The performance of Aeolus L2A products at Cabo Verde during JATAC and beyond – validation with ground-based lidar observations

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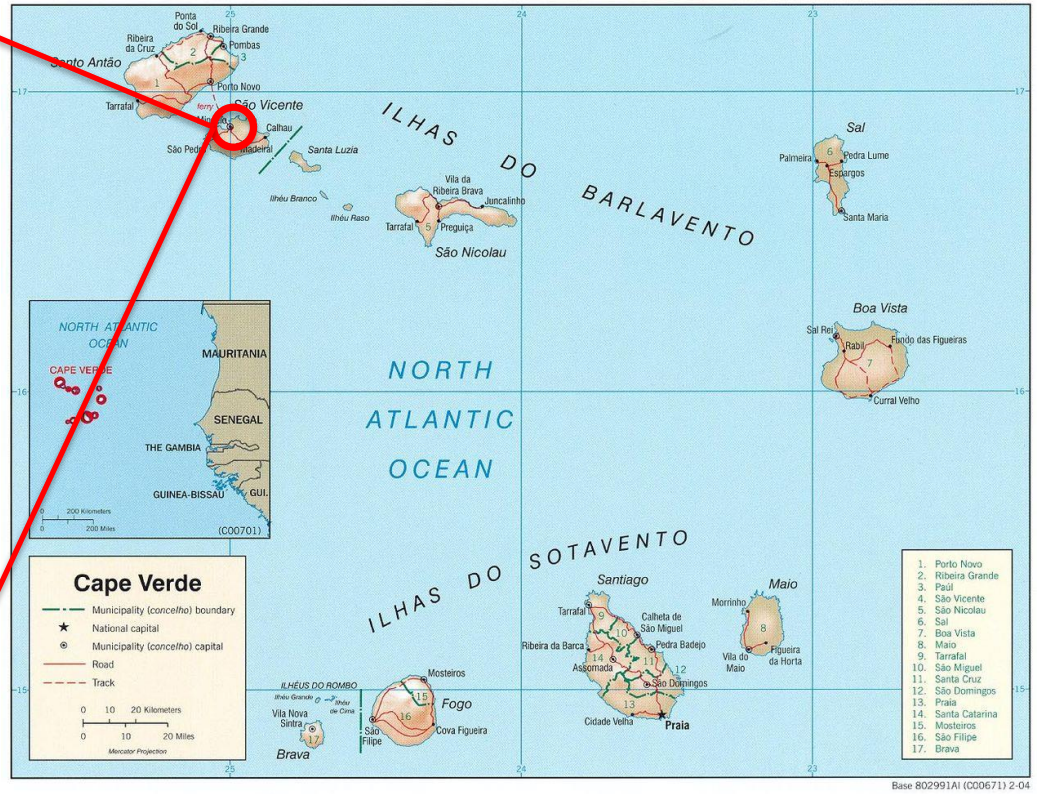
4 GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany

Patchwork ACTRIS Aerosol & Cloud remote sensing facility @ Mindelo, Cabo Verde



ASKOS in JATAC

- Ground-base phase: ASKOS Aerosol and wind RS component June-July 2021
- Intense phase: + Airborne RS and in situ August- Sept. 2021

ASKOS full phase

- Full ASKOS phase: + RS on clouds/ radiation/polarization + UAV/balloon in situ May - June 2022

+Sep 2022

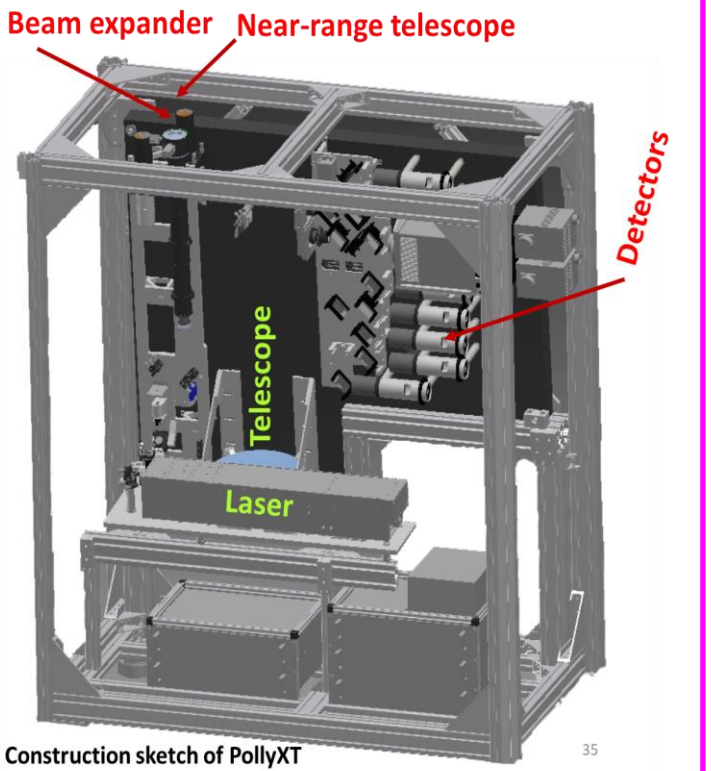
→ 4 campaigns within 2 years
→ **Continuous lidar observations since July 2021**
→ Thanks to all involved persons

Patchwork ACTRIS Aerosol & Cloud remote sensing facility @ Mindelo, Cabo Verde

PollyXT for Cabo Verde:

15 channel lidar for

- 3 backscatter coefficients (355, 532 1064 nm)
- 3 extinction coeff. (355, 532,1064 nm)
- 3 depolarization ratios (355, 532, 1064 nm)
  - Absolute depolarization calibration by ± 45° method
  - "Cleaning" of laser polarization
- Water vapor
- Near range detector (data from 100 m height)
- Diode pumped laser (100 Hz)
- Automatic data processing in PollyNET – NRT display: polly.tropos.de



Construction sketch of PollyXT

ASKOS in JATAC

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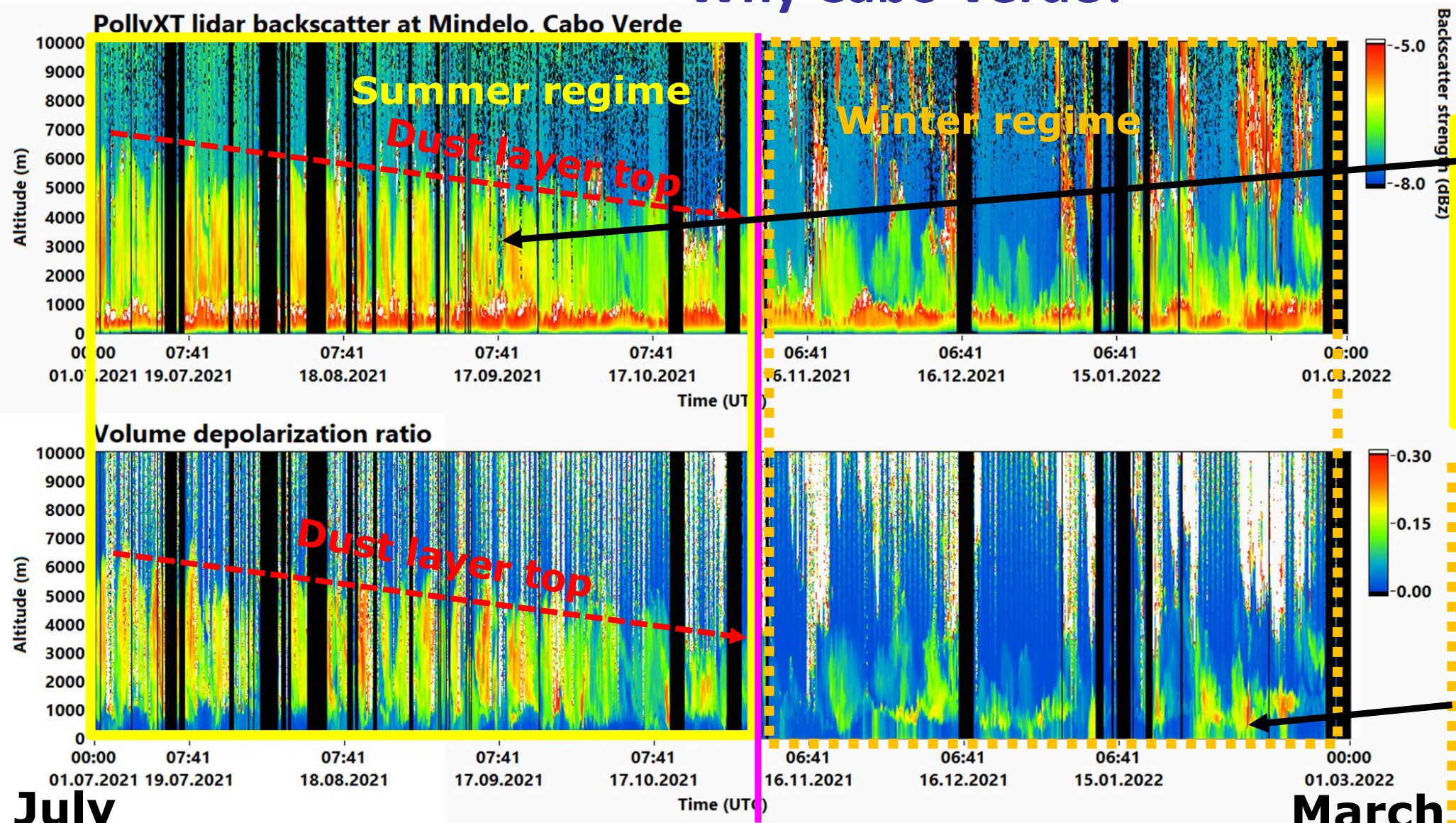
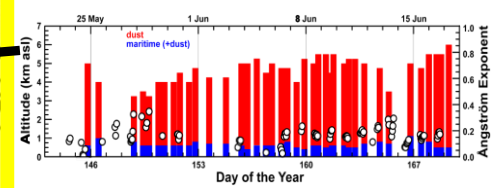
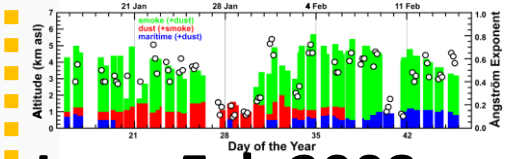
Why Cabo Verde?



SAMUM 2 results!



