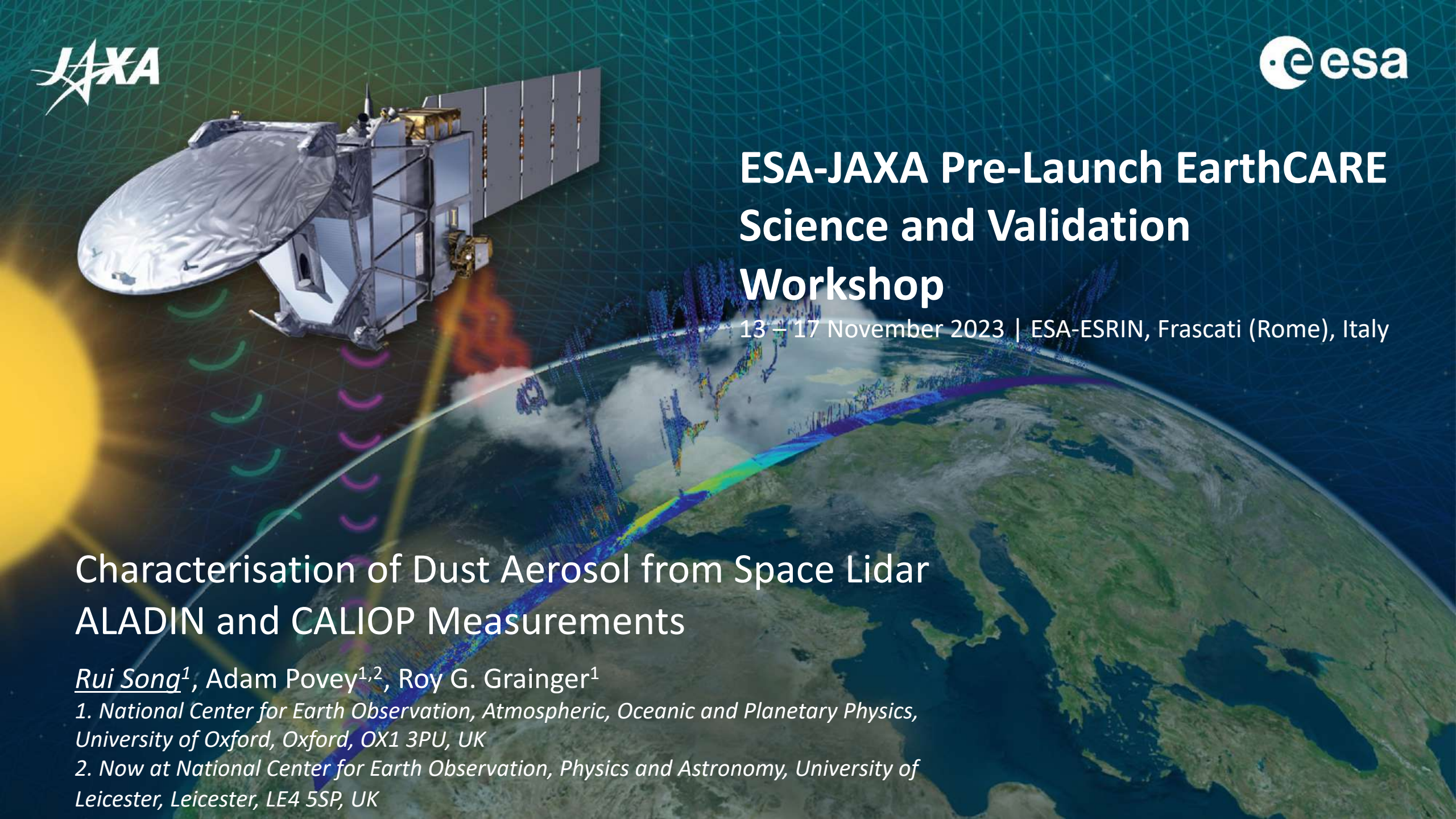

ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop

13 – 17 November 2023 | ESA-ESRIN, Frascati (Rome), Italy

Characterisation of Dust Aerosol from Space Lidar ALADIN and CALIOP Measurements

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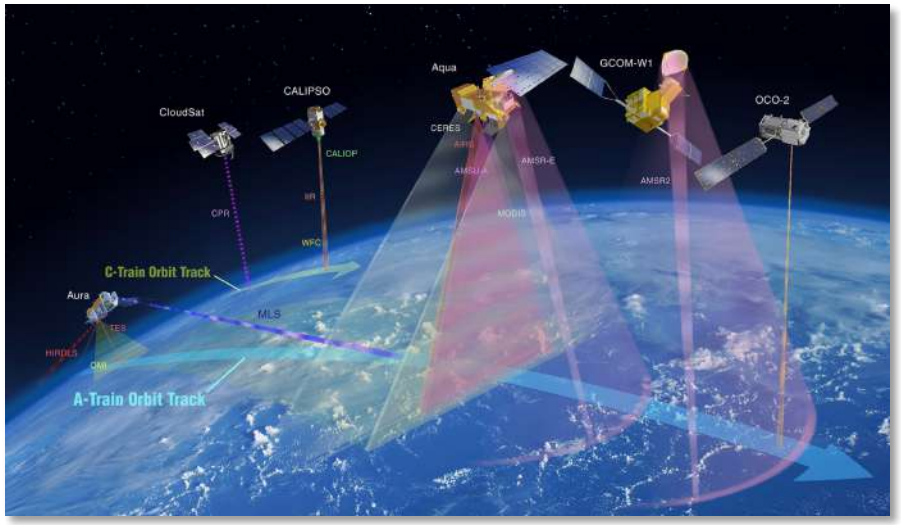
Outlines

- Space Lidar ALADIN and CALIOP
  - AEOLUS mission concept
  - Comparison between ALADIN/AEOLUS and CALIOP/CALIPSO
- Aerosol classification from space Lidar
  - CALIOP aerosol classification scheme
  - ALADIN aerosol and cloud discrimination
- Case study: 2020 Sahara dust
  - Retrievals of aerosol backscatter and extinction coefficients
  - Extinction coefficients at varying altitude layers
  - Correction of CALIOP extinction retrievals using ALADIN-measured lidar ratio
  - Synergy between ALADIN and CALIOP
- Conclusions

ALADIN/AEOLUS vs. CALIOP/CALIPSO



