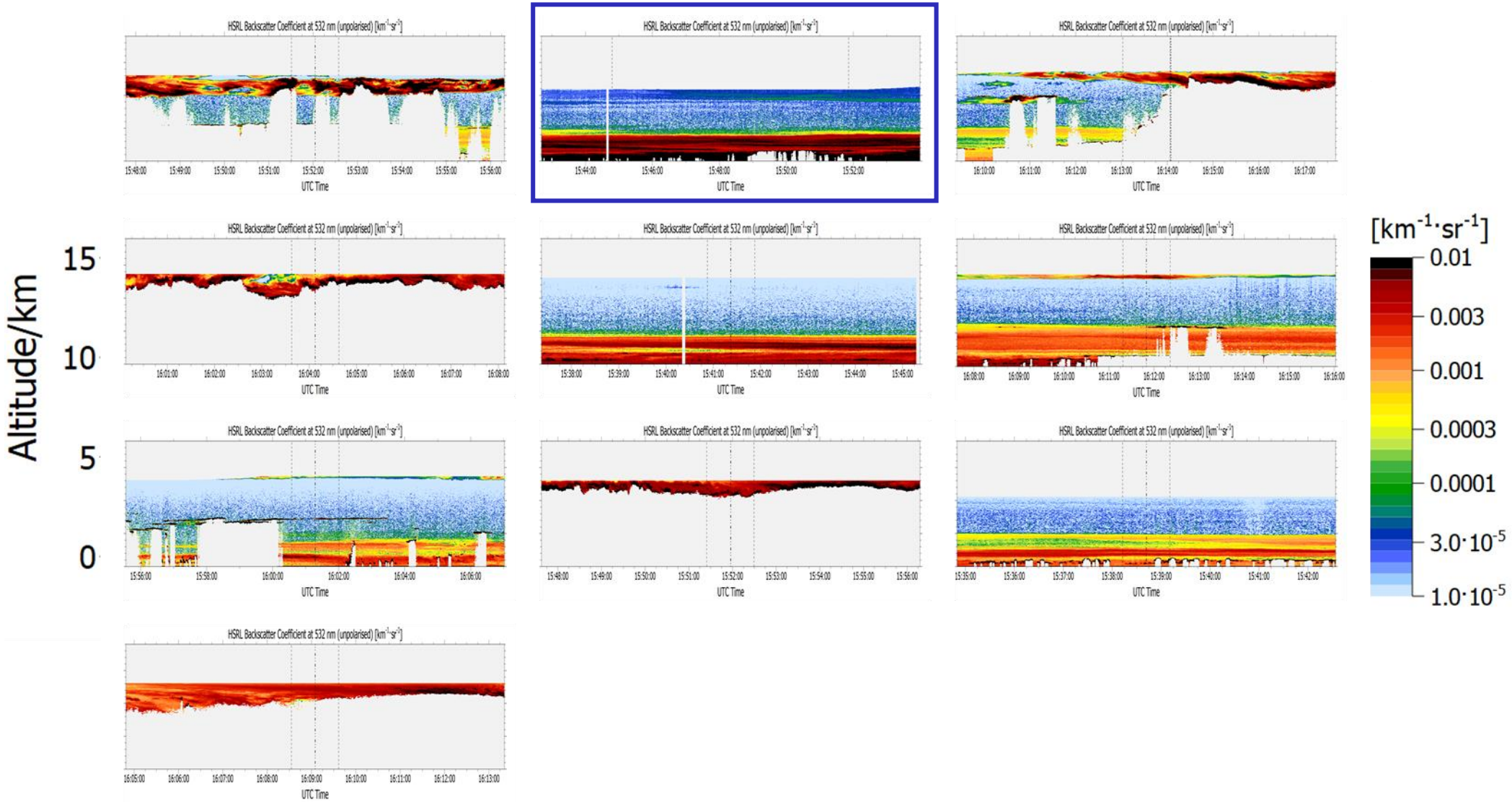
Oberpfaffenhofe



5 – 19 November 2024

- 12 EC underflights
- 2 overpasses (each) Lindenberg, Leipzig, Jülich, Munich, Antikythera
- 1 coordinated flight (profile) with BAe (FAAM)

PERCUSION – Meeting EarthCARE (Sal period)



PERCUSION – Meeting EarthCARE (Sal period)

Day	Target Scene	Comments
11 August	Cirrus, Aerosol (marine, BBA), lower level clouds	Mindelo overpass
13 August	Aerosol (dust, marine), shallow marine clouds	Coordinated (curtain) underpass with French ATR
16 August	Cirrus, Precipitation, Aerosol (marine, BBA)	
18 August	Cirrus, deep convection	
22 August	Deep convection, Precipitation	Coordinated (curtain) underpass with French ATR and King Air, Mindelo overpass
25 August	Aerosol (dust), thin cirrus, marine stratocumulus	Mindelo overpass
27 August	Multi-layer clouds, Aerosol	Coordination with King Air (and METEOR)
29 August	Deep convection, Precipitation, Cirrus outflow, Aerosol	Mindelo overpass, METEOR overpass
31 August	Aerosol (dust), Marine cumulus clouds	Coordination (curtain/profil) with French ATR and King Air, METEOR overpass
3 September	Deep convection, Precipitation	