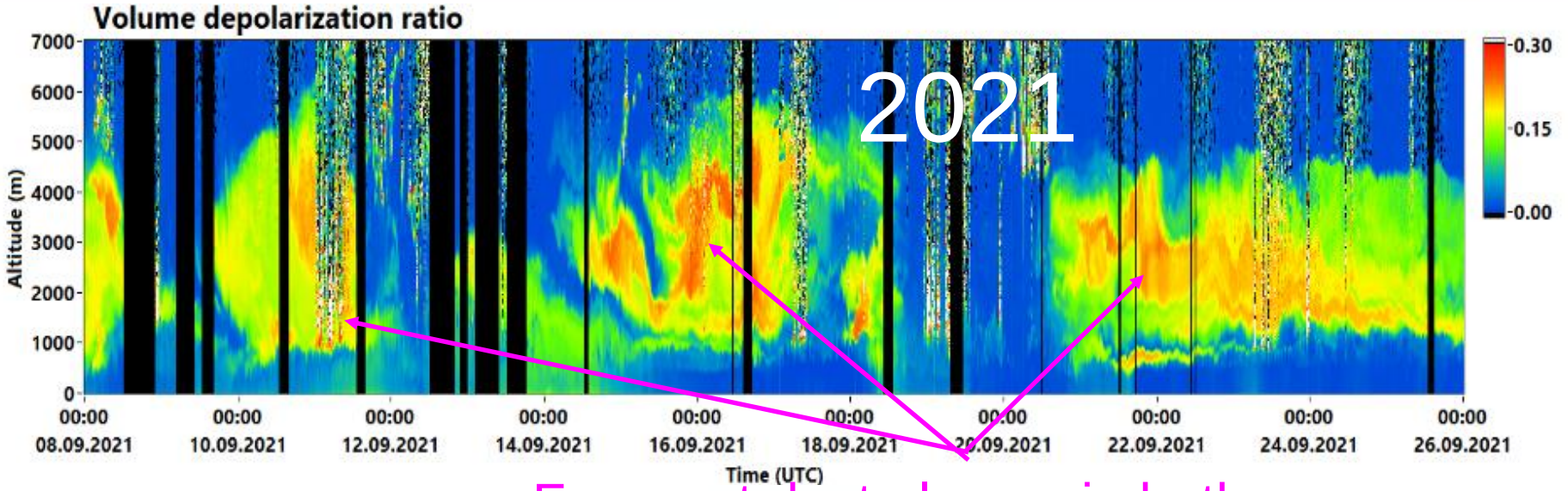
June – July 2008
→Pure dust above the MBL

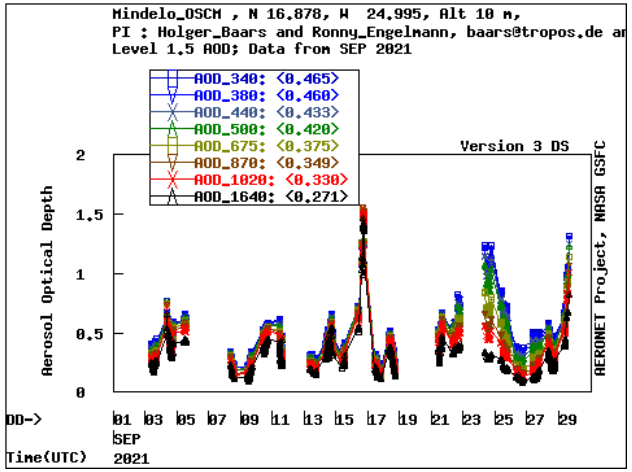


Jan – Feb 2008
Mixture of dust and smoke, often mixed in MBL

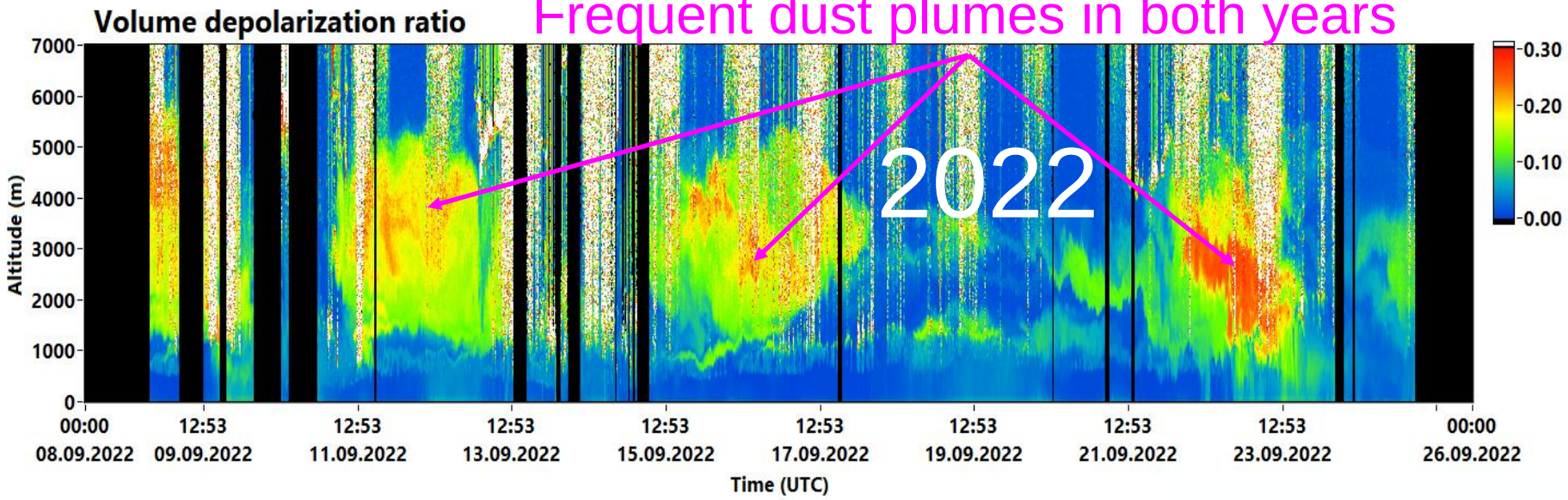
"Pure" dust season is over

September 2021+2022 observations



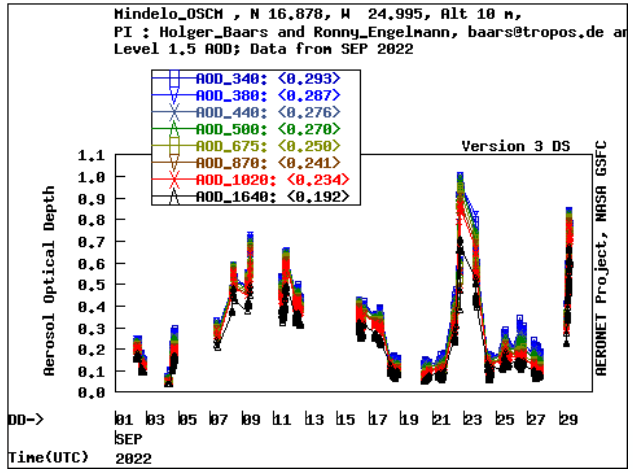


Frequent dust plumes in both years

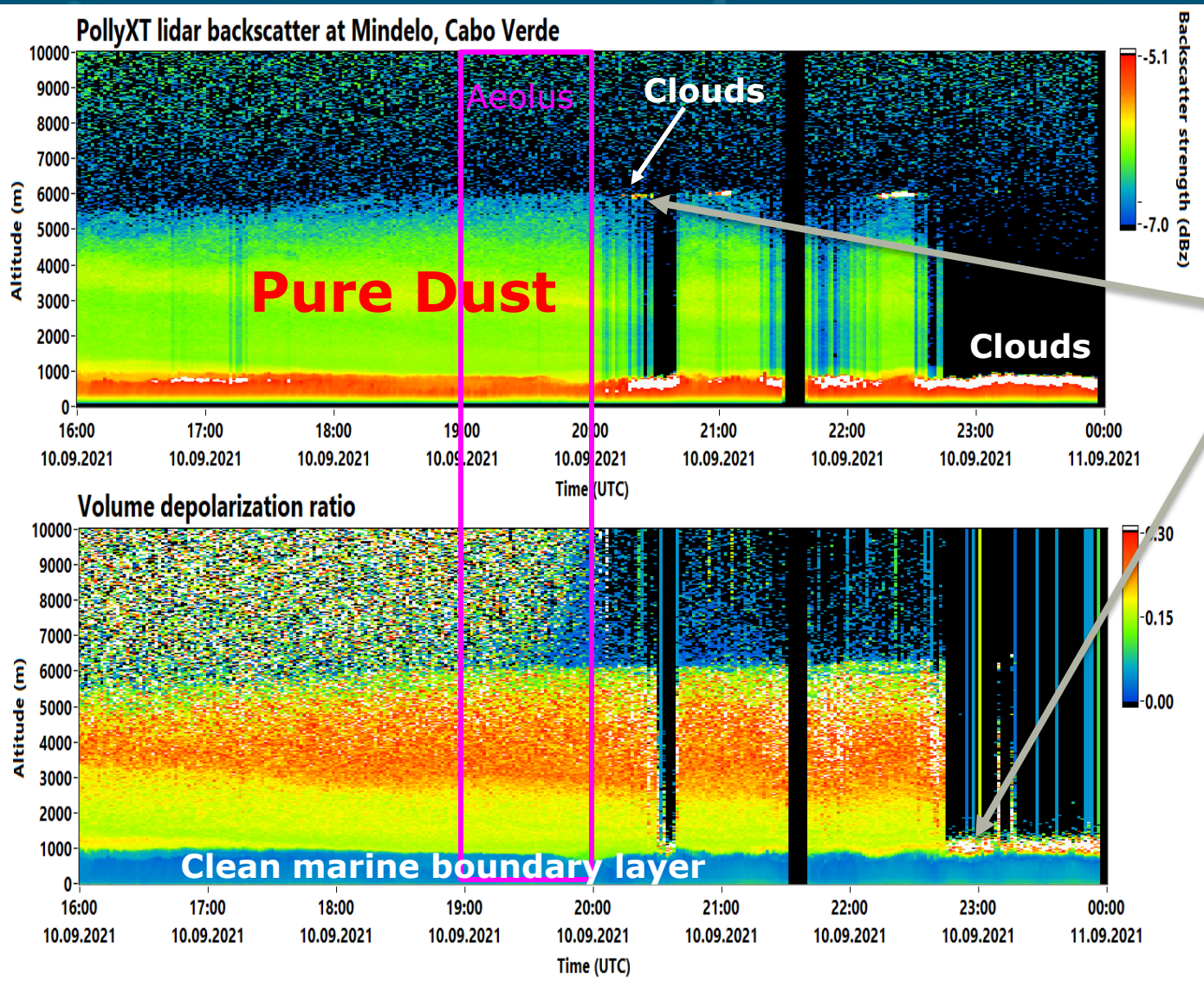


2021 vs. 2022

Similar AOD conditions



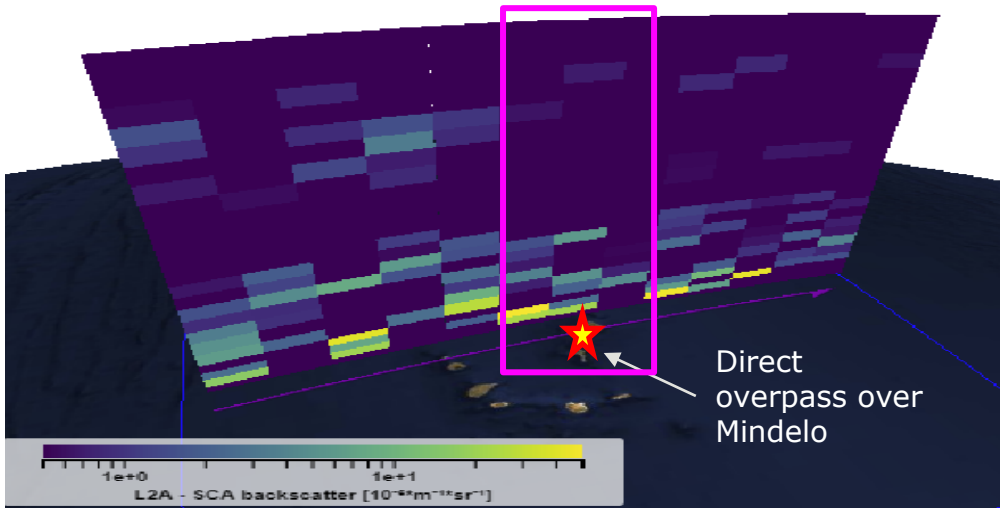
Aeolus vs. PollyXT lidar on Friday 10 September 2021