	ALADIN	CALIOP
Polar orbits	✓	✓
~15 tracks per day	✓	✓
Downwards sounding radiation	✓	✓
Detect backscattered signals.	✓	✓
Wavelength	355 nm	532/1064 nm
Observation geometry	35°	Near nadir
detection of particulate and molecular backscattered signals	Split	Joint
detecting aerosol depolarisation		✓

CALIOP aerosol classification

V3 and earlier

- clean marine
- dust
- polluted continental
- clean continental
- polluted dust
- and smoke

V4.1/4.2

Troposphere:

- clean marine
- dust
- polluted continental/smoke
- clean continental
- polluted dust
- elevated smoke
- dusty marine

Stratosphere:

- PSC aerosol
- volcanic ash
- sulfate/other
- elevated smoke

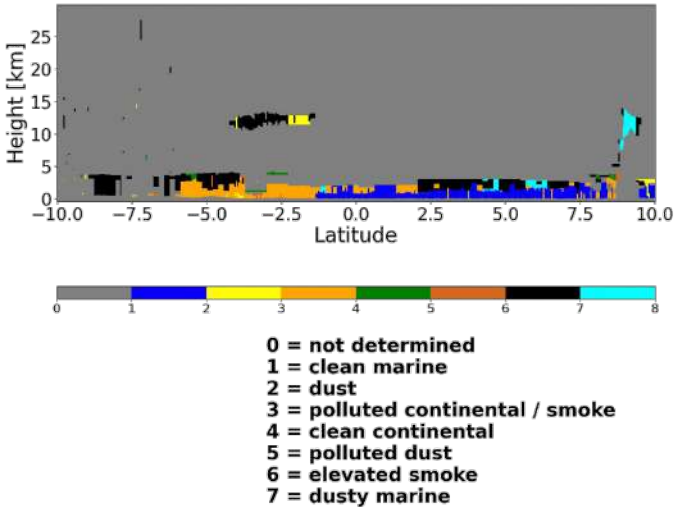
V4.5

Troposphere:

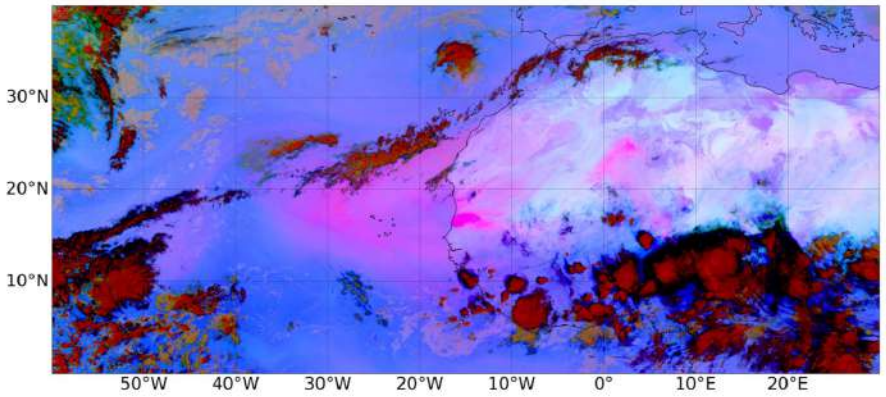
- clean marine
- dust
- polluted continental/smoke
- clean continental
- polluted dust
- elevated smoke
- dusty marine

