Profiling Saharan Airborne Dust with UAV-based in-situ Instrumentation during the ASKOS Experiment in Cape Verde

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**Climate and Atmosphere Research Center (CARE-C), The Cyprus Institute (CyI)*

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 856612 and the Cyprus Government. If approved, DAZSAL will be supported under Horizon 2020 through the ATMO-ACCESS Integrating Activity under grant agreement No 101008004.

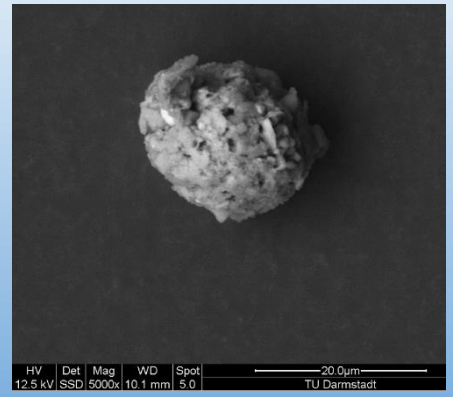
Many thanks to the Cesaria Evora International Airport and the Ocean Science Centre Mindelo for their support, which has been decisive for the success of this campaign.

ASKOS Campaign Objectives

- Evaluate the Aeolus L2A aerosol and cloud product
- Estimate the uncertainty in the Aeolus backscatter caused by the undetected cross-polar signal return from dust particles
- Estimate the impact of particle orientation in Aeolus products for mineral particles and ice crystals
- Provide quality assured datasets for a number of applications

→ e.g. improvements in desert dust modelling and sea salt emission estimations

- Study Sahara dust properties over Cape Verde



Atmos. Chem. Phys., 20, 12955–12982, 2020
https://doi.org/10.5194/acp-20-12955-2020

Atmospheric Chemistry and Physics Open Access EGU

Models transport Saharan dust too low in the atmosphere: a comparison of the MetUM and CAMS forecasts with observations

Debbie O'Sullivan[1], Franco Marenco[1], Claire L. Ryder[2], Yaswant Pradhan[1], Zak Kipling[3], Ben Johnson[1], Angela Benedetti[3], Melissa Brooks[1], Matthew McGill[4], John Yorks[4], and Patrick Selmer[4]

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[3]European Centre for Medium-Range Weather Forecasts, Reading, RG2 9AX, UK
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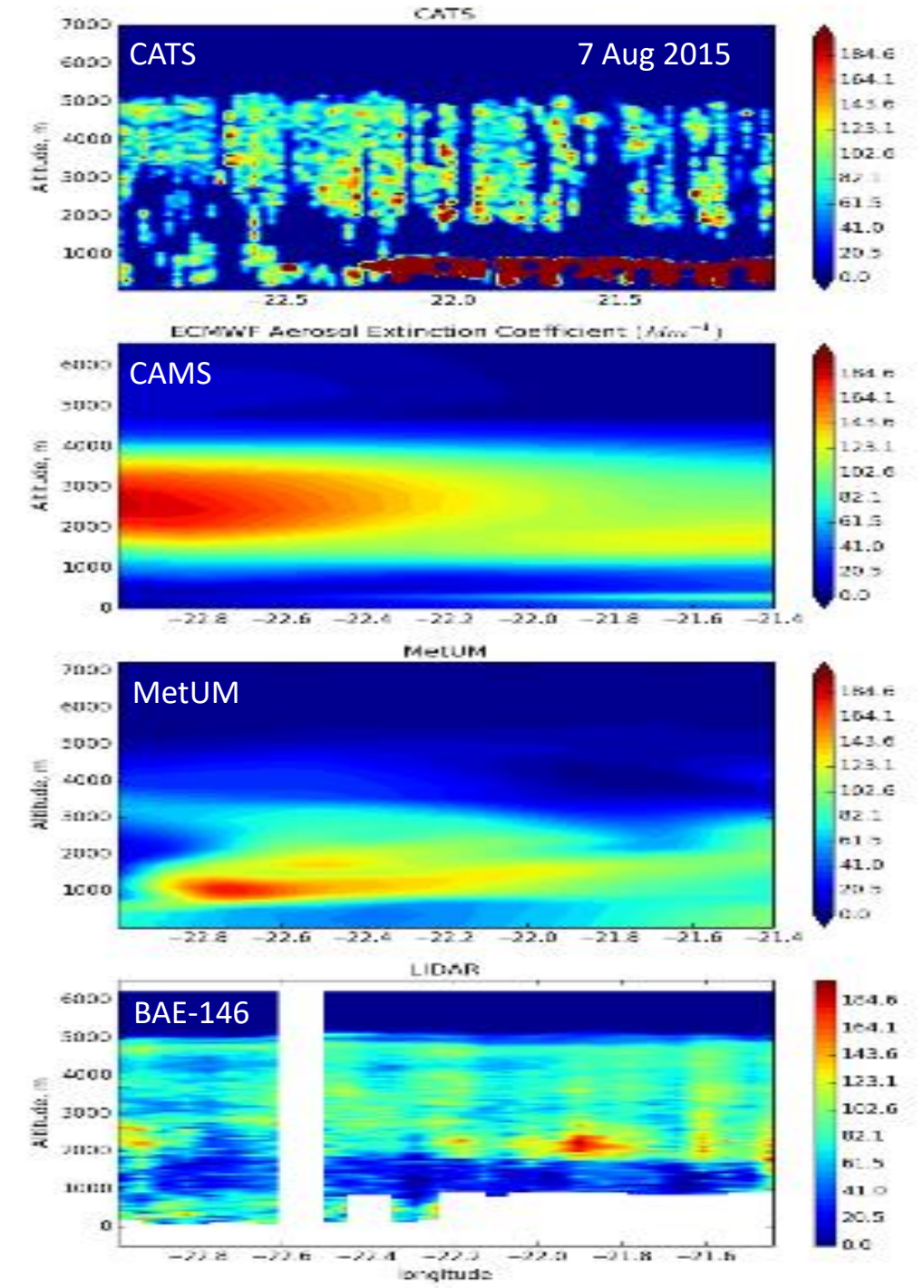