DLR

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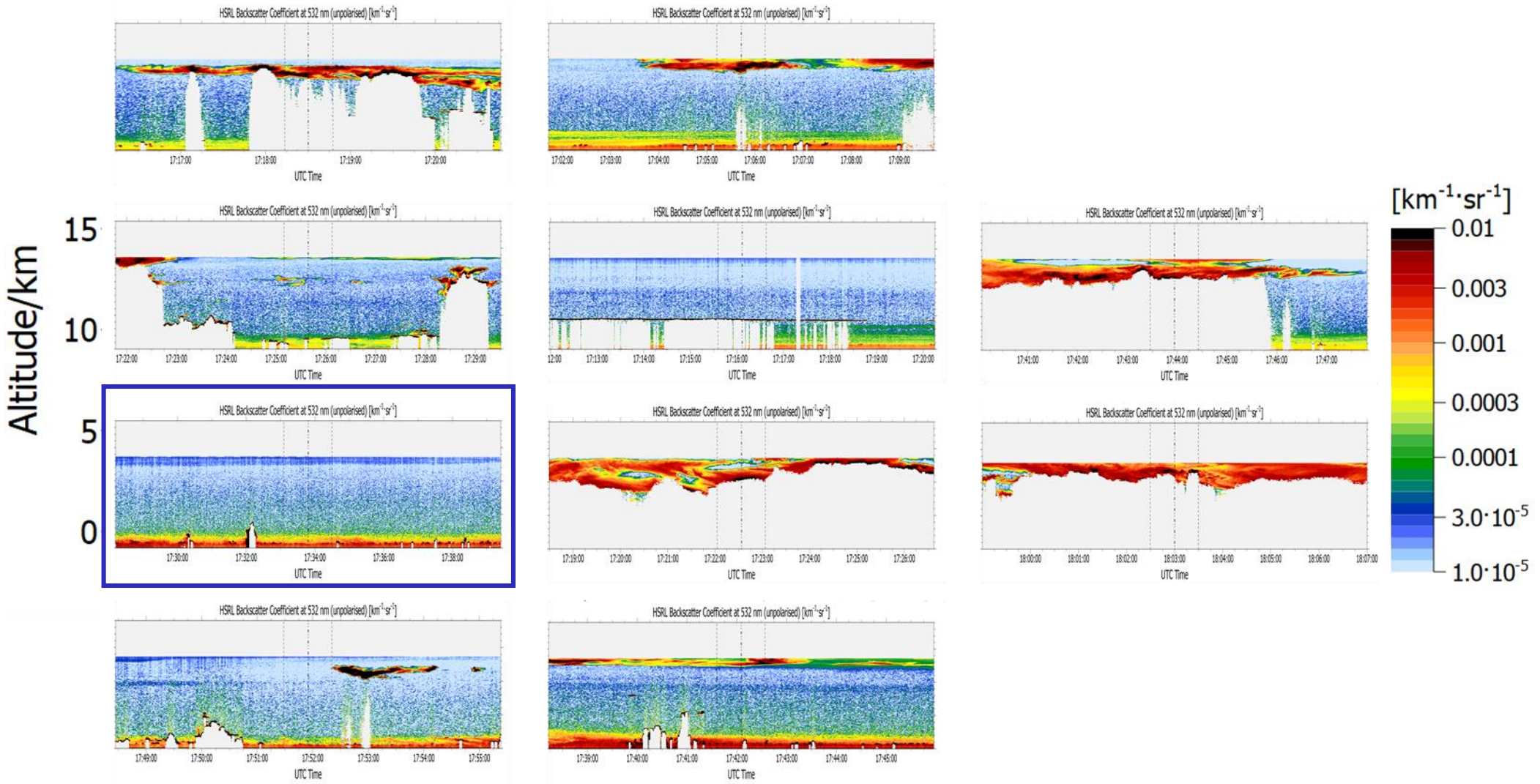
ORCESTRA

PERCUSION – Meeting EarthCARE (Barbados period)



PERCUSION – Meeting EarthCARE (Barbados period)

Day	Target Scene	Comments
7 September	Thin cirrus, clouds, Aerosol (dust, marine)	METEOR overpass, crossing PACE track
9 September	High cirrus, Aerosol (marine), convection	METEOR overpass
12 September	Aerosol (marine), mid-level strato	METEOR overpass
14 September	Cirrus, meso scale convection, Aerosol (marine)	METEOR overpass
16 September	Mid-level strato / mulit-layer clouds	PACE underpass
19 September	Cirrus, Aerosol (marine)	METEOR overpass, PACE underpass
21 September	Background conditions, some Aerosol (marine), shallo marine clouds	METEOR overpass
23 September	Cirrus, multi-layer cloud structur	METEOR overpass
24 September	Cirrus, deep convection, precipitation	
26 September	Background conditions	
28 September	Background conditions, dolldrums	Within PACE swath

DLR

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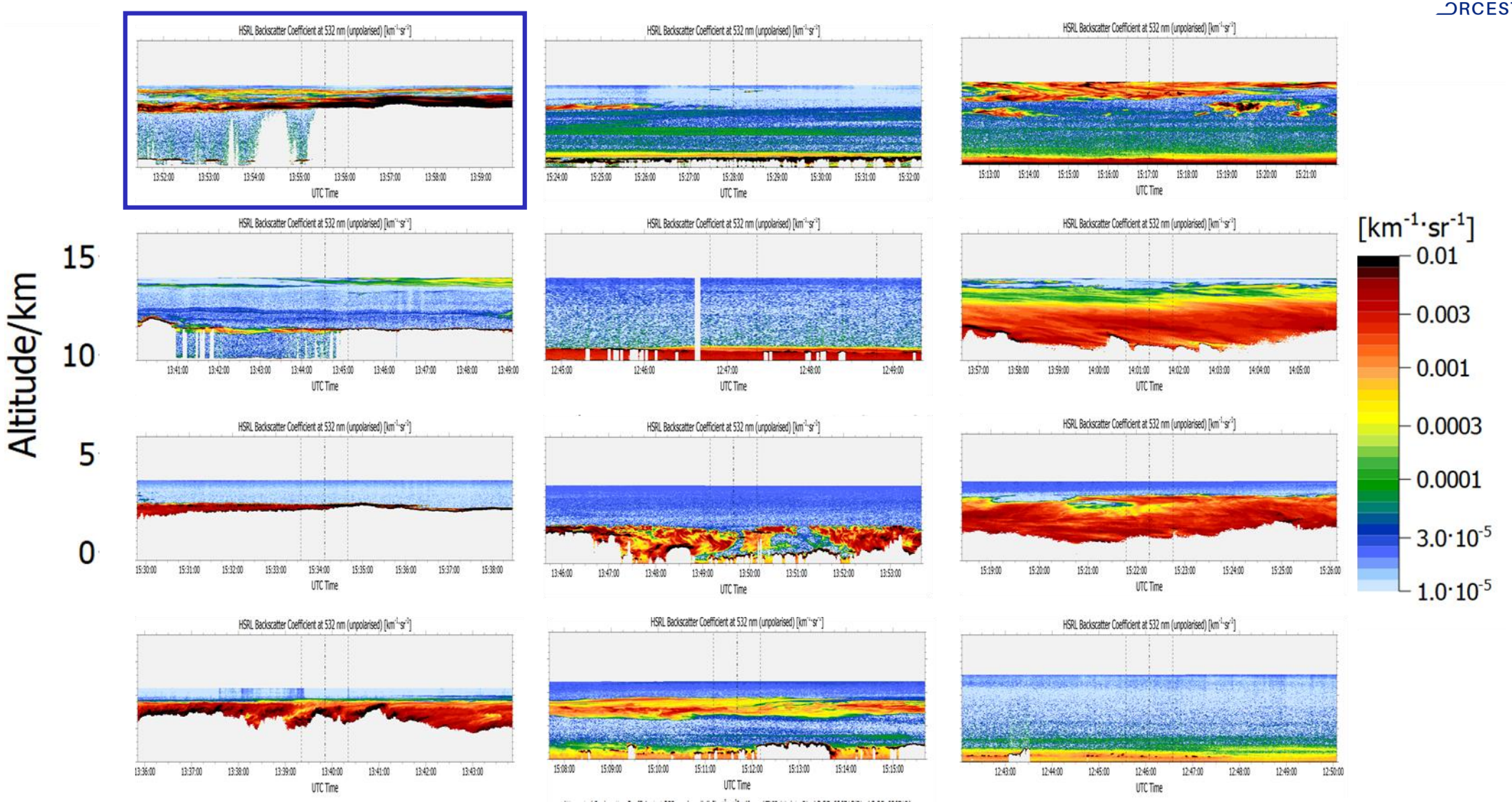
ORCESTRA