- Dense and stable dust layer seen from ground
- Aeolus pattern is very patchy

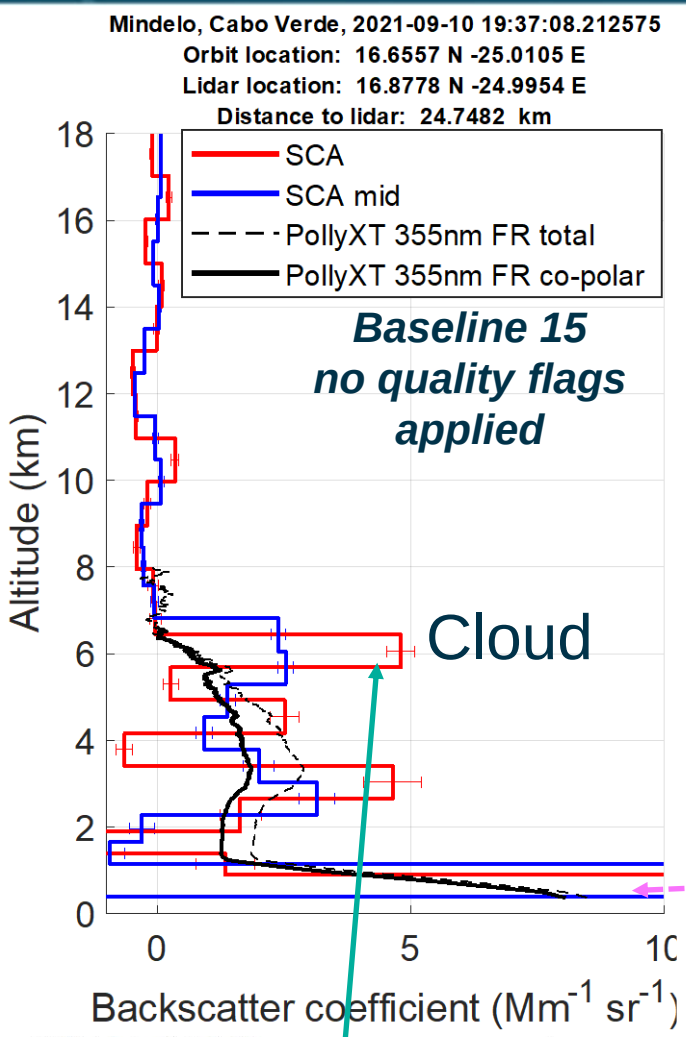
→ Cloud contamination

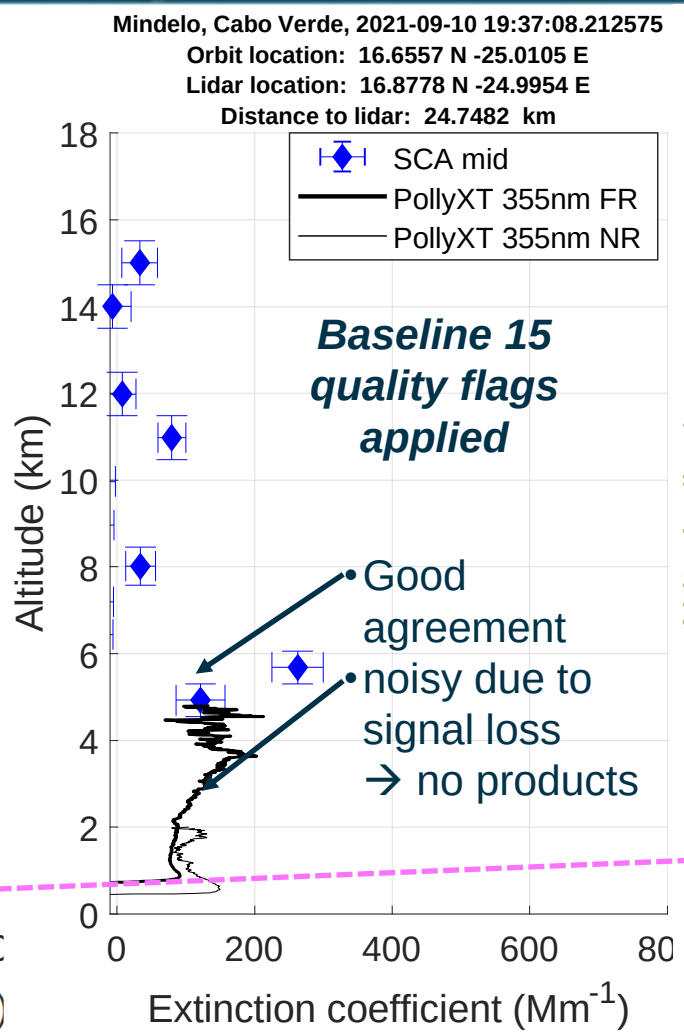
→ Matter of representativeness

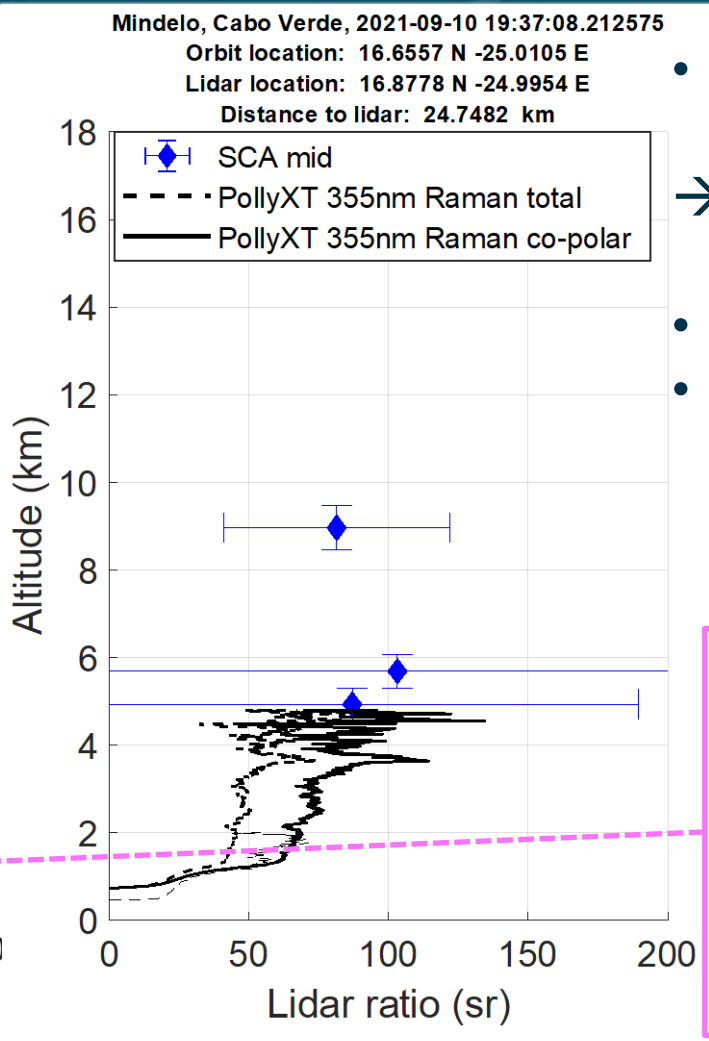


Baseline 15

Friday 10 September: Pure dust @ Mindelo

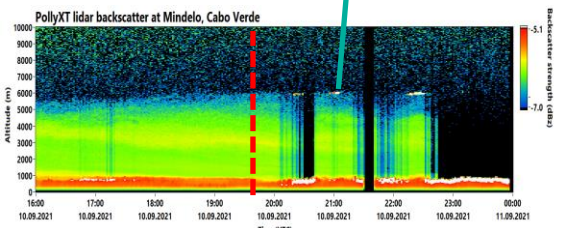






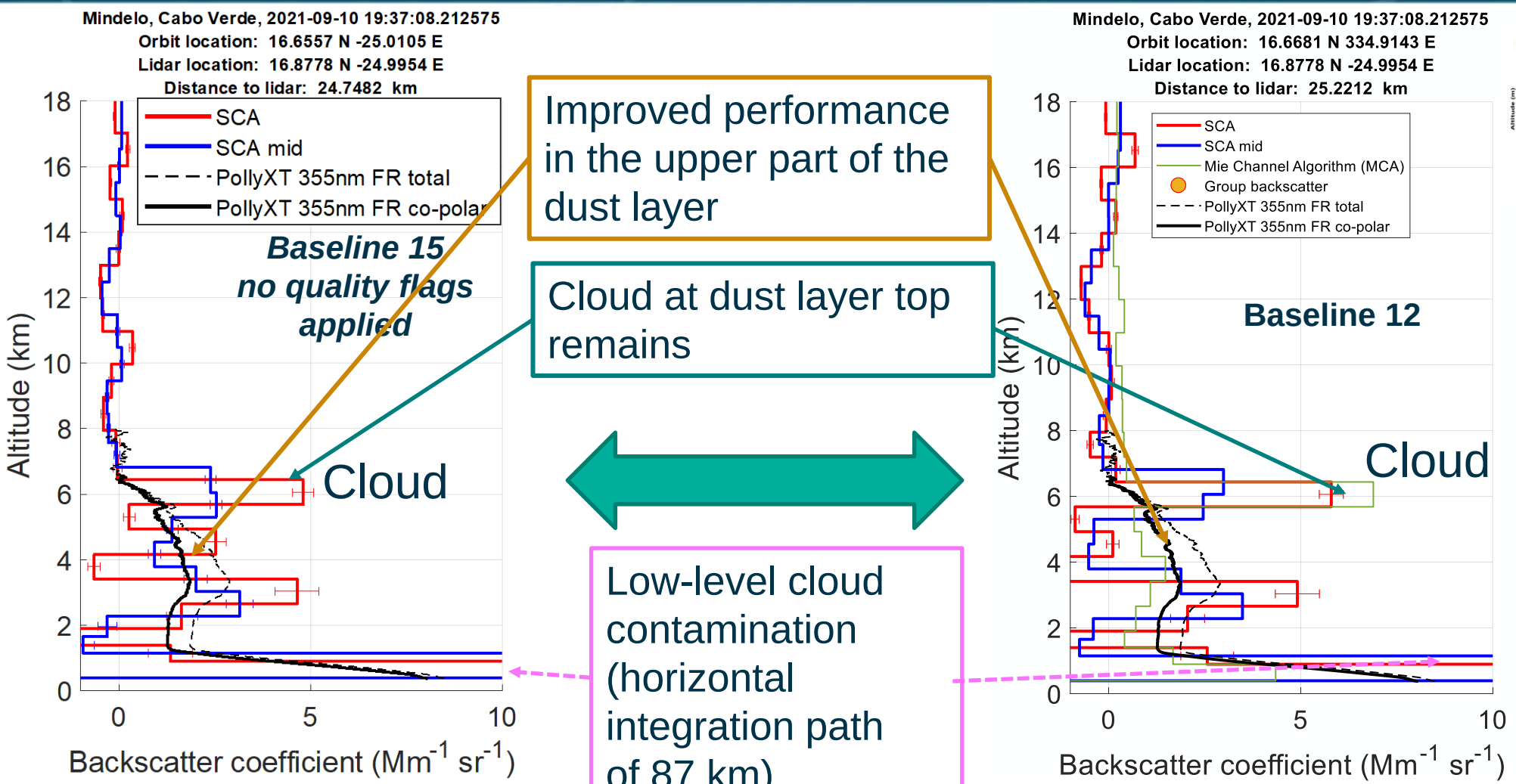
- Good agreement in dust layer center
→**aerosol profiles as spin-off possible**
- Cloud contamination
- Noisy for extinction products (less signal)

Low-level cloud contamination (horizontal integration path of 87 km) or ground return?