Stratosphere:

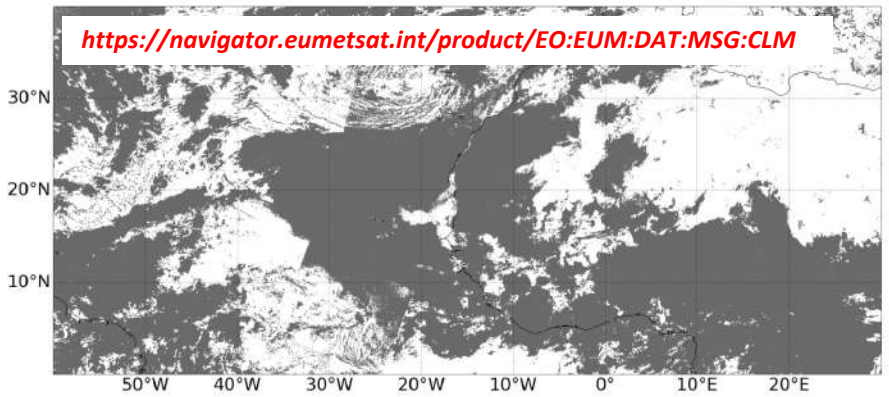
- PSC aerosol
- volcanic ash
- sulfate/other
- elevated smoke



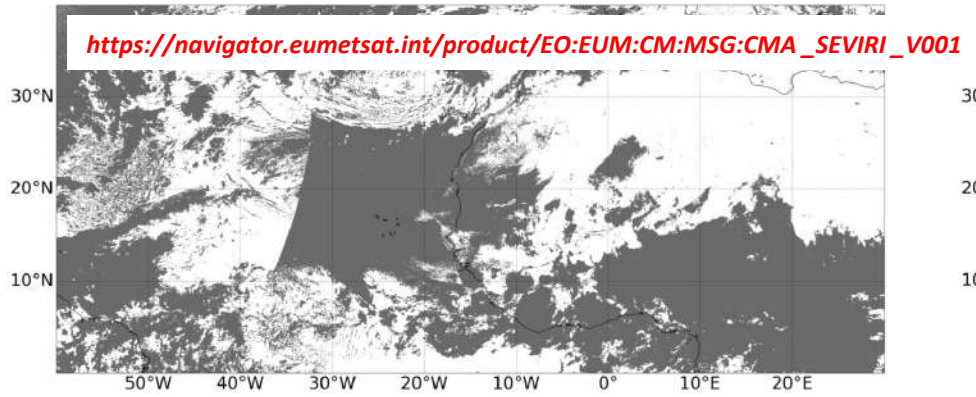
ALADIN aerosol and cloud discrimination



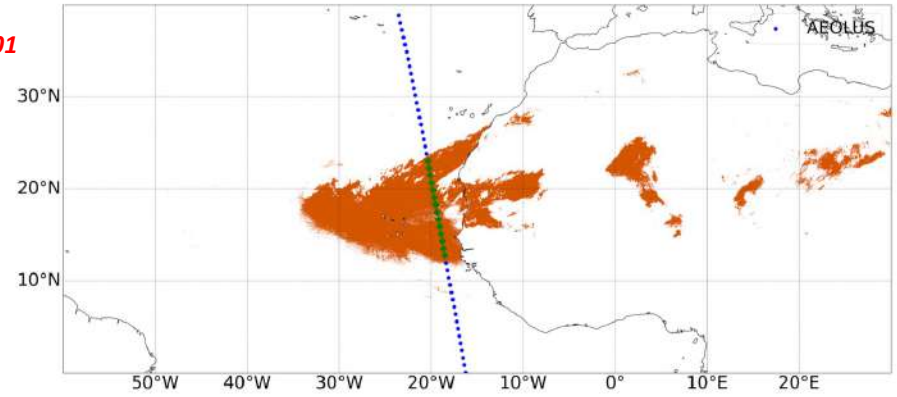
- SEVIRI dust RGB (shades of pink to violet denote dust)