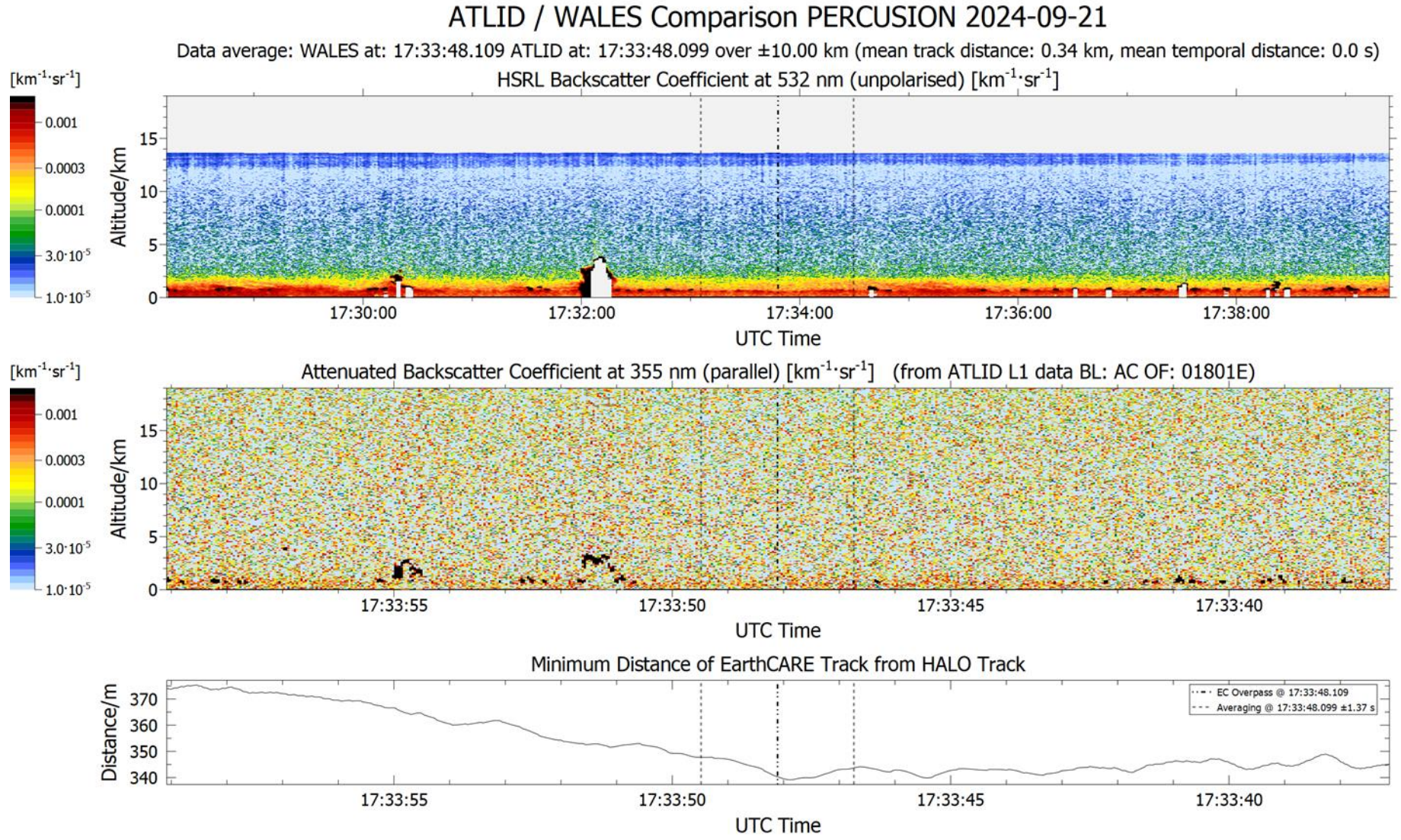
PERCUSION – Meeting EarthCARE (Oberpfaffenhofen period)



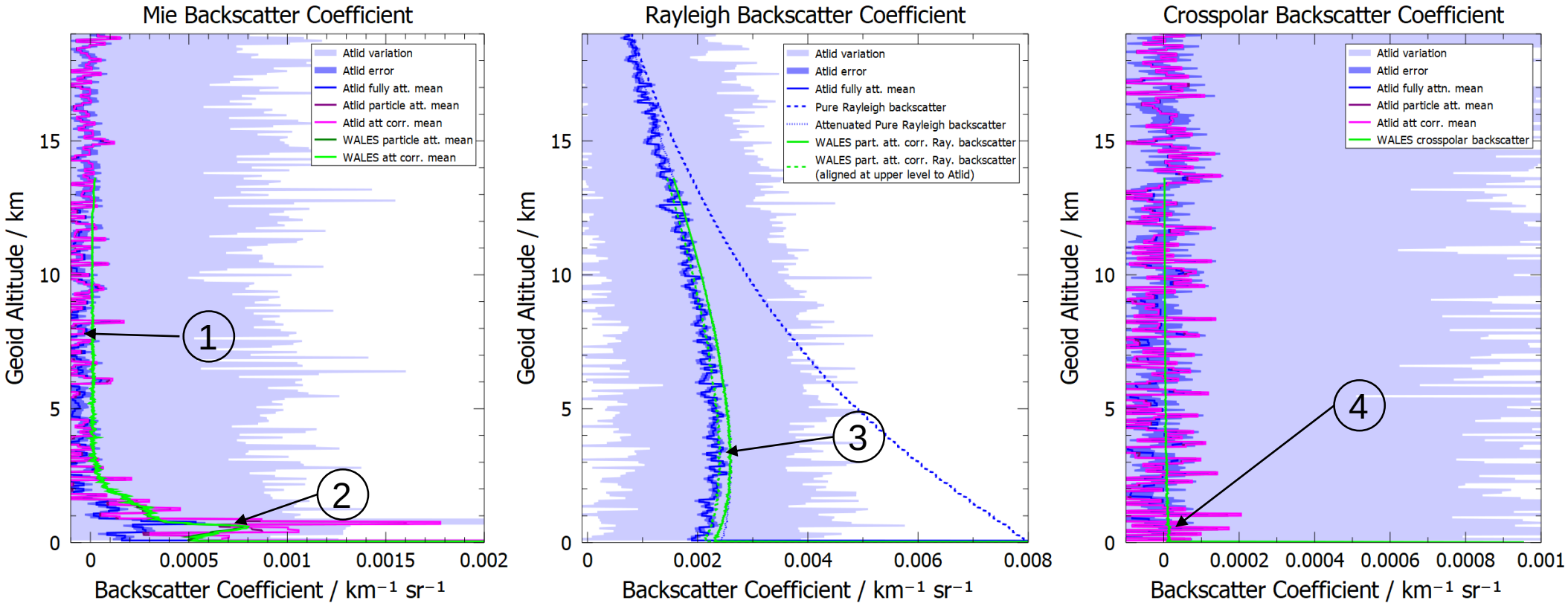
PERCUSION – Meeting EarthCARE (Oberpfaffenhofen period)