Differences between different baselines?

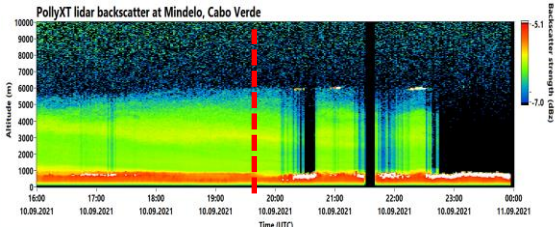
Friday 10 September: 15 vs. 12



Improved performance in the upper part of the dust layer

Cloud at dust layer top remains

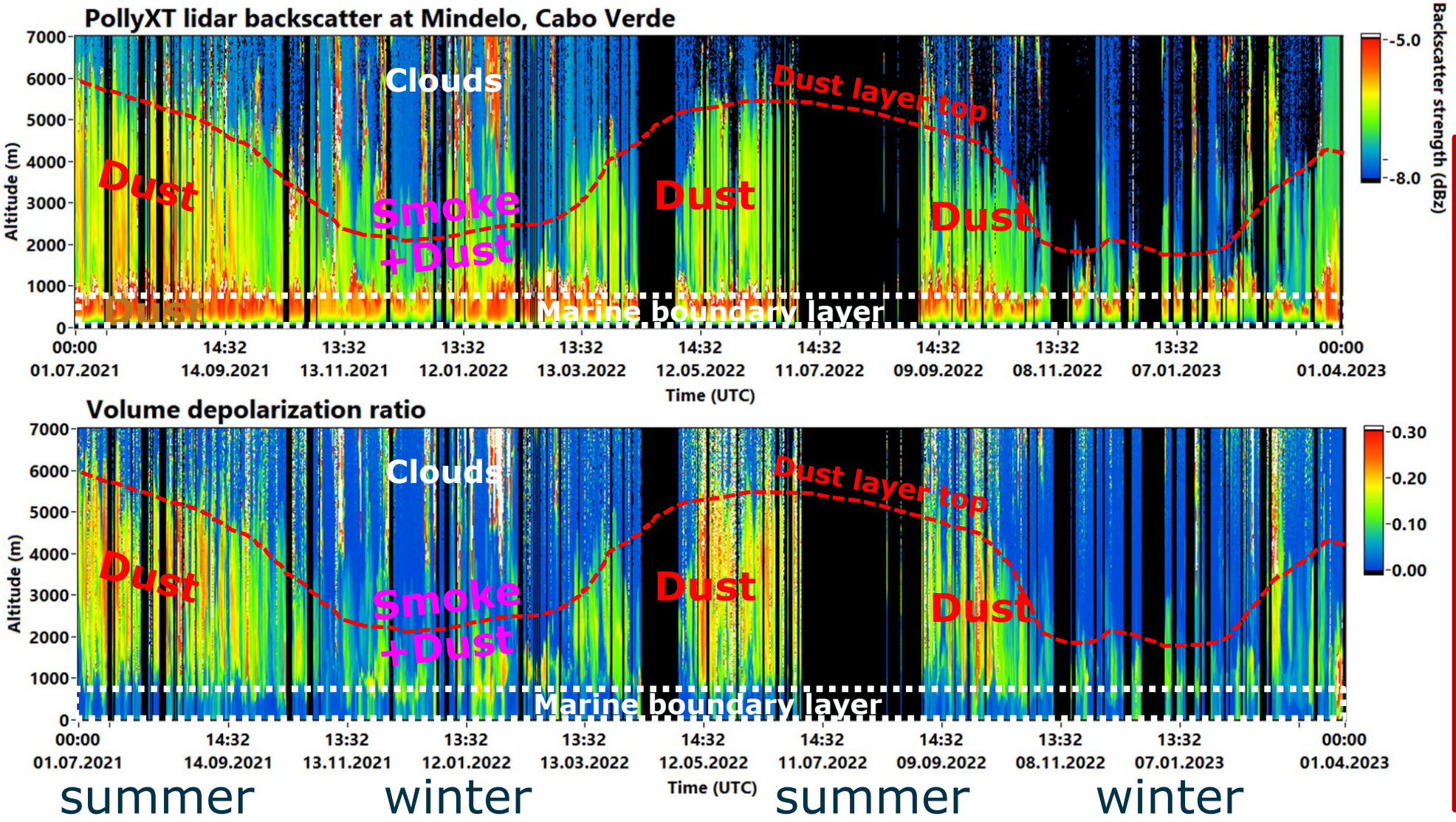
Low-level cloud contamination (horizontal integration path of 87 km)



Steady algorithm improvements

Case studies representative for long-term validation?

Beyond JATAC: Long-term assessment

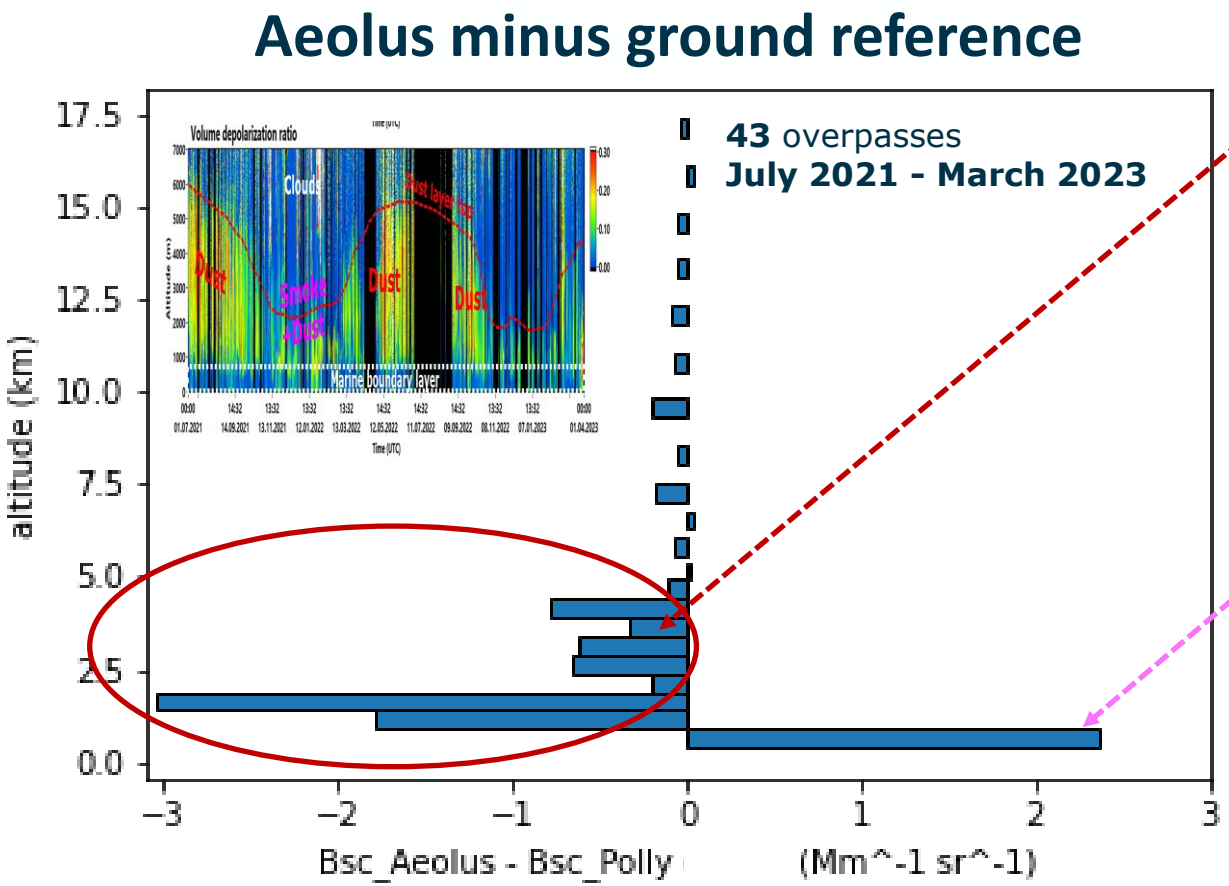


PollyXT ground observation at Mindelo

- Long-term lidar time series for almost 2 years
- Rainy and cloudy cases skipped
- **43** “Friday evening overpasses” between **July 2021 and March 2023**
- Same as used by ECMWF
- Several baselines covered
- In summer dust above local boundary layer up to 4 - 6 km

Beyond JATAC: Long-term assessment

Comparison of backscatter coefficient



Underestimation in the vicinity of dust due to missing depol component

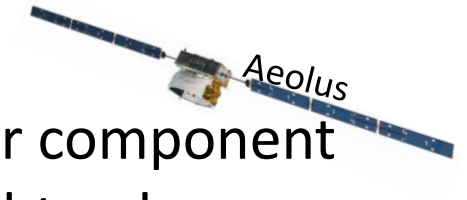
→ Depolarization matters

- Low-level cloud contamination (horizontal integration path of 87 km)
- Or ground contamination?