SEVIRI CLM cloud mask



SEVIRI CM SAF cloud mask



SEVIRI dust flag

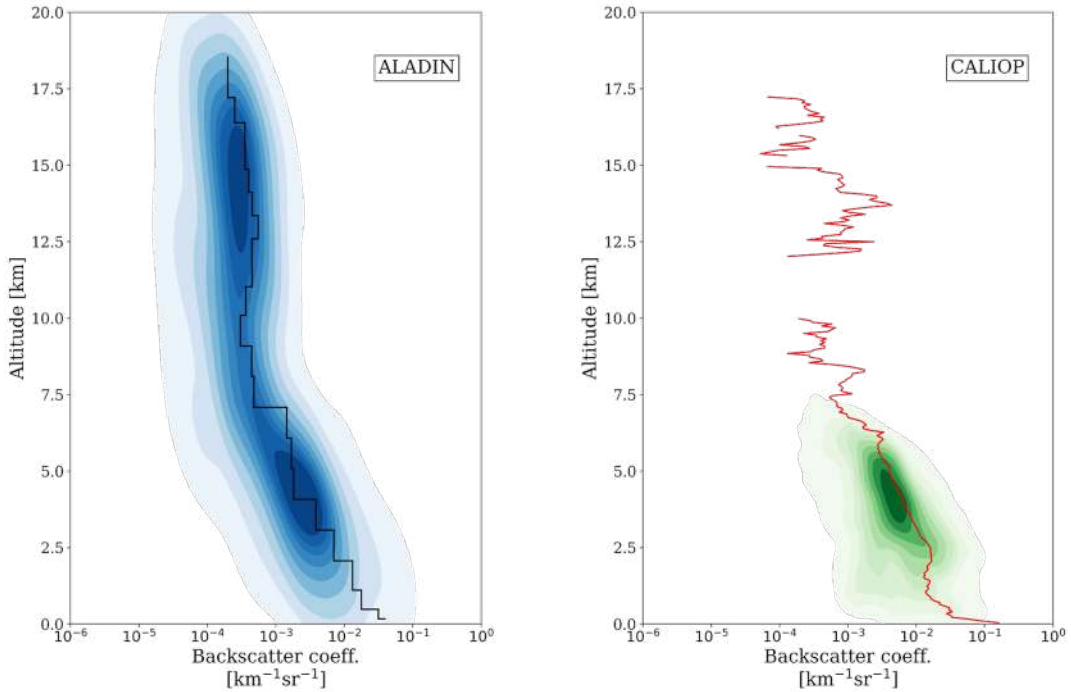
Ashpole and Washington (2012)

Case study: 2020 Sahara dust

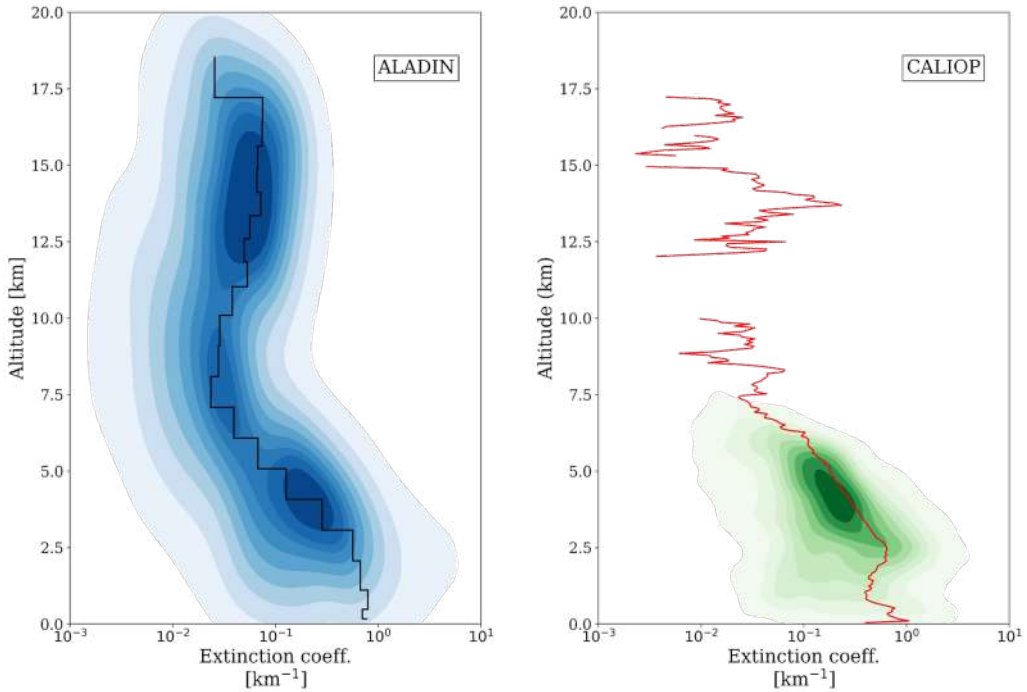
- The most intense dust event over the past two decades
- Elevating dust particles to altitude exceeding 6 km
- Transporting all the way into the Americas across the tropical Atlantic Ocean