Day	Target Scene	Comments
5 November (EC1)	(Arctic/frontal) cirrus	
5 November (EC2)	Aerosol	
7 November (EC1)	(Arctic) cirrus	Leipzig, Lindenberg Jülich overpasses
7 November (EC2)	Stratiform clouds, aerosol	
10 November	Mediterranean background aerosol	Antikythera overpass
12 November (EC1)	Frontal clouds	
12 November (EC2)	Frontal clouds	
14 November (EC1)	Ice and mixed-phase clouds	
14 November (EC2)	Frontal clouds	
16 November	Frontal clouds	Leipzig, Lindenberg, Jülich, Munich overpasses
16 November	Cirrus	
19 November	Mediterranean (background) aerosol	Antikythera overpass

Comparison background condition – 21 Sept. 2024 (Barbados)

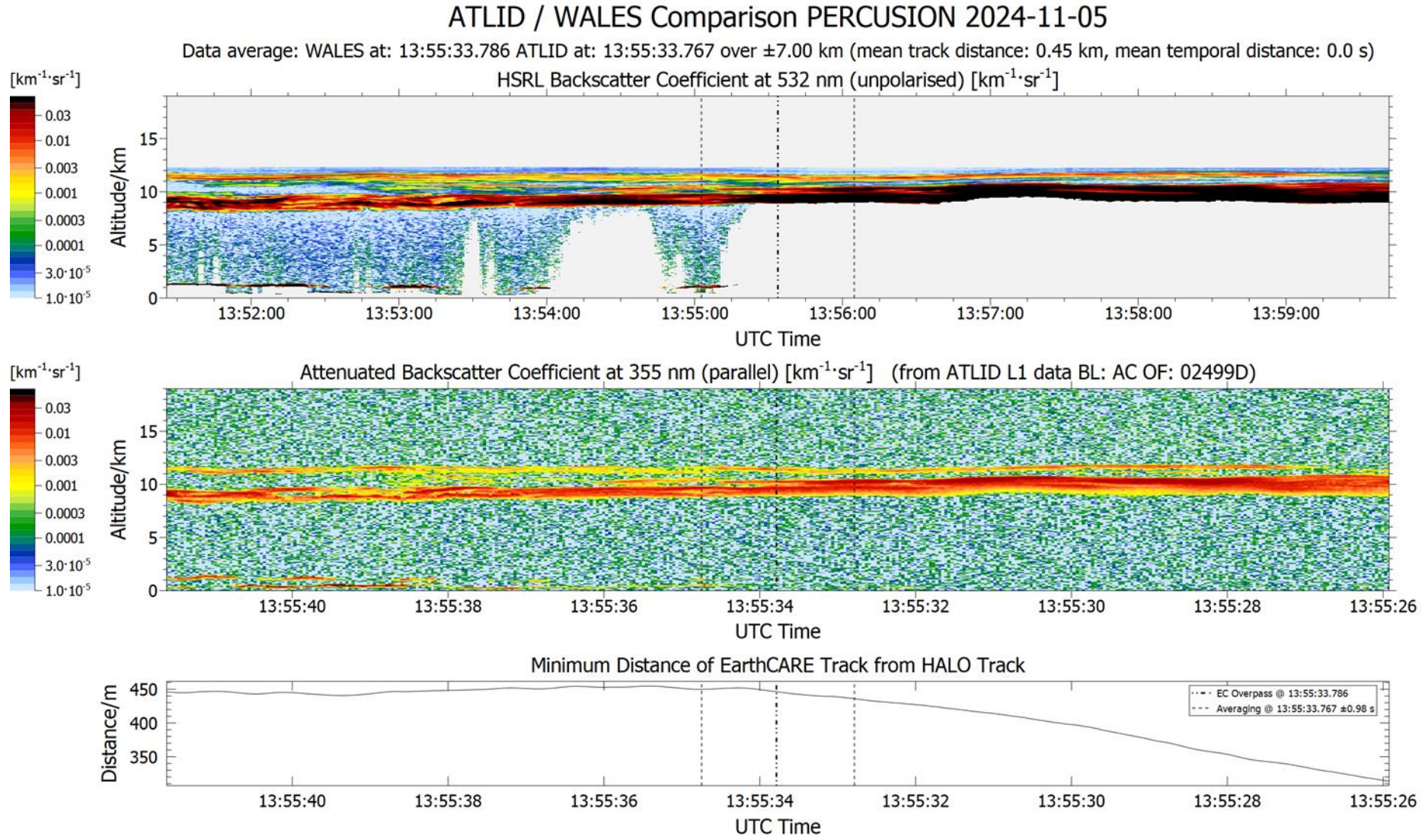


Comparison background condition – 21 Sept. 2024 (Barbados)