→ Horizontal resolution matters

- Aeolus emits **circular-polarized** light
- But detects the co-polar component of the backscattered light only
- Signal loss in case of polarizing particles

Reminder: ALADIN emits **circular-polarized** light



Particle type	Linear depolarization ratio	Circular depolarization ratio
Cirrus	~50%	~200%
Ash	~30%–40%	~85%–130%
Dust	~20%–30%	~50%–85%

- But detects the co-polar component of the backscattered light only
- Signal loss in case of polarizing particles

Transformation needed

Most aerosol lidars

Aeolus

underestimated

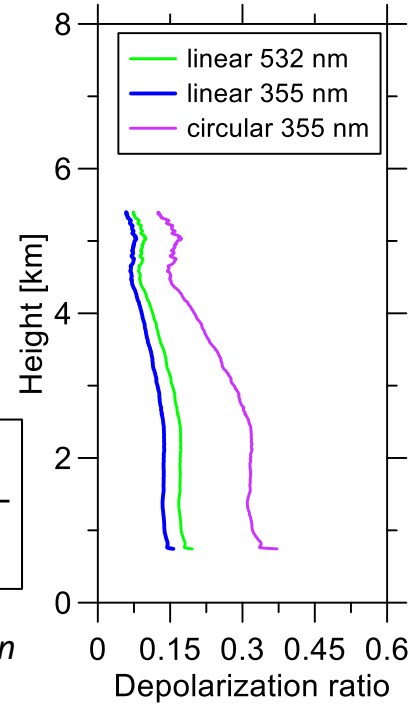
overestimated

linear polarization

$$\delta_{lin} = \frac{\beta_{\perp}}{\beta_{\parallel}}$$

$$\delta_{circ} = \frac{2\delta_{lin}}{1-\delta_{lin}}$$

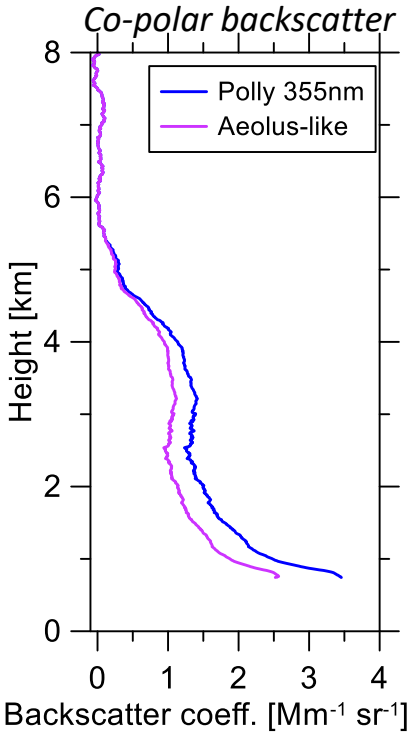
circular polarization



$$\beta_{co} = \frac{\beta_{tot}}{(\delta_{circ}+1)}$$

co-polar backscatter

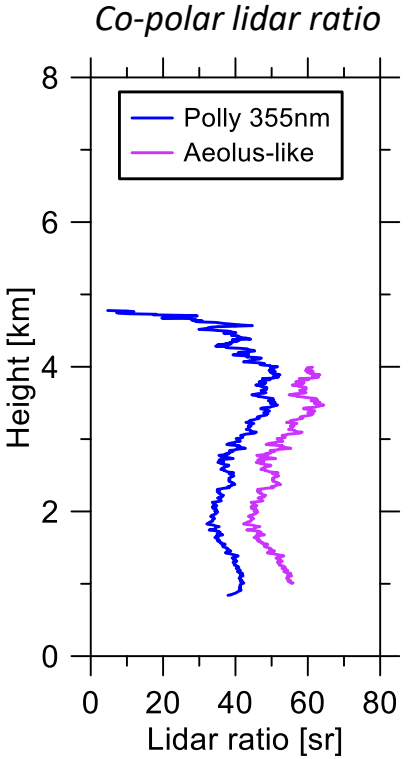
Co-polar backscatter



$$S_{co} = S(\delta_{circ}+1)$$

co-polar lidar ratio

Co-polar lidar ratio

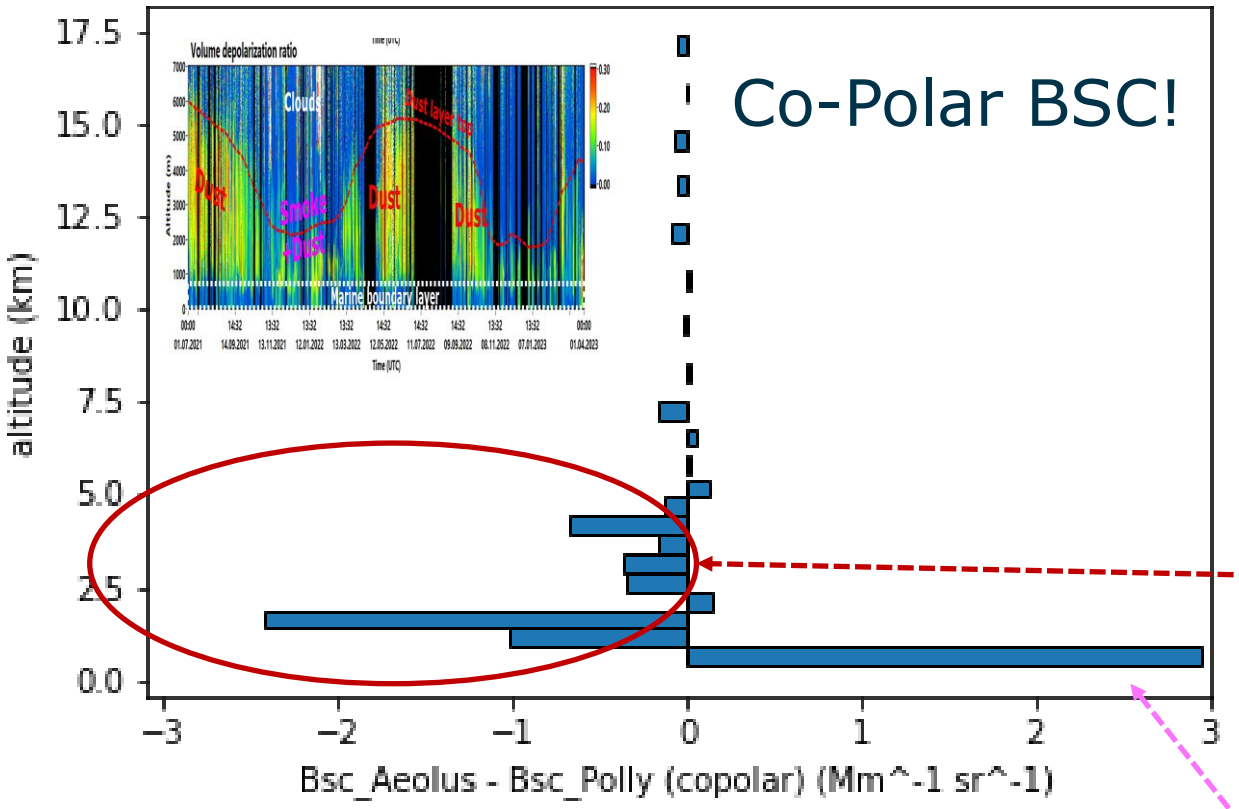


Beyond JATAC: Long-term assessment

Comparison of backscatter coefficient – **co-polar component**

SCA

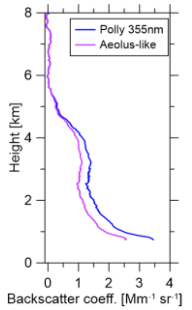
Aeolus minus ground reference



Co-polar backscatter:
"Simulation from the ground-based reference what Aeolus should observe"

circular polarization → *co-polar backscatter*

$$\delta_{circ} = \frac{2\delta_{lin}}{1-\delta_{lin}} \quad \Rightarrow \quad \beta_{co} = \frac{\beta_{tot}}{(\delta_{circ}+1)}$$



- Simulation of co-polar backscatter **improves comparison**,
- but does not compensate everything

→ **other reasons for underestimation as well**

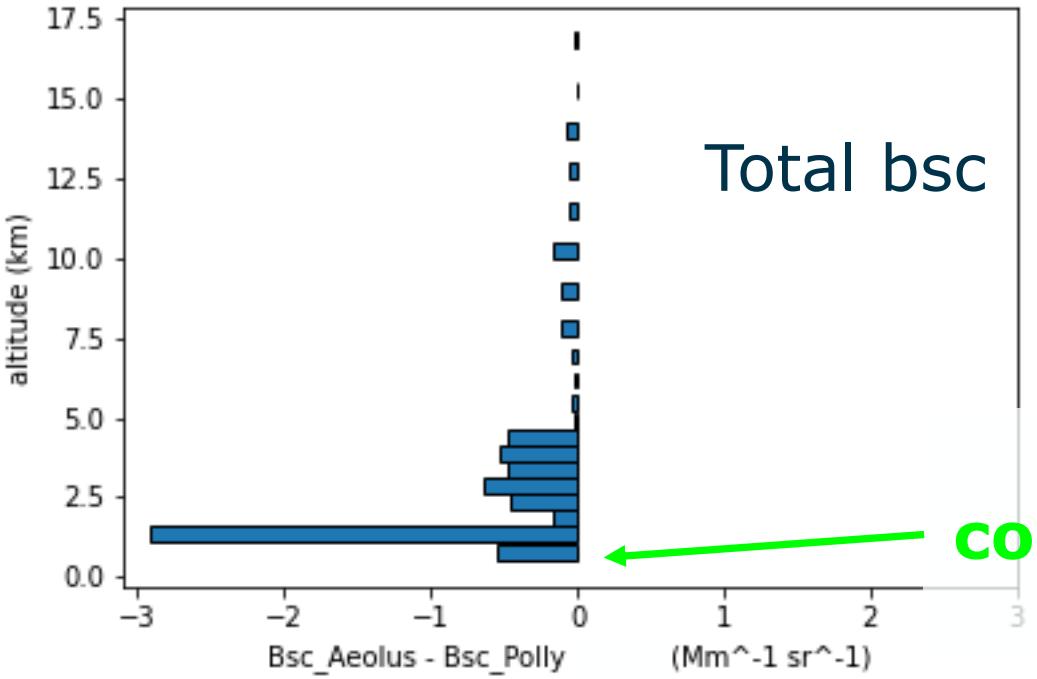
- Low-level cloud contamination remains
  → matter of resolution

Beyond JATAC: Long-term assessment

- 43 “Friday evening overpasses” between July 2021 and March 2023
- rainy and cloudy cases skipped

SCA mid

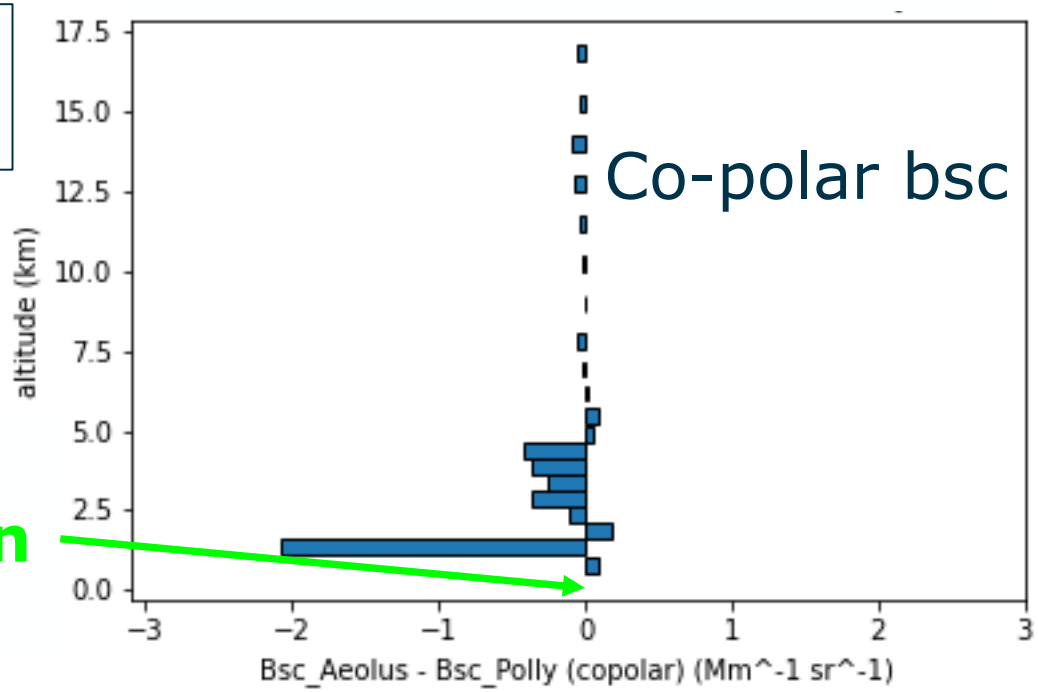
Aeolus minus ground reference



$$\beta_{co} = \frac{\beta_{tot}}{(\delta_{circ} + 1)}$$

No Cloud contamination ?