Aerosol backscatter and extinction coefficients

Backscatter



Extinction



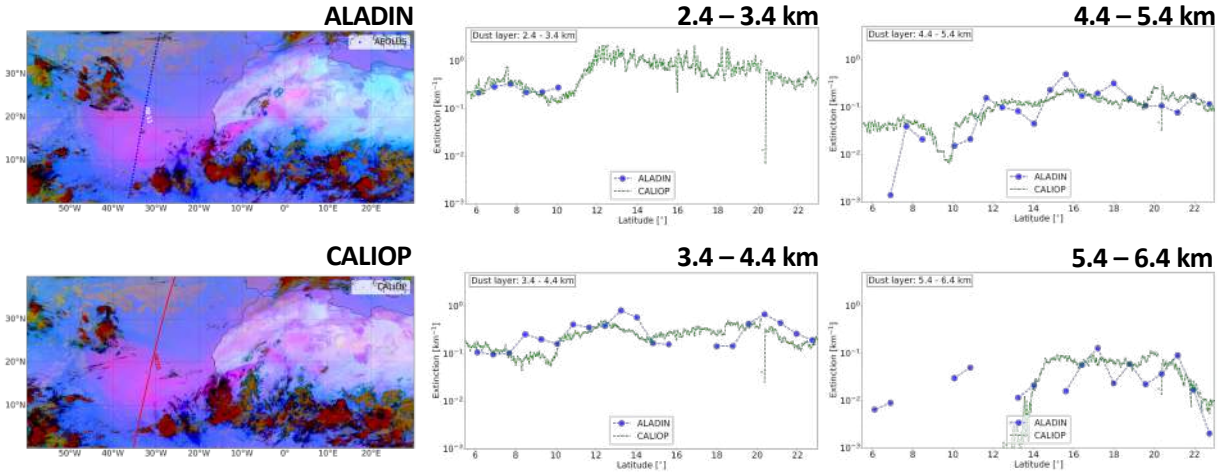
- *Average of all retrievals between 14th - 24th June 2020.*
- *ALADIN backscatter coefficient needs co-polar to total conversion.*
- *Both instruments indicating that the dust ascended up to 7 km.*

Discrepancies are attributed to:

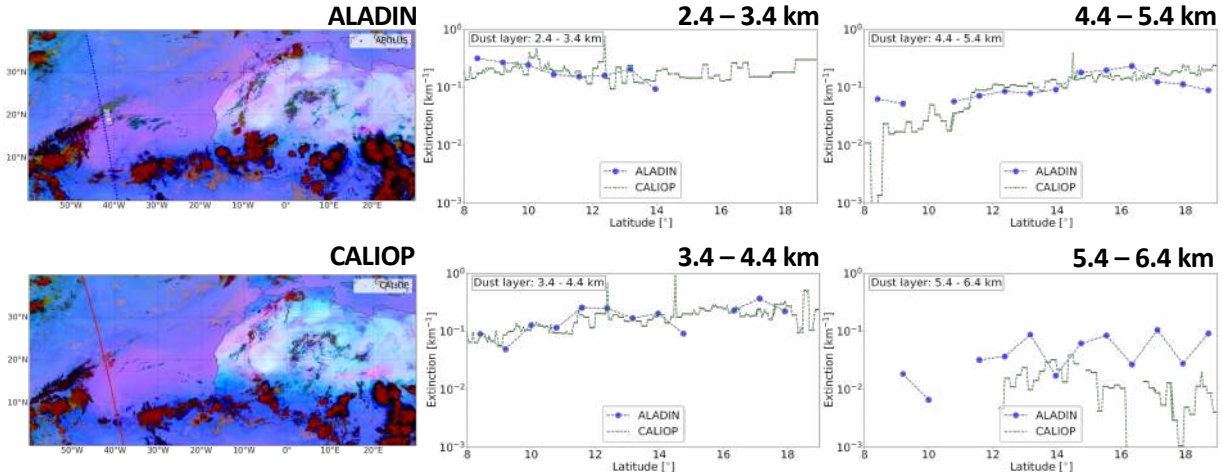
- Different spectral range; (ALADIN 355 nm, CALIOP 532 nm)
- Different overpass time;
- Different spatial sampling rate; (ALADIN 87 km, CALIOP 5 km)

Extinction coefficients at varying altitude layers

24th June 2020



19th June 2020



Collocation:

- CALIOP is ***4 hours*** ahead of ALADIN.