University of Reading

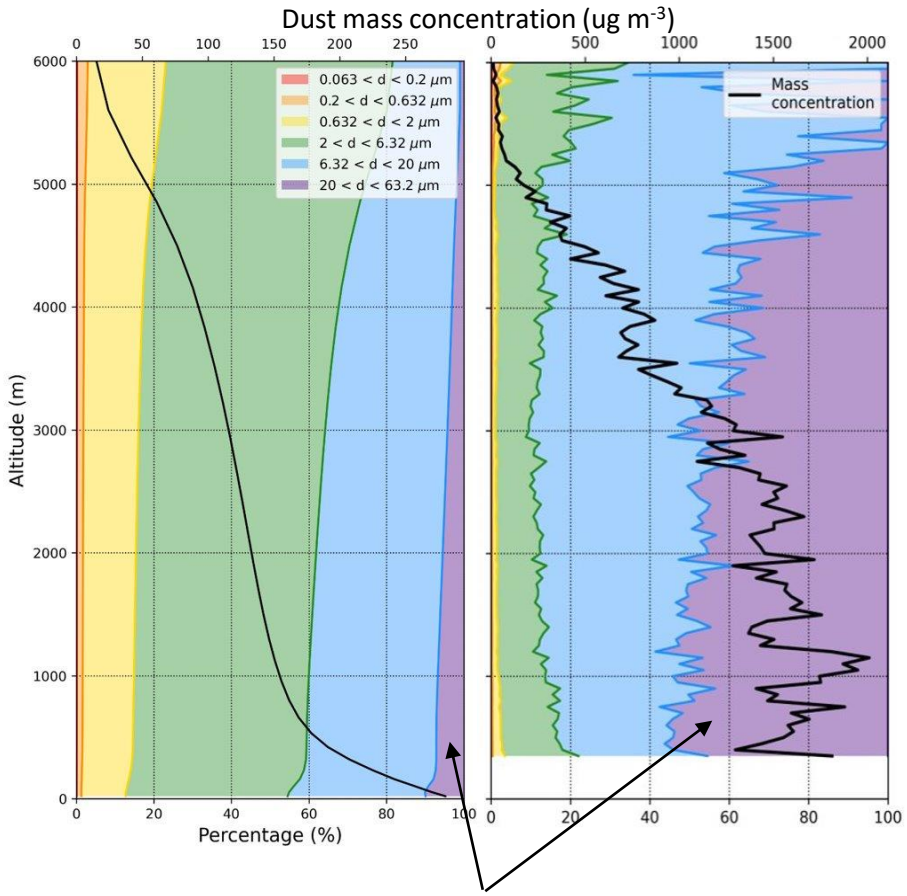
DAZSAL

Diurnal vAriation of the vertically resolved siZe distribution in the Saharan Air Layer

Claire Ryder (UoR), Natalie Ratcliffe (UoR), Angela Benedetti (ECMWF)