Aeolus minus ground reference

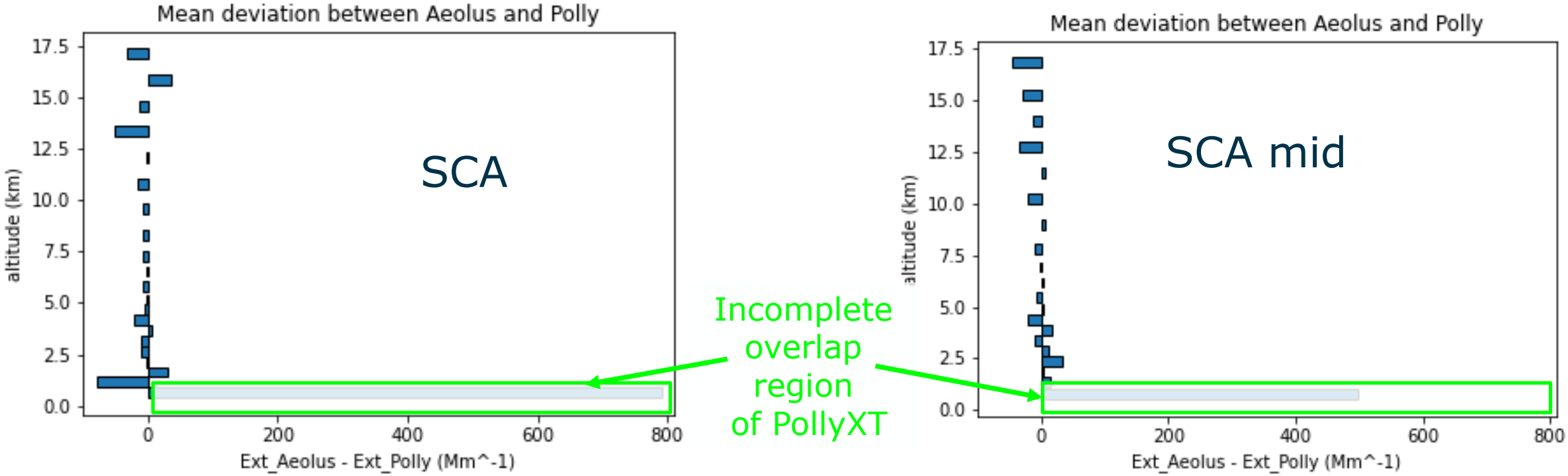


- No cloud contamination in mid products?→ to be investigated
- **Negative bias** in dust layer **remains**

Beyond JATAC: Long-term assessment

- 43 “Friday evening overpasses” between July 2021 and March 2023
- rainy and cloudy cases skipped

Extinction

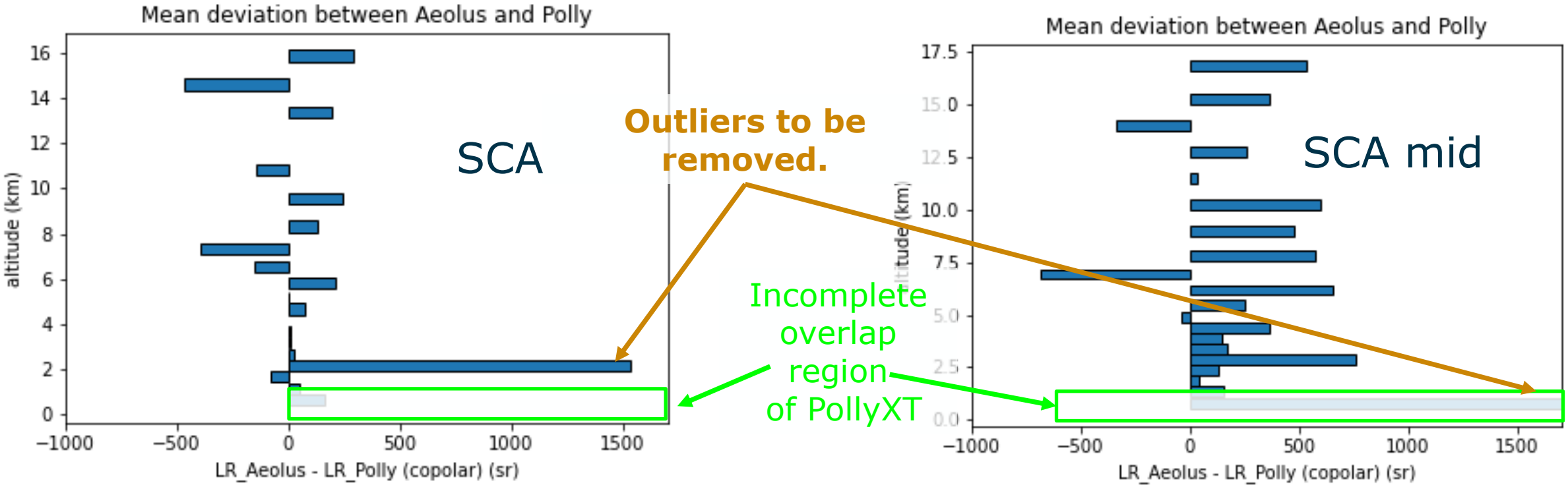


- **No real systematic biases**
- Use of SCA mid for extinction products recommended

Statistics

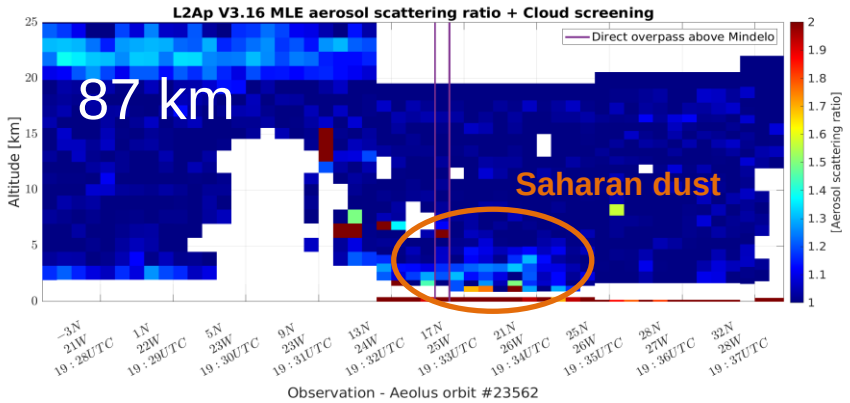
- 43 “Friday evening overpasses” between July 2021 and March 2023
- rainy and cloudy cases skipped

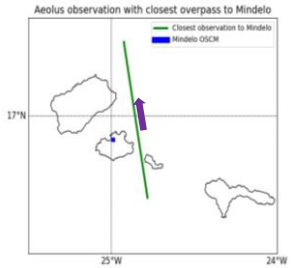
Lidar ratio

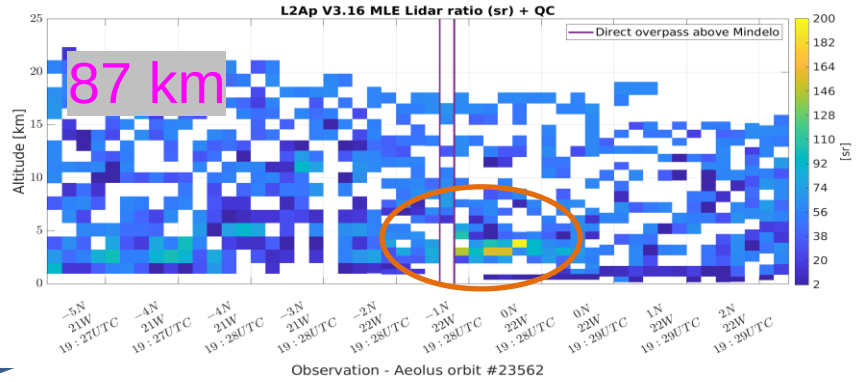


- **No** real systematic (atmospheric explainable) **biases**
- **Not yet a valid** measure for long-term analysis

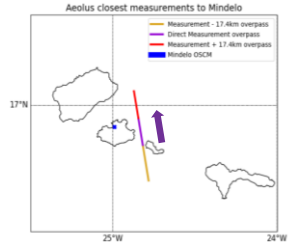
ASKOS 2022: Prototype (B16) development and validation

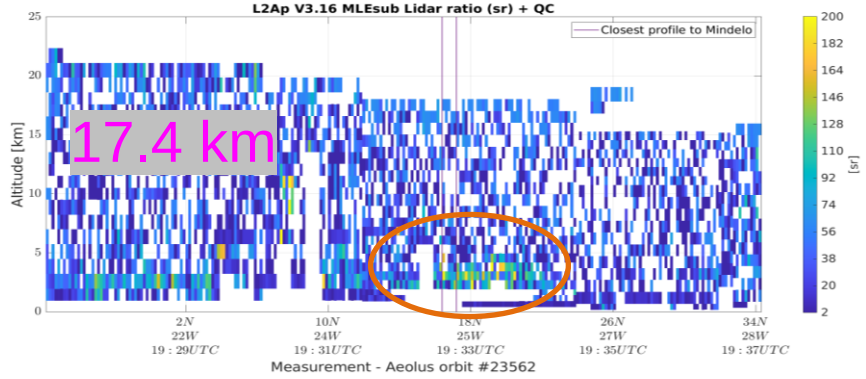






subgrid products

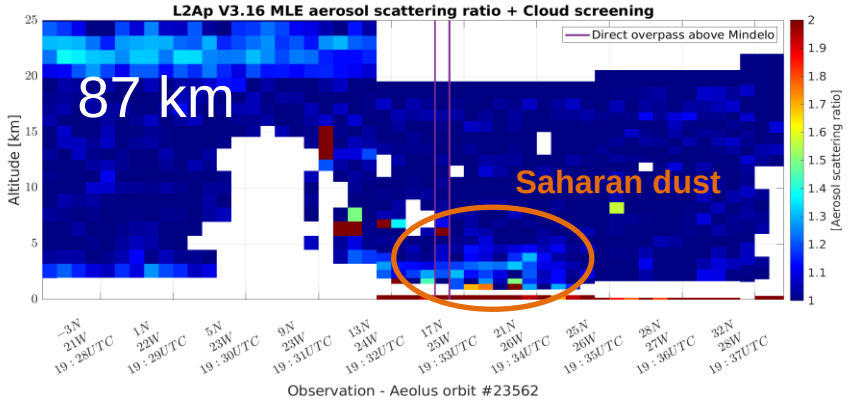


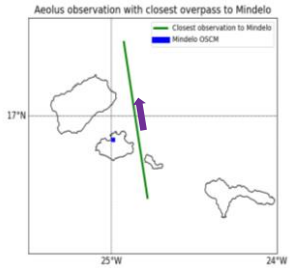


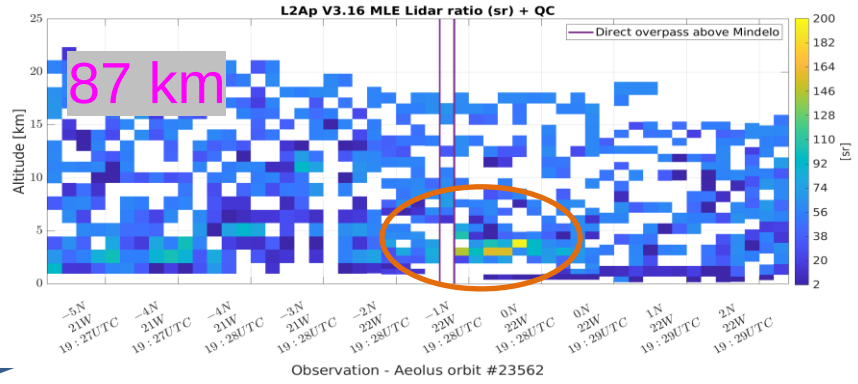
New features of baseline 16: -- see presentation of D. Trapon