Vertical resolution:

- CALIOP retrievals were upscaled from a vertical resolution of 0.03 km to match ALADIN's ***1-km resolution***.

Dust layer:

- Layers beneath 2.4 km are not included due to the known reduction in accuracy from ALADIN resulting from ***low SNRs***.

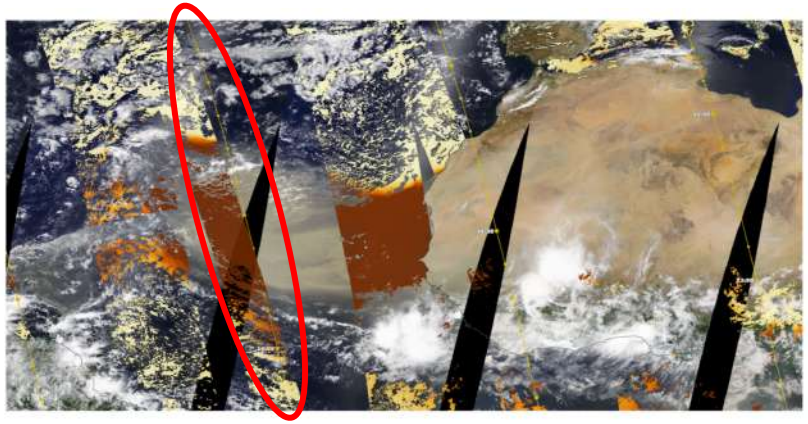
Intercomparison between ALADIN and CALIOP:

- The two extinction retrievals demonstrate good agreement in capturing dust aerosols' spatial distribution.
- At bottom layers (e.g. 2.4 – 3.4 km), ALADIN often fails to provide quality-controlled retrievals, due to heavy attenuation from layers above.

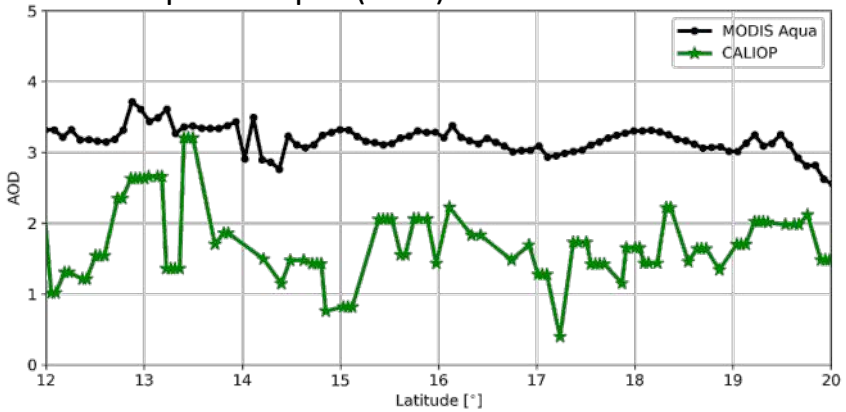
Discrepancy in extinction coefficients:

- Temporal and spatial variability in two Lidar observations.
- Different retrieval method: CALIOP relies on ***Lidar Ratio***, ALADIN does not.

Lidar Ratio from two space lidars



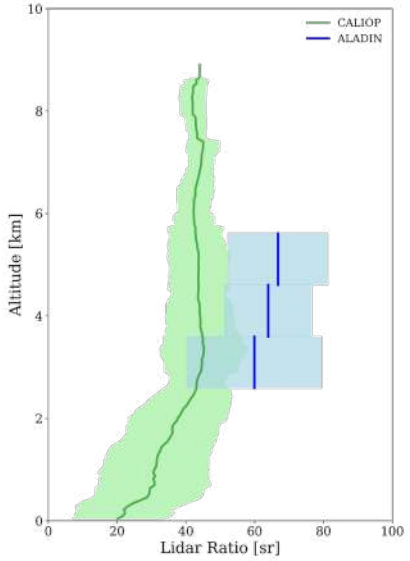
Collocated MODIS and CALIPSO measurements can be used to evaluate the total aerosol optical depth (AOD)



CALIOP underestimates AOD (CALIOP measurements with attenuated bins have been removed)

$$LR(\text{Lidra Ratio}) = \frac{\alpha\ (\text{extinction coefficient})}{\beta\ (\text{backscatter coefficient})}$$

- Elastic backscatter lidar (CALIOP): relies on *LR* to retrieve the extinction coefficients
- High spectral resolution lidar (ALADIN): directly measures *LR*, but extinction retrieval is ***independent*** of *LR*