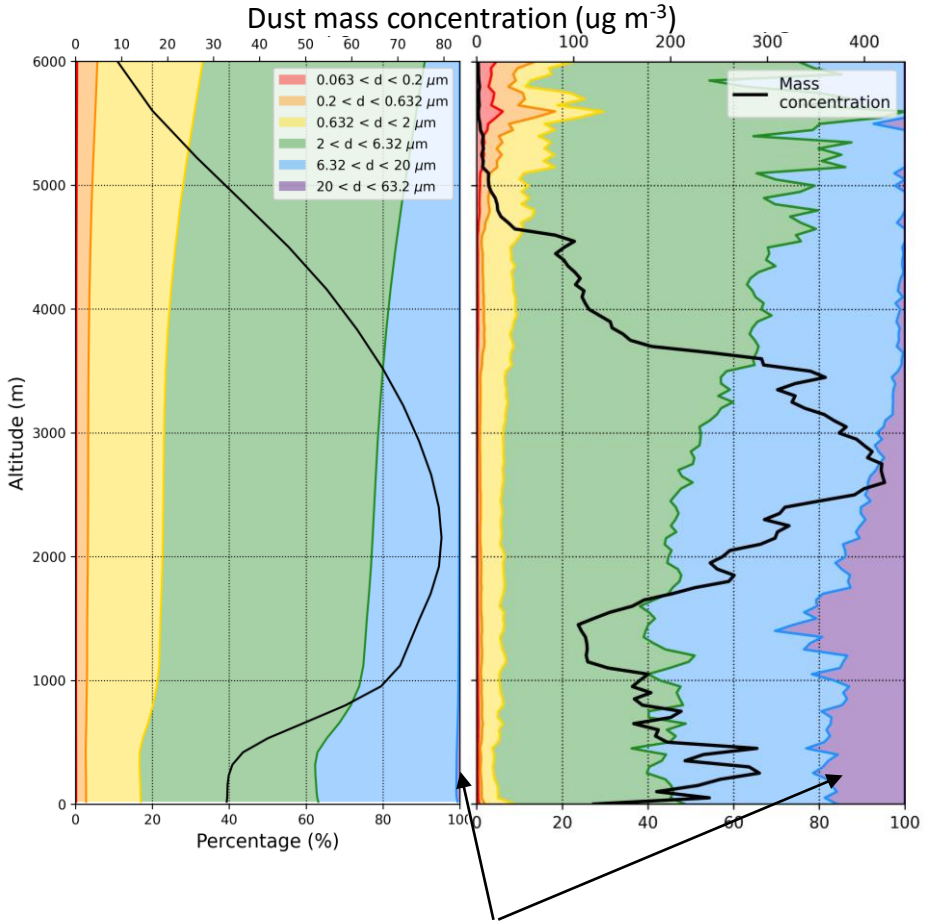
In Collaboration with CyI, Franco Marenco

Sahara



Model underestimates mass concentration especially of coarse particles.

Cape Verde



The model deposits the largest particles too quickly so that they are negligible in quantity at Cape Verde.

Model: June climatology (5-year modelled June mean) (HadGEM3A)
Observations: Mean of all campaign flights per location (Fennec for Sahara, AER-D for Cape Verde)