- Cloud screening (based on model data)
- Sub-grid products

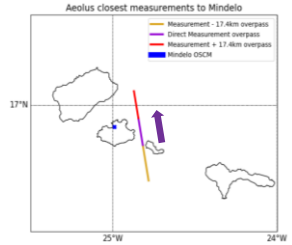
ASKOS 2022: Prototype (B16) development and validation

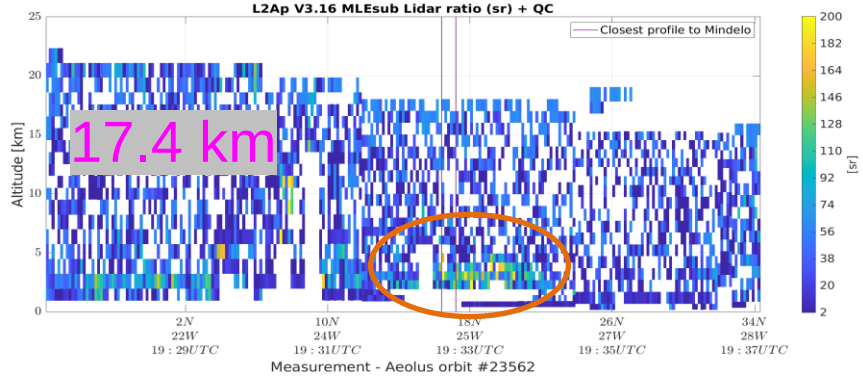


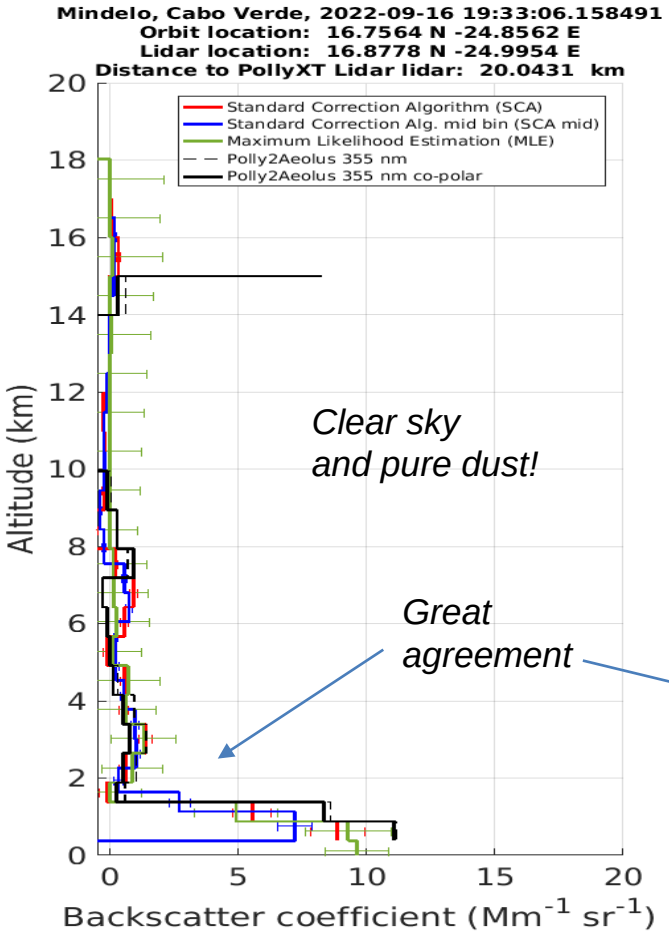


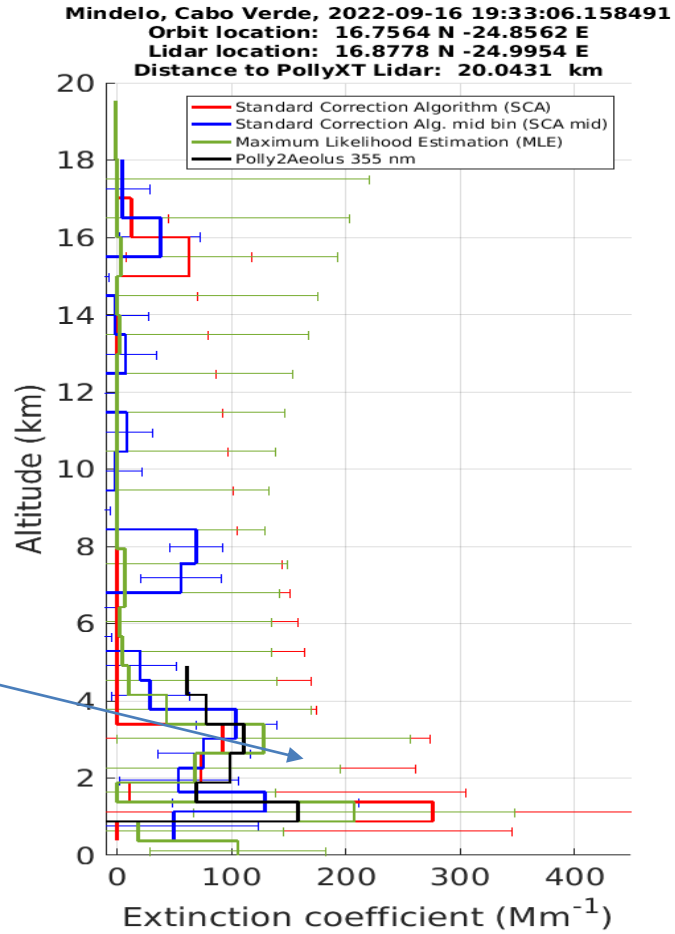


subgrid products





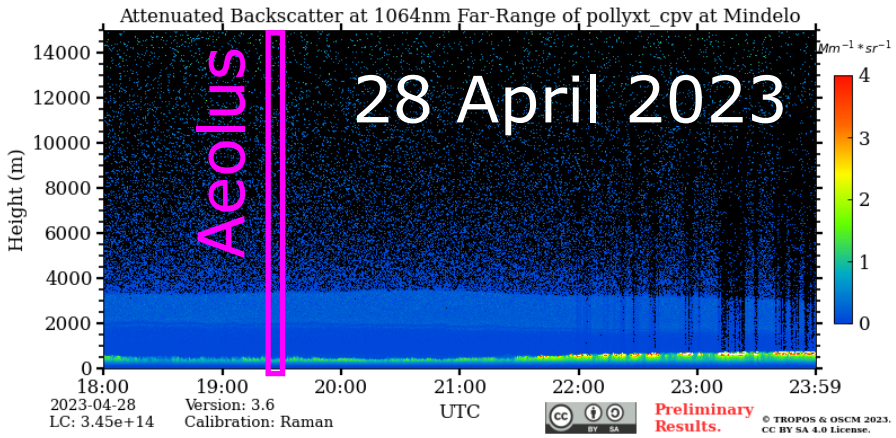




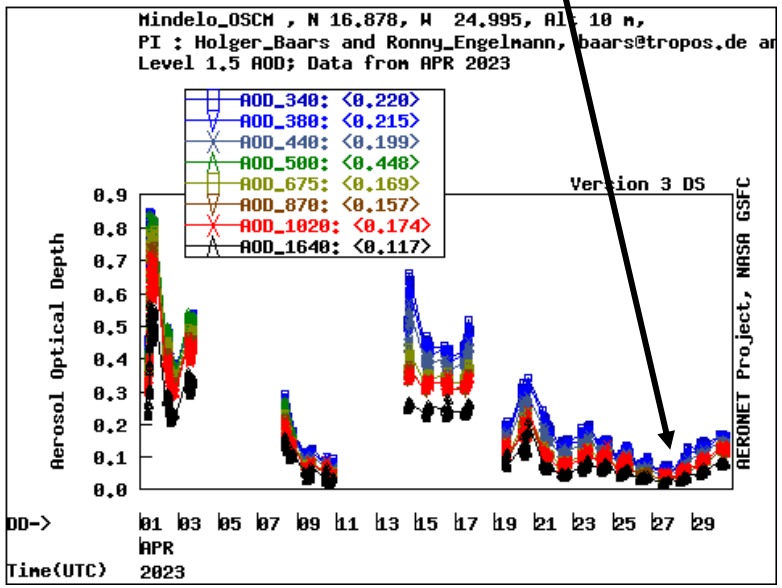
- Cloud screening performing well
- Sub-grid products improve the representativeness of Aeolus aerosol products