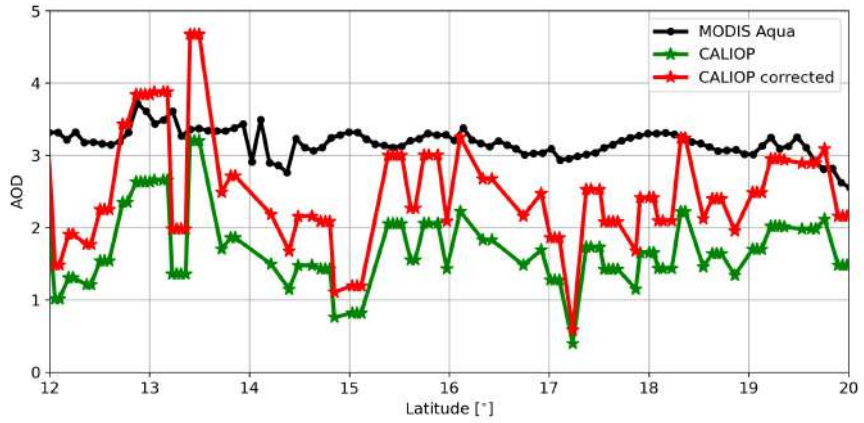
Dust lidar ratio:

$$LR_{CALIOP} = 43.5\ sr$$

$$LR_{ALADIN} = 63.5\ sr$$

Correction of CALIOP extinction coefficients

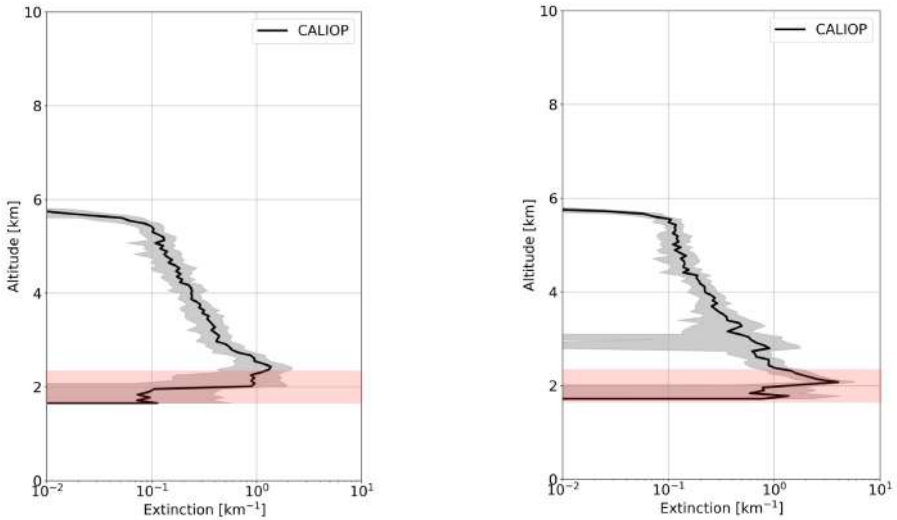
	lidar Ratio (lr)		
	$LR_{355\ nm}$	$LR_{532\ nm}$	$LR_{355\ nm}$ / $LR_{532\ nm}$
Feb 2021 (Haarig et al., 2022)	47 sr	50 sr	0.94
Mar 2021 (Haarig et al., 2022)	49 sr	46 sr	1.07
Jan 2008 (Groß et al., 2011)	63 sr	63 sr	1.0
May 2006 (Tesche et al., 2009)	55 sr	56 sr	0.98