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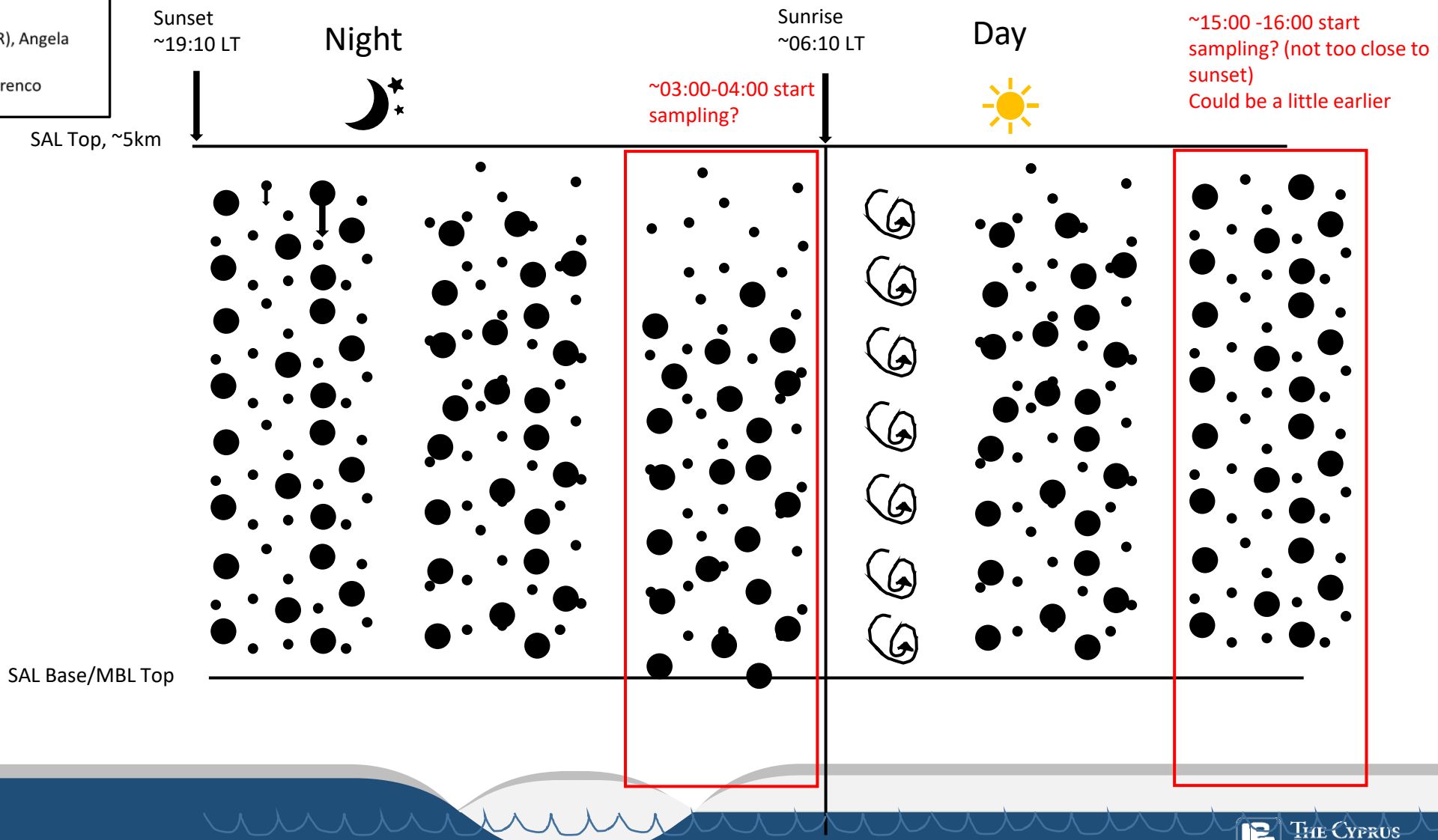
DAZSAL Sampling Times

DAZSAL Hypothesis



Mindelo City

A dust-free day

A "normal" day

ASKOS instrumentation: VARDUST-SAL Spanish contribution

VARDUST-SAL campaign: **variability of dust composition and dust properties** in the core path of the Saharan Air Layer

PI: Sergio Rodríguez

contribution of **VARDUST-SAL** to **ASKOS**

measurements of:

- **aerosol chemistry (1h resolution)**, PIXE elemental composition (Si, Al, Fe, Na, Mg, Mn, S, K, Ca, Sr, Cl, Ti, Cu, V, Ni, Zn, Br, Cr…)
- **aerosol scattering and back scattering**, **3 λ**
- **aerosol absorption**, **7 λ**