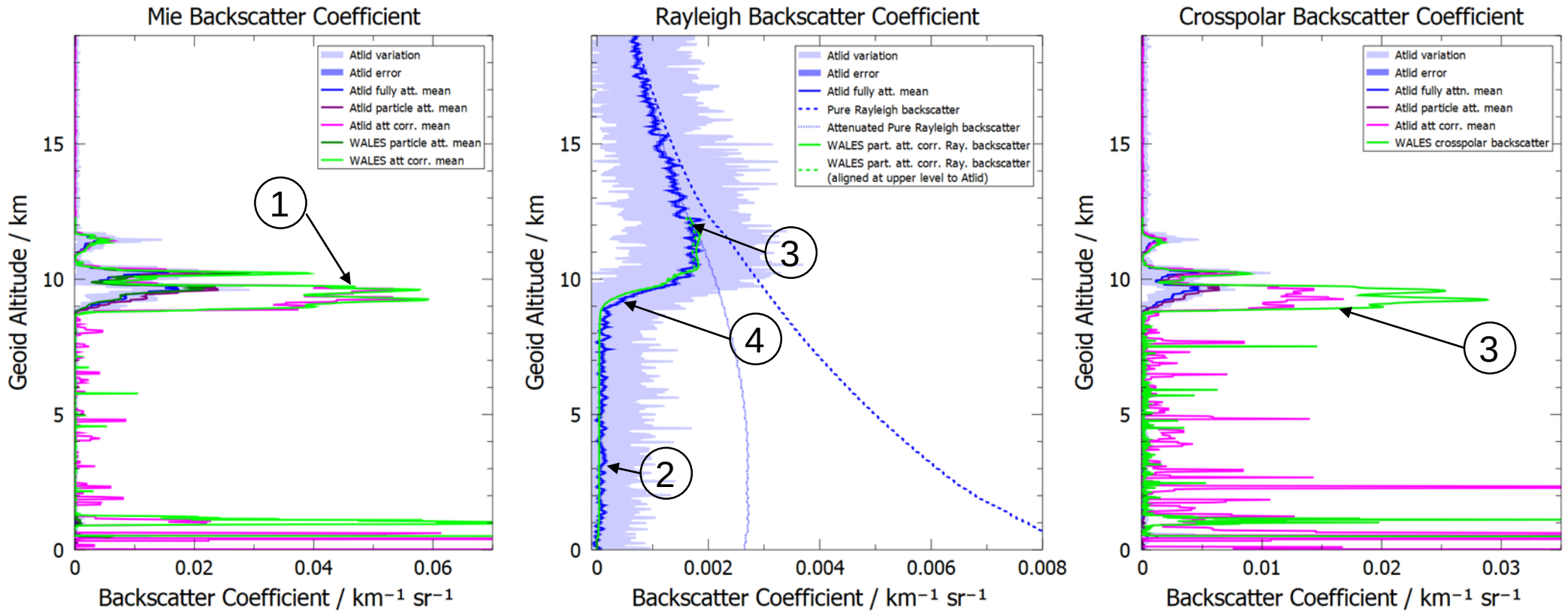


1. Mie signal shows negative offset in low aerosol region
2. Backscatter of maritime boundary layer lower at 532 nm (as expected?).
3. Rayleigh signal looks fine
4. Very low depolarization of maritime boundary layer not detectable by the spaceborne lidar

Comparison cirrus – 5 Nov. 2024 (Oberpfaffenhofen)

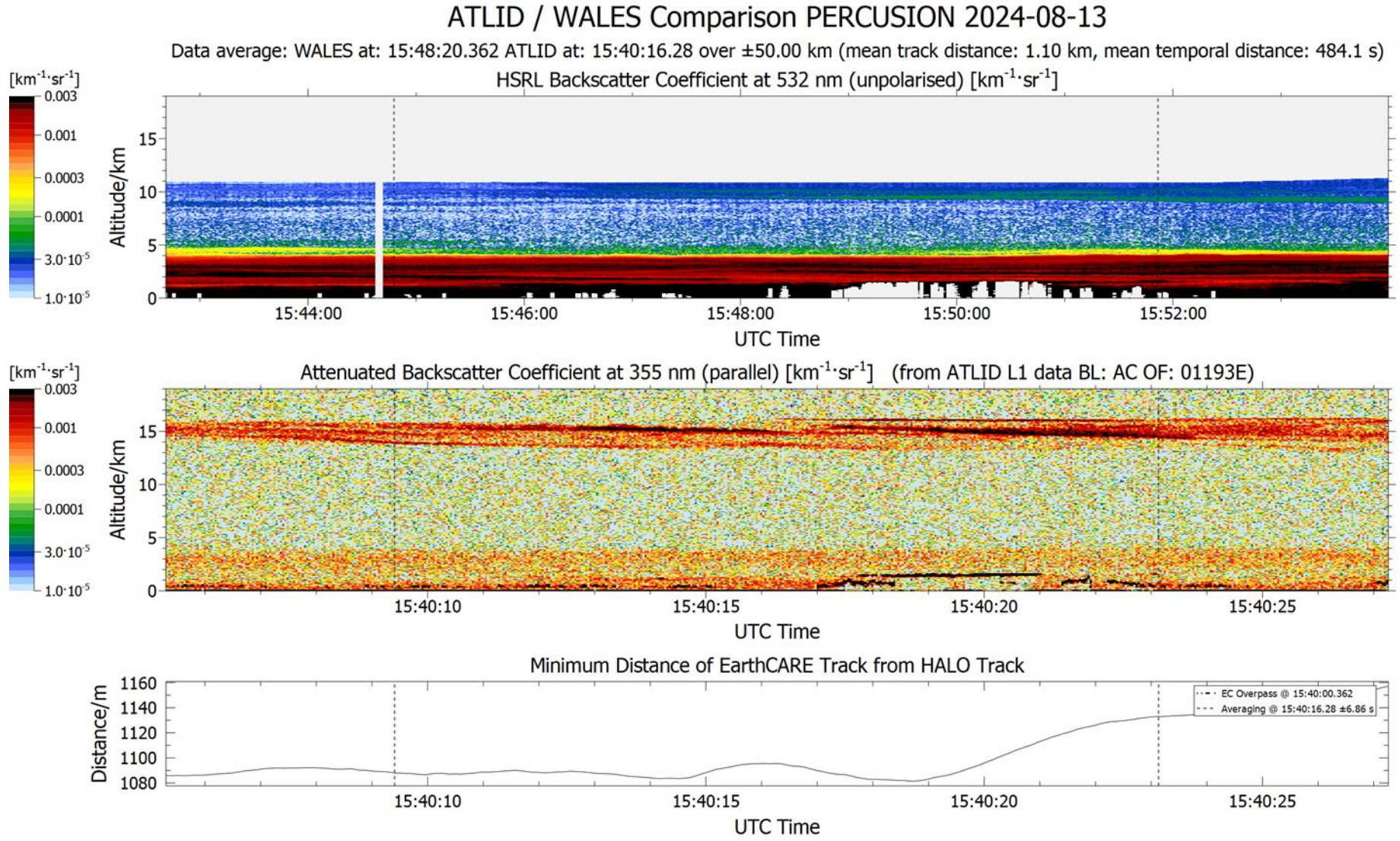


Comparison cirrus – 5 Nov. 2024 (Oberpfaffenhofen)