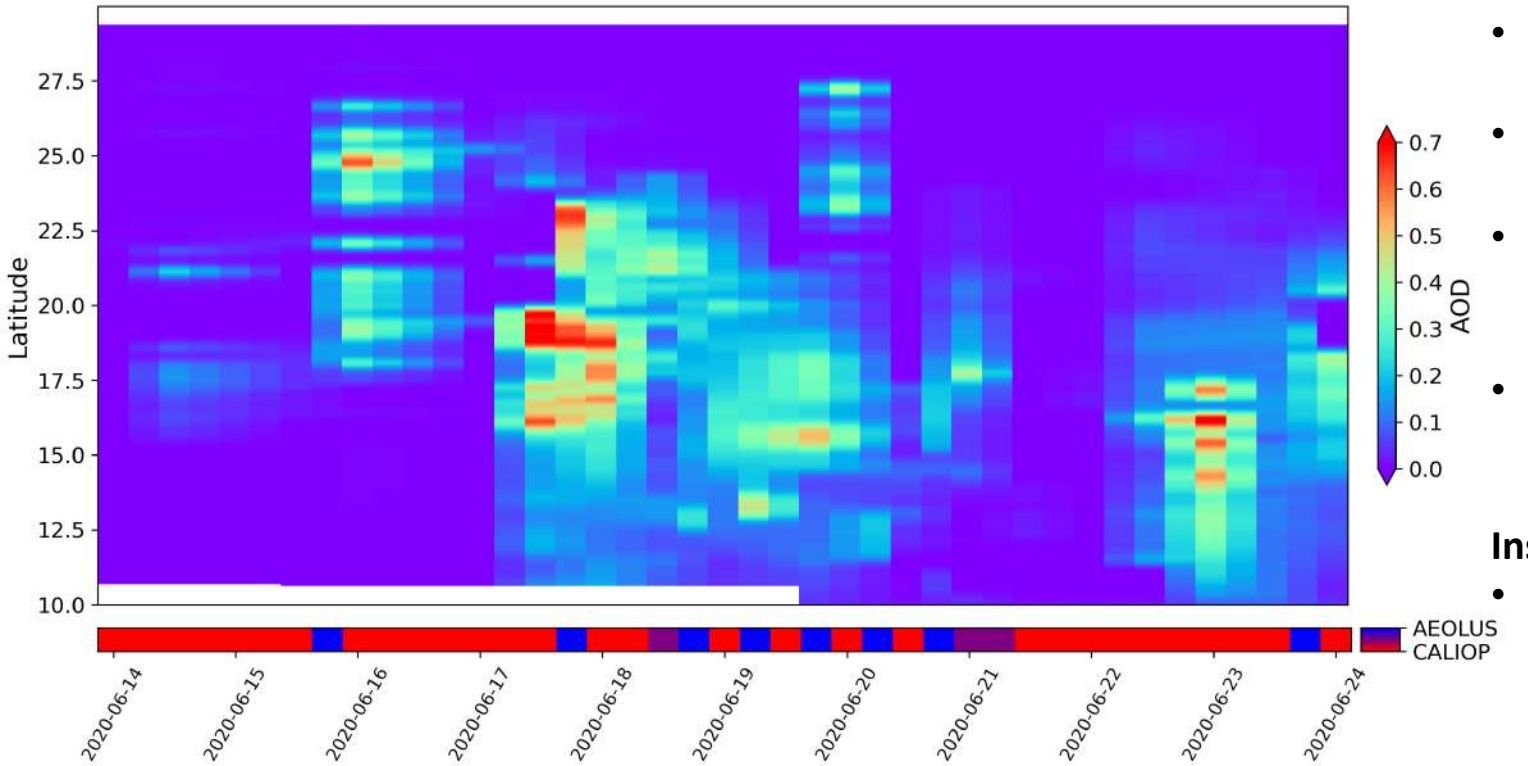
	Dust layer AOD	
	layer between 0 and 2.4 km	layer between 2.4 and 7 km
Total column AOD < 1.8	0.413 ± 0.443	1.015 ± 0.365
Total column AOD > 1.8	1.094 ± 0.884	1.021 ± 0.542

Multiple experiments with ground-based Raman lidars and airborne HSRLs have demonstrated no wavelength dependence of dust lidar ratios at 355 and 532 nm.

From collocated observations, apply ALADIN measured lidar ratio (at 355 nm) on CALIOP extinction retrievals (at 532 nm)



Synergy between CALIOP and ALADIN



- Align well in detecting the dust aerosols that ascended to a height of 4.5 - 6.5 km on the 16th and 17th.
- The peak was noted by the end of the 17th, when the layer AOD surpassed 0.7.
- The dust aerosols remained confined within this region, and were continuously observed by the two satellites over the subsequent 5 days.
- Consistent with reanalysis data from ECMWF and trajectory data from HYSPLIT.

Insights:

- The growing presence of atmospheric lidars in space is expected to enhance synergies among different lidars
  - **EarthCARE** (scheduled for launch in 2024)
  - **AEOLUS-2** (expected by the end of the decade)

Conclusions

- Due to the absence of depolarization measurements, ALADIN faces challenges in effectively differentiating aerosols and clouds. To address this, this study uses collocated SEVIRI measurements to create a dust mask specifically for ALADIN observations;
- During the the 2020 Sahara dust event (14^{th} – 24^{th} June), averaged retrievals reveal a good agreement in both backscatter and extinction coefficients;
- Within the bottom layer of the dust, ALADIN's extinction retrievals are strongly affected by diminished SNRs as a result of signal attenuation;
- A large discrepancy in total AOD is observed when comparing collocated A-Train data from CALIOP and MODIS;
- Our experimental results underscore that using the lidar ratio derived from ALADIN observations can notably enhance CALIOP's extinction retrievals.
- Overall, this research demonstrates the potential of spaceborne HSRL ALADIN in aerosol retrievals and offers invaluable insights for forthcoming HSRL missions such as EarthCARE and AEOLUS-2.