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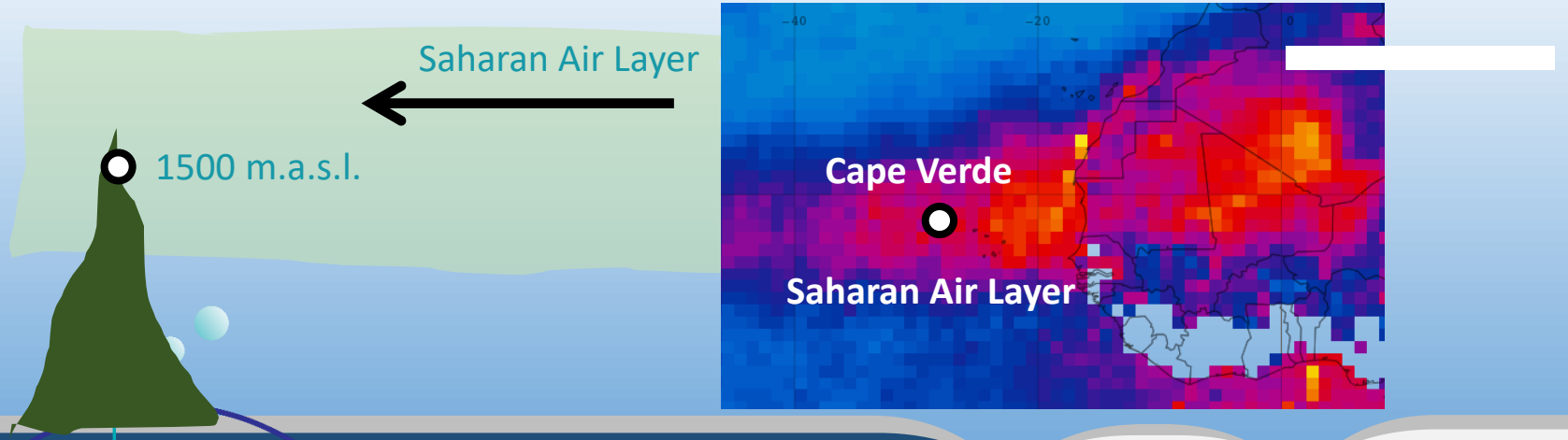
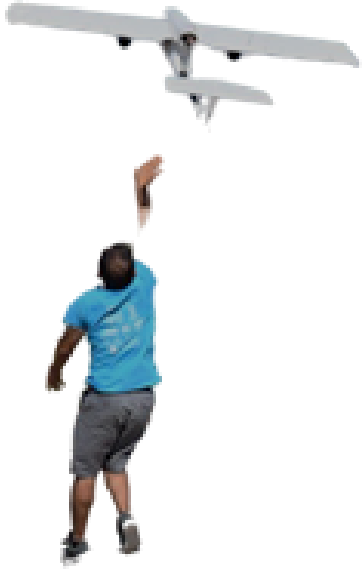
into the high altitude (1500 m.a.s.l.) Saharan Air Layer

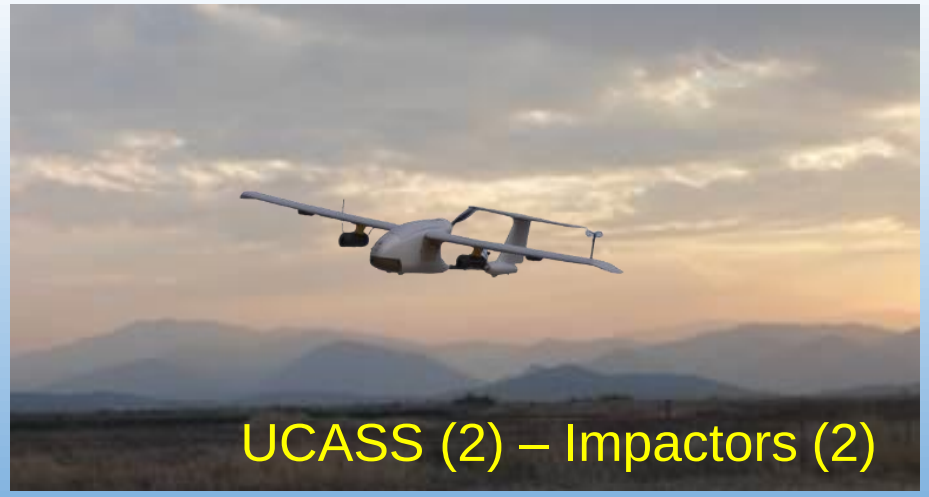


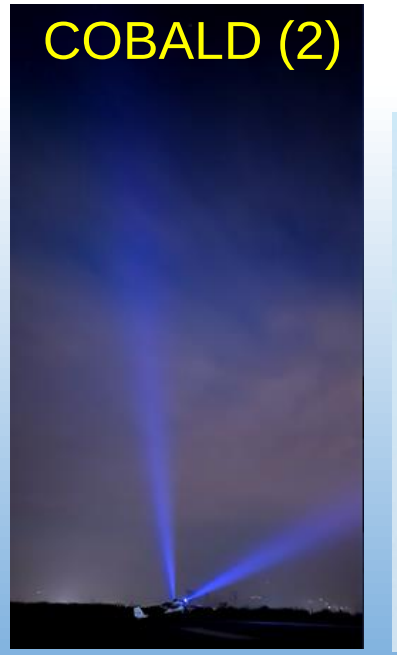
Courtesy of Sergio Rodriguez

Unmanned Aerial Systems (UAS)