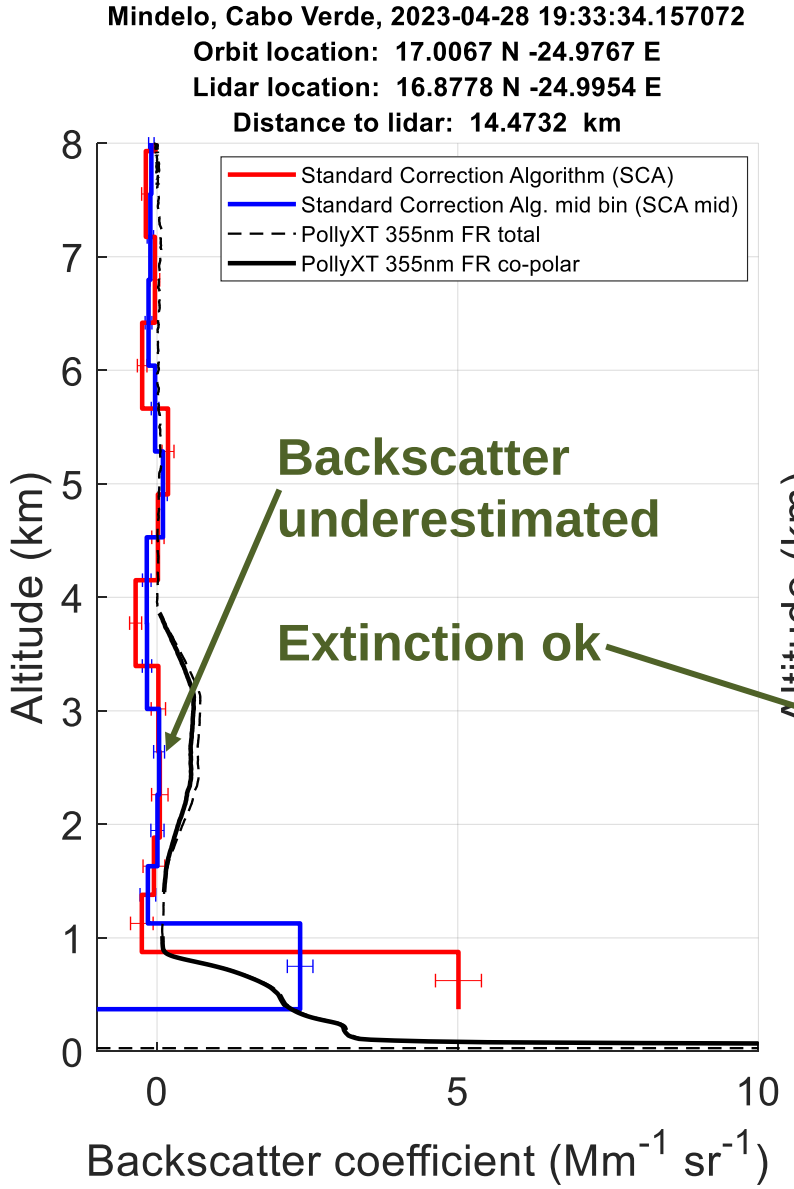
➡ Horizontal Resolution matters

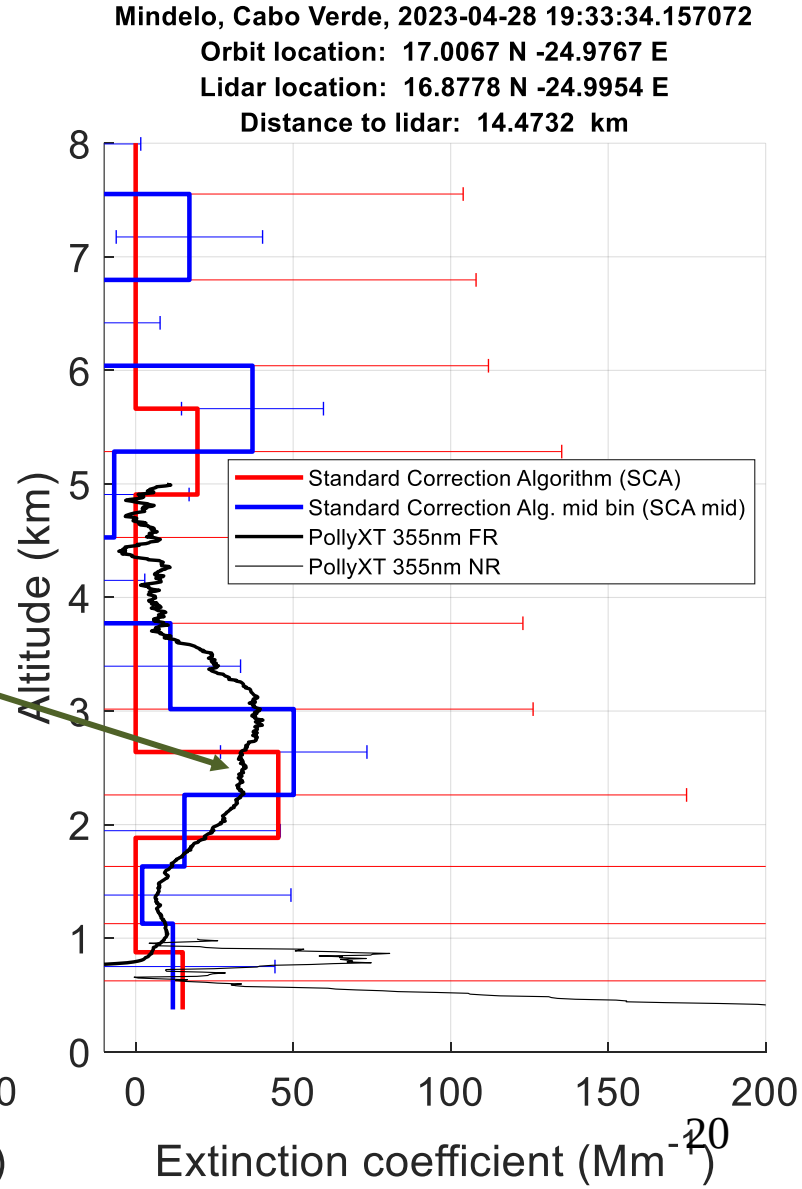
Latest (and last) validation with FM-A (B16) at Mindelo



- No clouds
- Very clean

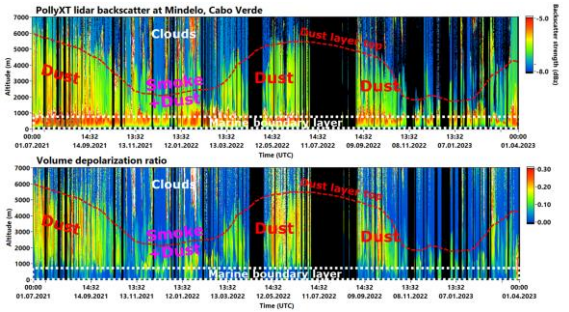






Conclusions

Questions?



- Almost **2 years** of lidar observations in Mindelo
- **Observations continue** in the frame of ACTRIS (25+ years)
- Great data set for Aeolus validation in a **dusty region**:

  →Retrieving **aerosol information** from Aeolus **is possible**

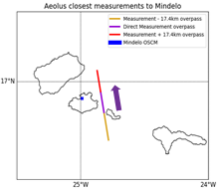
  - **Cloud contamination** due to **coarse resolution** one of the biggest challenge

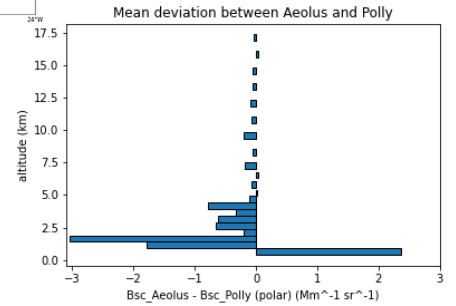
    → For **Aeolus follow-on** (Aeolus-2/EPS-Aeolus), the **highest** possible horizontal and vertical **resolution** shall be aimed for
  - **Underestimation** of the Aeolus backscatter **in dusty regions** due to missing cross-polar detector → **additional noise** due to less signal

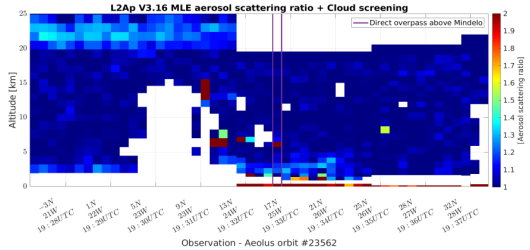
    → **Depolarization channel** for Aeolus follow-on **highly recommended**
  - Steady improvements in retrieval algorithms: e.g., sub grid products, cloud screening, quality flags, etc.

Data visualization:

- *polly.tropos.de*
- *askos.space.noa.gr*
- *aeronet.gsfc.nasa.gov*







Federal Ministry of Education and Research

TROPOS
Leibniz Institute for Tropospheric Research

OSCM
Ocean Science Centre Mindelo

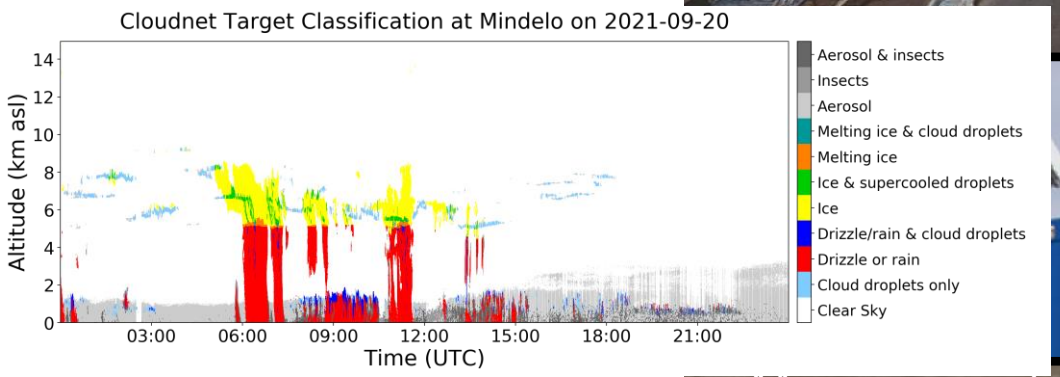
ACTRiS

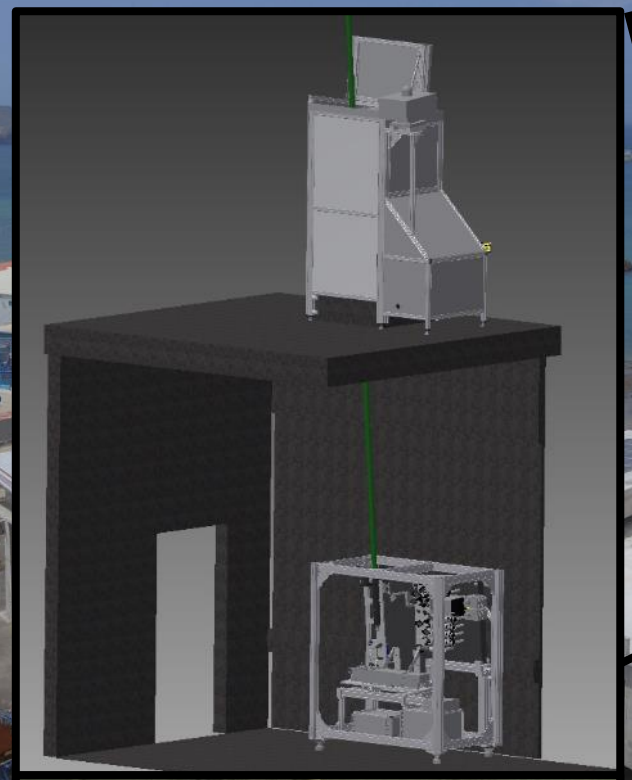
GEOMAR

Further, continuing measurements foreseen in the frame of ACTRIS

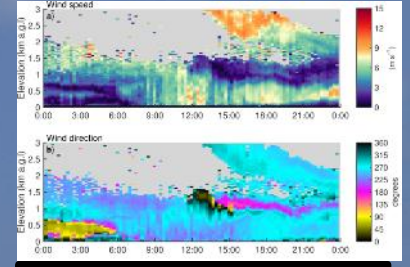
Continuous operation for the next years

- **New aerosol lidar system optimized for dust (PollyXT)**
- **Scanning Doppler wind lidar (HALO)**
- **Cloud radar**
- **AERONET sun photometer**
- **Microwave radiometer**



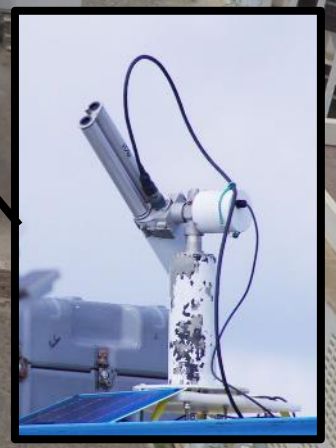


TROPOS Lidar room



Doppler wind lidar

AERONET Sun Photometer



Microwave radiometer