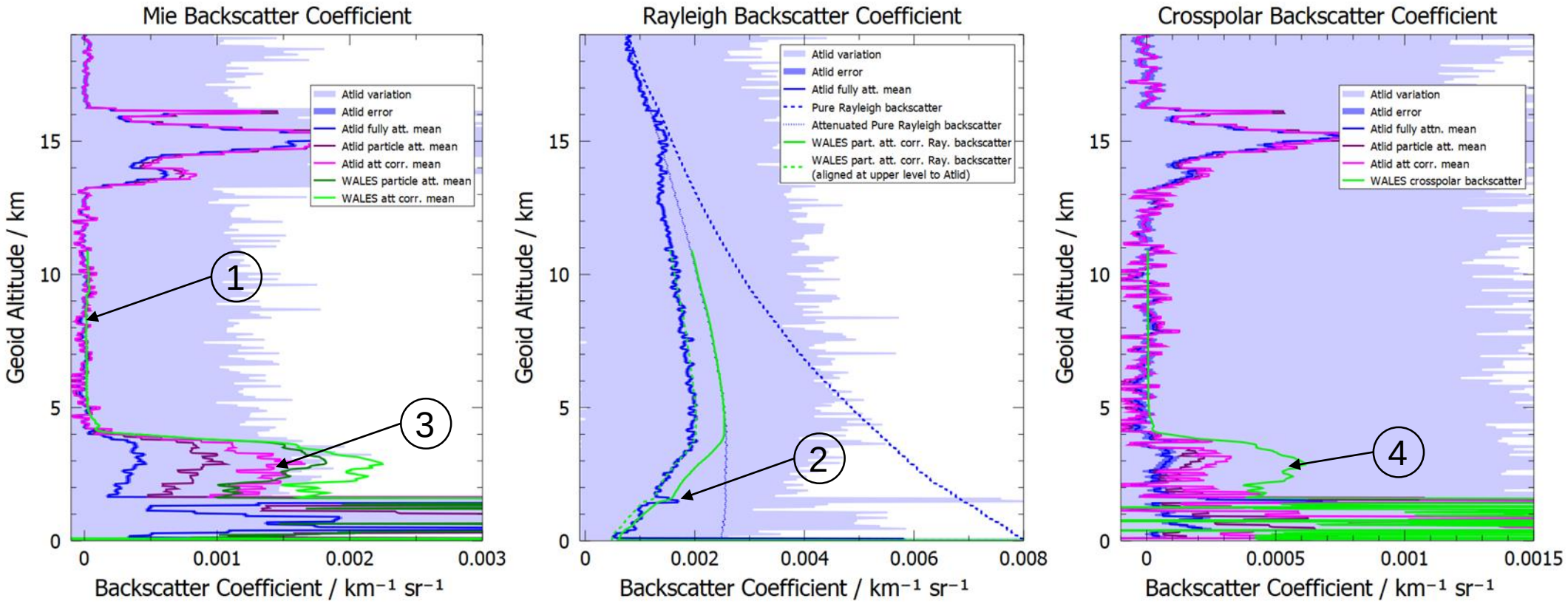


1. Comparable backscatter in cirrus cloud, as expected
2. Optical thickness lower than WALES below cloud (still positive below opaque cloud)
3. Slightly positive step in transmission, where negative one is expected
4. Extinction in cloud seems to be more stretched (multiple scattering effect?)
5. Depolarization in optically thick part of the cirrus significantly lower than for 532 nm (extinction correction?)

Comparison dust (mixture) – 13 Aug. 2024 (Sal)



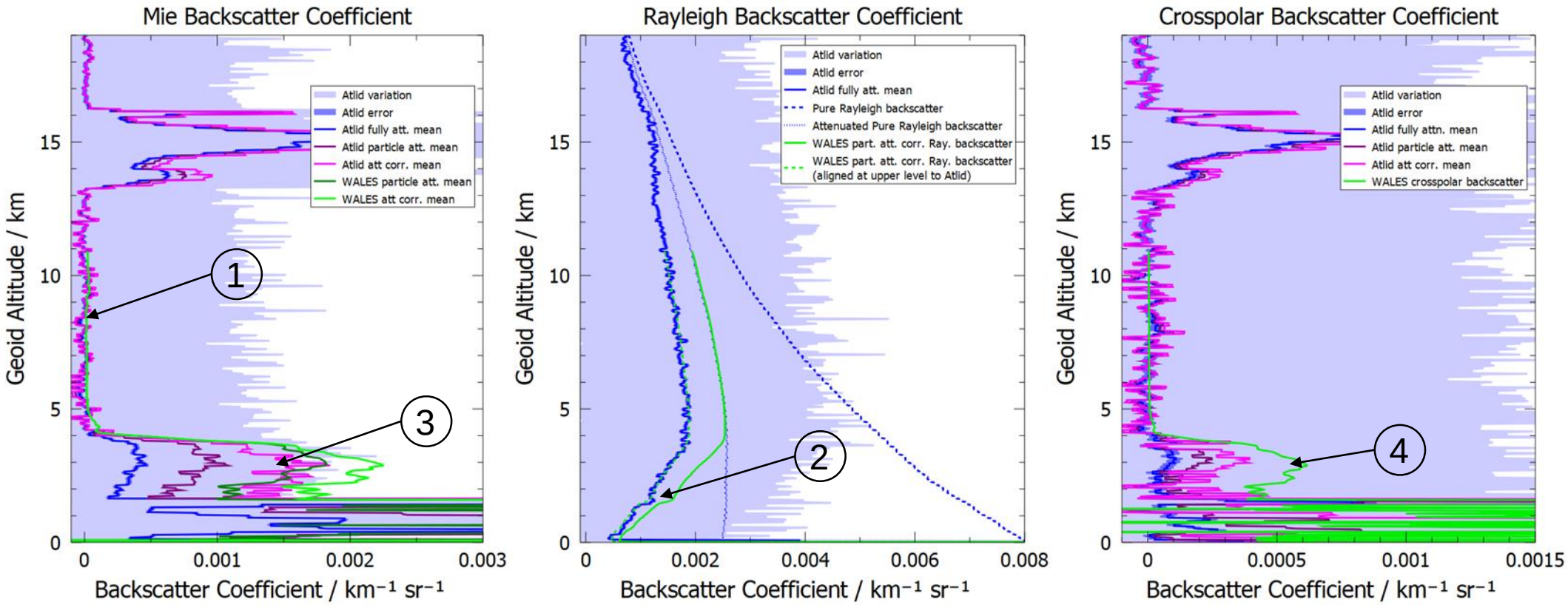
Comparison dust (mixture) – 13 Aug. 2024 (Sal)