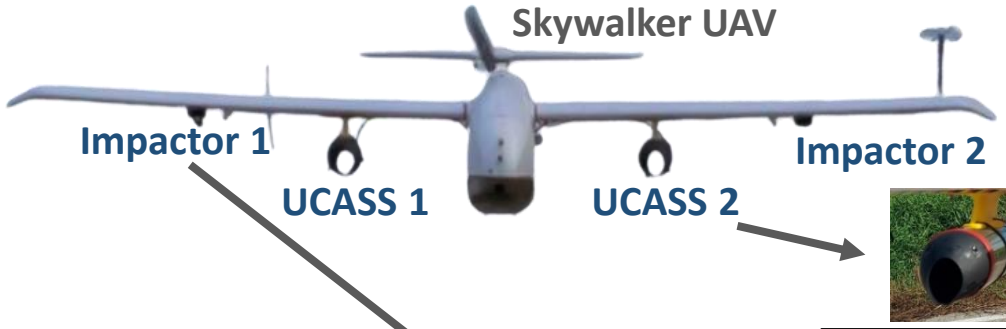
UAS - Sensors





UAV-based measurements during ASKOS

A. OPC measurements (from 0.1 up to 80 µm)



B. Impactor sampling

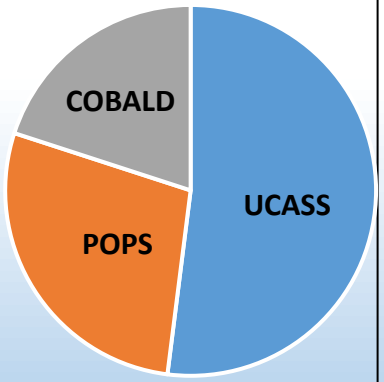
C. COBALD – Indication on dust orientation

Campaign Highlights

- **10 June – 30 June 2022**
- **25 flights in total**
- Very **windy** over CV in June (gusts > 40km/h)

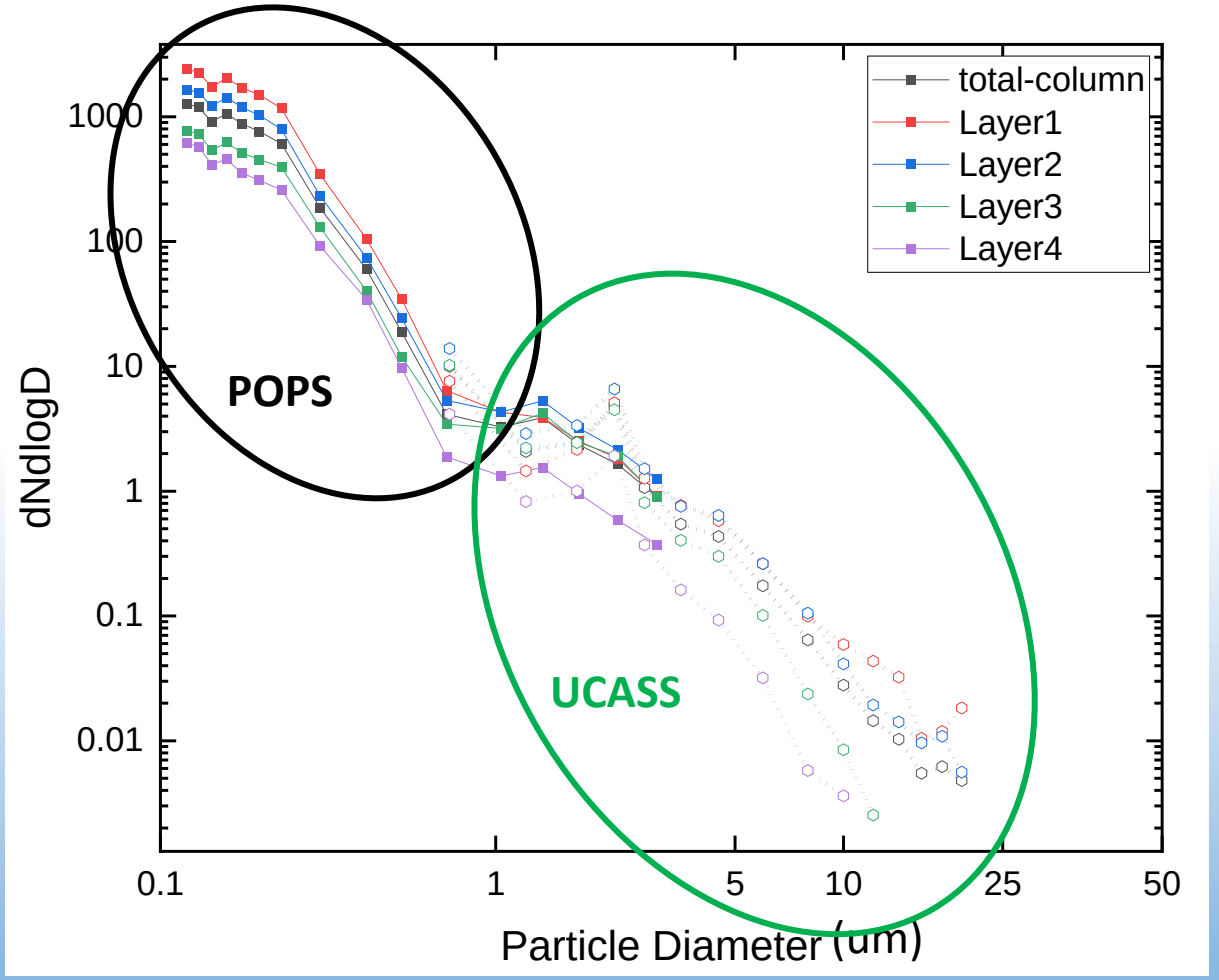
→ 15 planned flights: cancelled due to strong winds

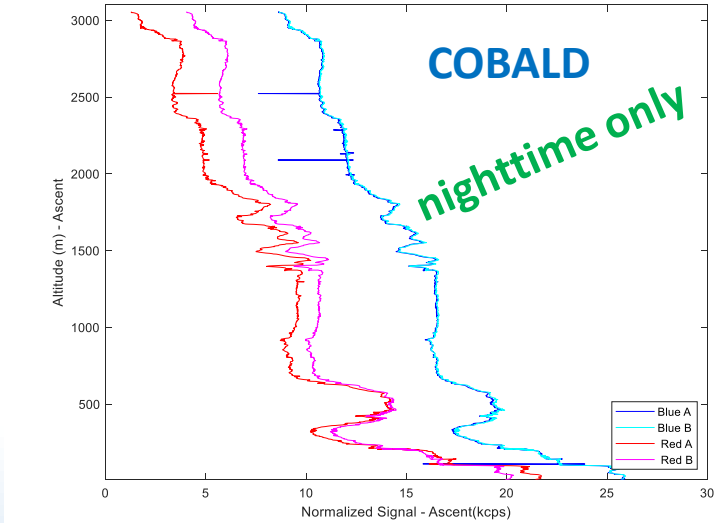
- **11 out of 25 night-time flights**
- 5 flight days out of 6 days of AEOLUS overpass
- **Max UAV-sensor altitude: 5,300m ASL**
- **24 samples** collected within different dust layers – SEM analysis



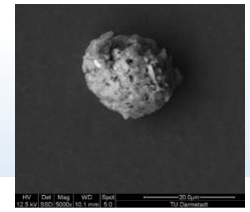
Instruments on-board UAVs for ASKOS

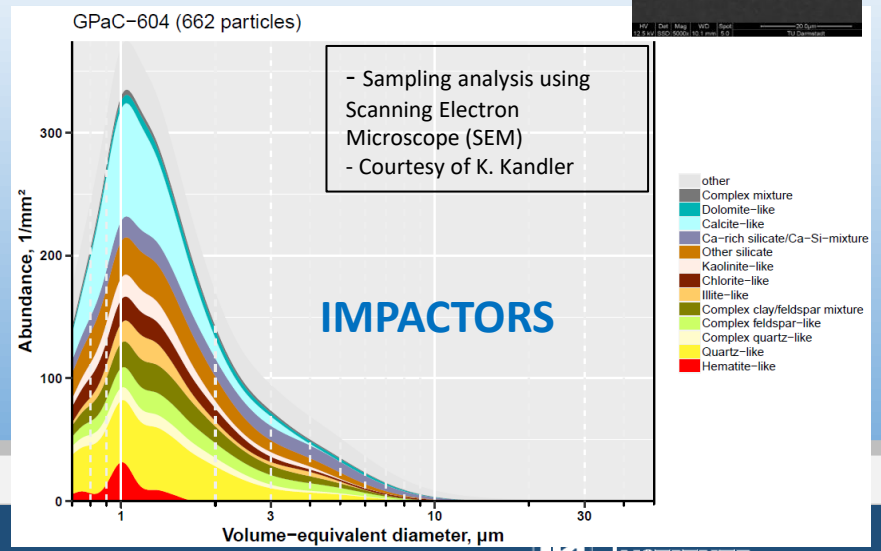
Height-resolved PSD, particle orientation, and sample collection