1. Mie signal slightly below zero in clean atmosphere region
2. Rayleigh signal shows cross talk from marine boundary layer clouds
3. About equal backscatter within dust layer (should be slightly higher for 355 nm signal?)
4. Depolarization significantly lower than WALES measurement (wavelength dependence has to be checked)

Comparison dust (mixture) – 13 Aug. 2024 (Sal)

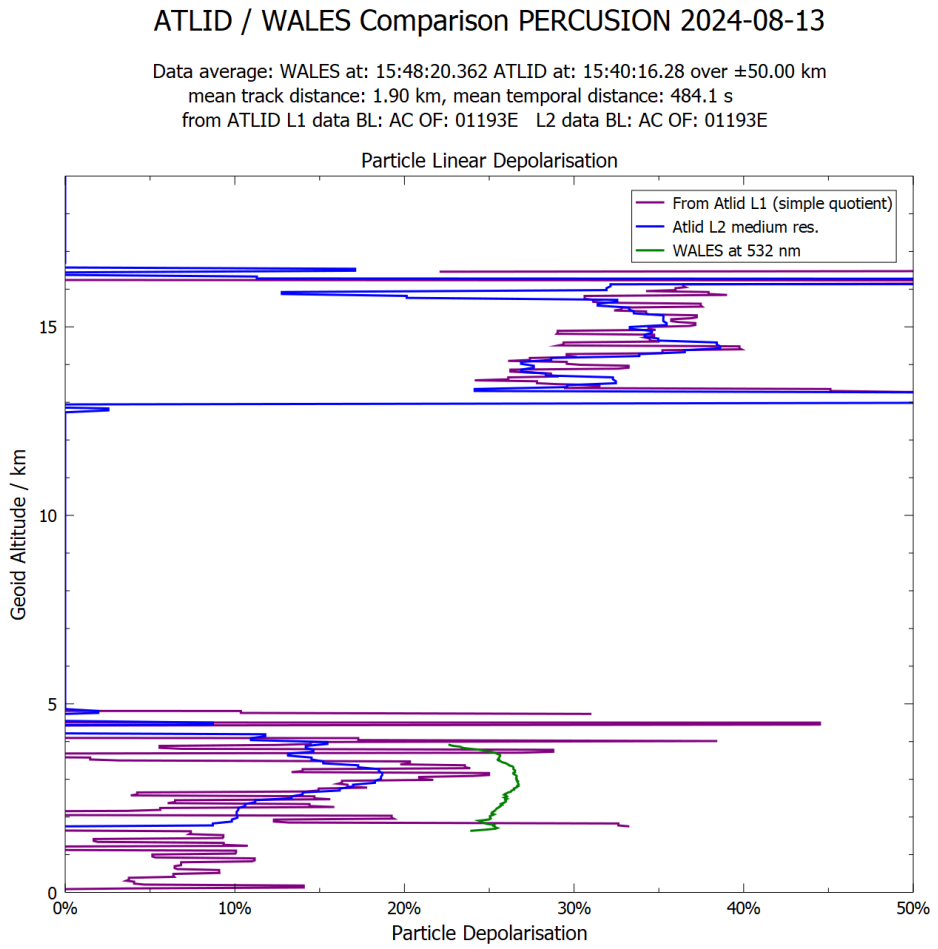
ATLID: reprocessed data (BL:XY OF: 01193E)

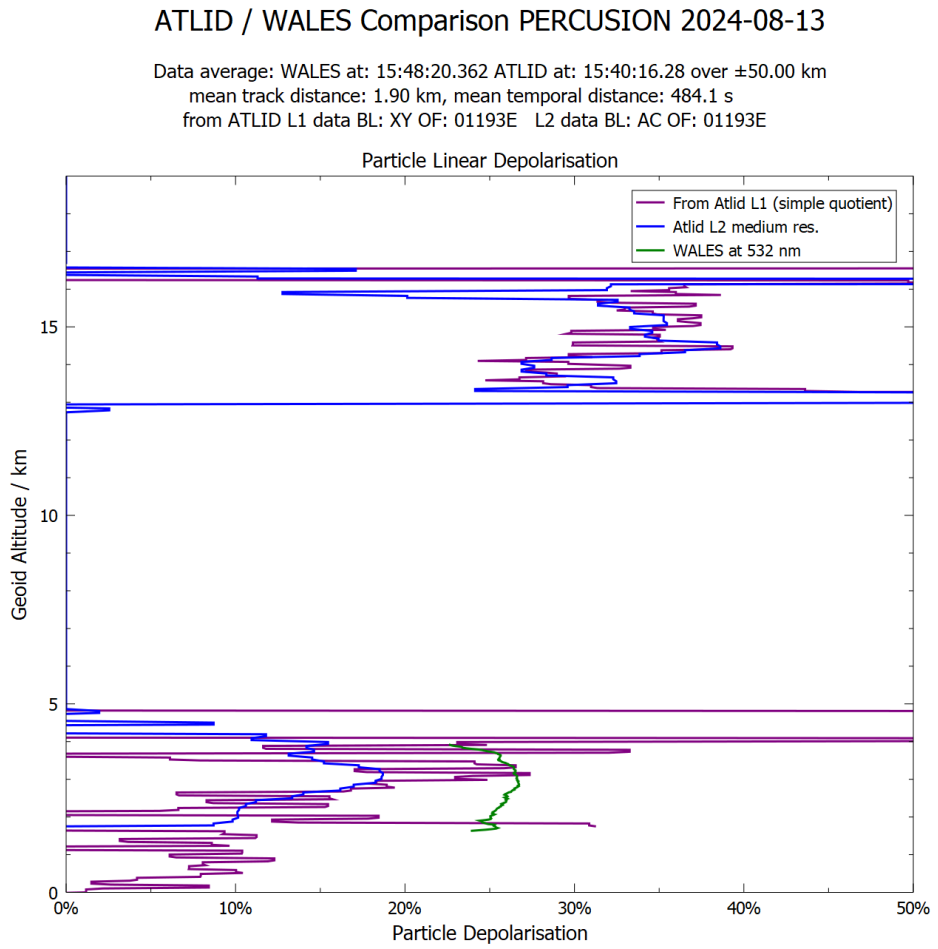


1. Still: Mie signal slightly below zero in clean atmosphere region
2. Improvement: Cross talk significantly improved
3. Improvement: Increased backscatter within dust layer
4. Improvement: Depolarization increased in dust layer (but still lower than WALES; wavelength dependence has to be checked)

Outlook: L2 Particle depolarization ratio – 13 Aug. 2024 (Sal)

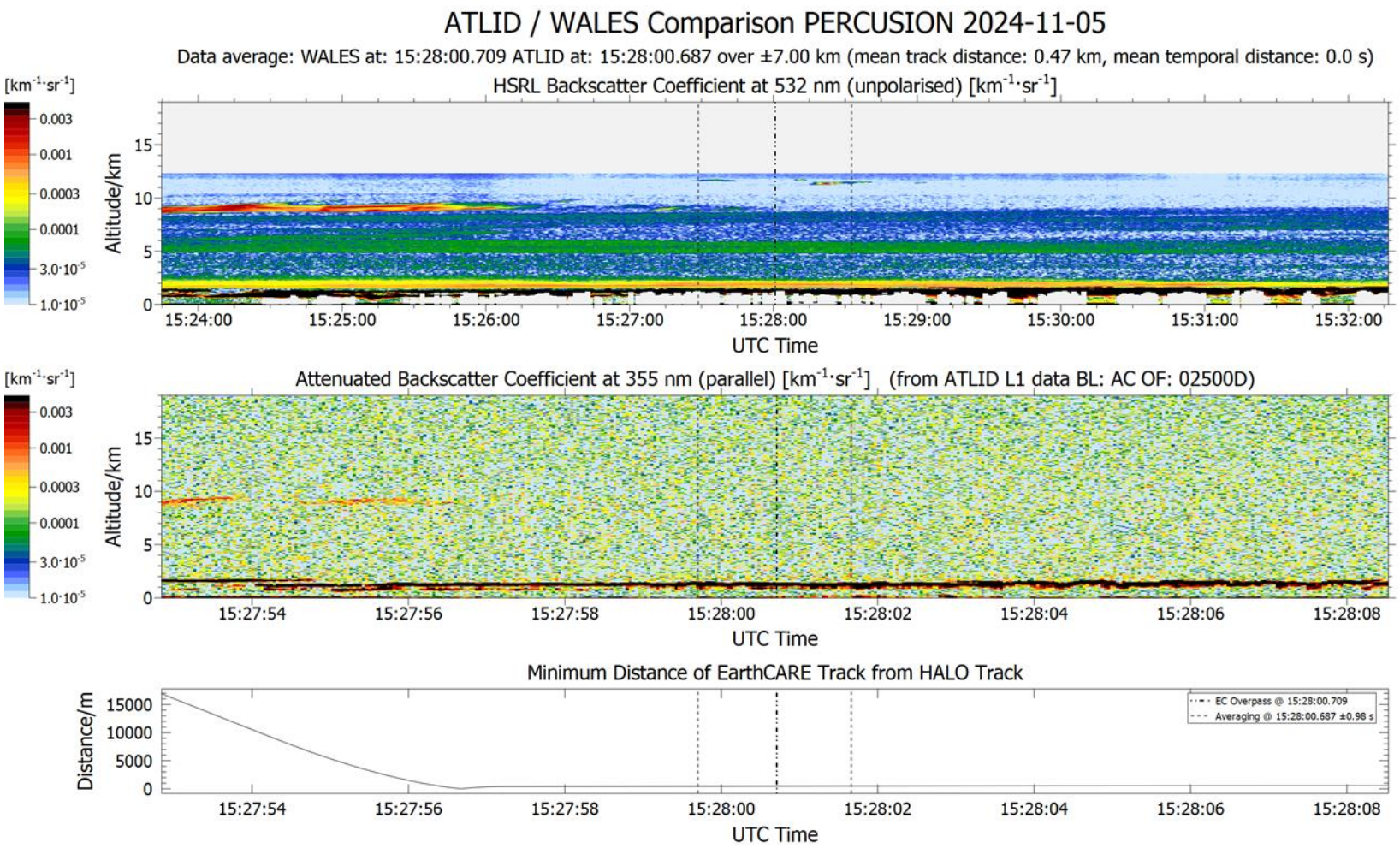
ATLID: reprocessed data (BL:XY OF: 01193E)

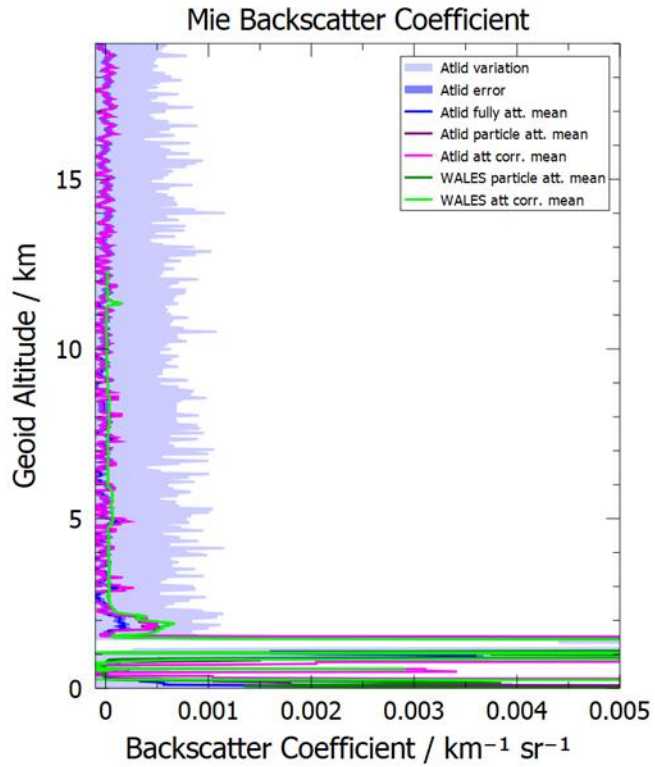




→ Increase of particle depolarization ratio in reprocessed data (detailed comparisons will follow)

Outlook: Sensitivity – L2 Feature Mask / layer base and top height





Summary of findings

- Depolarization in cirrus clouds often too low (by 10%-50%).
- Parallel signal in cirrus clouds slightly too low (10%-20%)
- Difference smaller in the third campaign part → night time conditions
- Depolarization in dust hardly visible without averaging over larger area. But if, than lower than WALES data (wavelength dependence?)
  → Further investigations needed!
- Sometimes still visible cross-talk from Mie to Rayleigh channel.
- Signals are sometimes significantly negative, or positive where they should be zero (e.g. below opaque clouds). Related to cross-talk correction?

→ L1 comparisons for all underflights uploaded