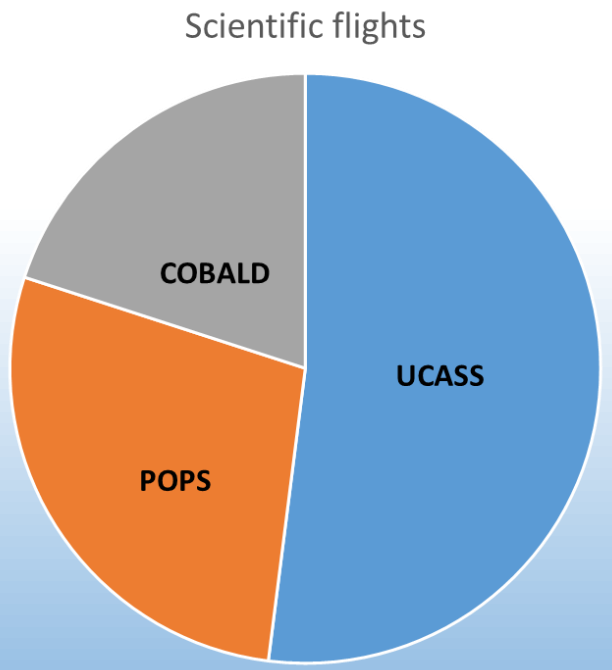


Courtesy of Maria Kezoudi





- 25 flights (14 daytime, 11 nighttime).
- 12 days with science flights.
- 5 Aeolus overpasses (out of 6).
- Max altitude reached: 5,300 m.
- 24 high-altitude samples collected.



Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
5	6	7	8	9	ASKOS 1st Day 10	11
	First 2 team members arrived in Cape Verde Arranging customs clearance and logistics	Larnaca-Athens-Lisbon	Lisbon-Mindelo flight 6 team members arrived in Cape Verde	Test flights without instruments on-board	1720 LT UCASS Skywalk. flight (3,900m) 1835 LT POPS CoBi flight (750m) – no time to fly higher -	1700 LT UCASS Skywalk. flight (3,500m) 2050 LT COBALD Skywalk. Flight (3,200m)
12	13	14	15	16	17	18
(NO FLIGHTS) Recovery	(NO FLIGHTS) Waiting at airport for 3h to fly but excessive winds cancelled flights	(NO FLIGHTS) Too windy higher than 25 kt at airport the entire day	0930 LT POPS CoBi flight (5,300m) 1100 LT UCASS Skywalk. Flight (3,000m) 1730 LT POPS CoBi flight (4,900m)	(NO FLIGHTS) No dust	1650 LT UCASS Skywalk. flight (3,250m) 2100 LT POPS CoBi flight (4,100m)	(NO FLIGHTS) Flights cancelled due to excessive winds (25 kt) and gusts (35 kt)
19	20	21	22	23	24	25
1435 LT POPS CoBi flight (5,300m) 1700 LT UCASS Skywalk. flight (3,100m)	0240 LT COBALD Skywalk. Flight (2,500m) 0400 LT UCASS Skywalk flight (3,000m) 0455 LT POPS CoBi flight (5,100m)	(NO FLIGHTS) No dust	(NO FLIGHTS) No dust	1630 LT UCASS Skywalk. flight (3,300m) 1810 LT POPS CoBi flight (5,300m)	1440 LT POPS CoBi flight (4,920m) 1720 LT UCASS CoBi flight (4,500m)	(NO FLIGHTS) Flights cancelled due to excessive winds (25 kt) and gusts, and unwell team members.
26	27	28	29	ASKOS Last Day 30	1	2
0250 LT UCASS CoBi flight (4,800m) 0405 LT COBALD Skywalk. flight (3,400m)	(NO FLIGHTS) 0300 LT Technical issue with CoBi UAV take-off	1100 LT UCASS Skywalk. flight (2,900m)	0240 LT UCASS Skywalk. Flight (1,600m) 0350 LT COBALD Skywalk. Flight (3,100 m)	0300 LT UCASS Skywalk. Flight (3,200m) 0500 LT COBALD Skywalk. Flight (3,300m) 1825 LT UCASS Skywalk. Flight (3,300m)	Packing equipment	Mindelo-Lisbon-Athens Team left Cape Verde

- A lot of waiting for winds easing, “ready to fly”
- 15 planned flights cancelled due to strong winds
- 9 days with no useful science
  - 3: no science interest
  - 4: high winds
  - 1: UAV failure
  - 1: rest day

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
5	6	7	8	9	ASKOS 1st Day 10	11
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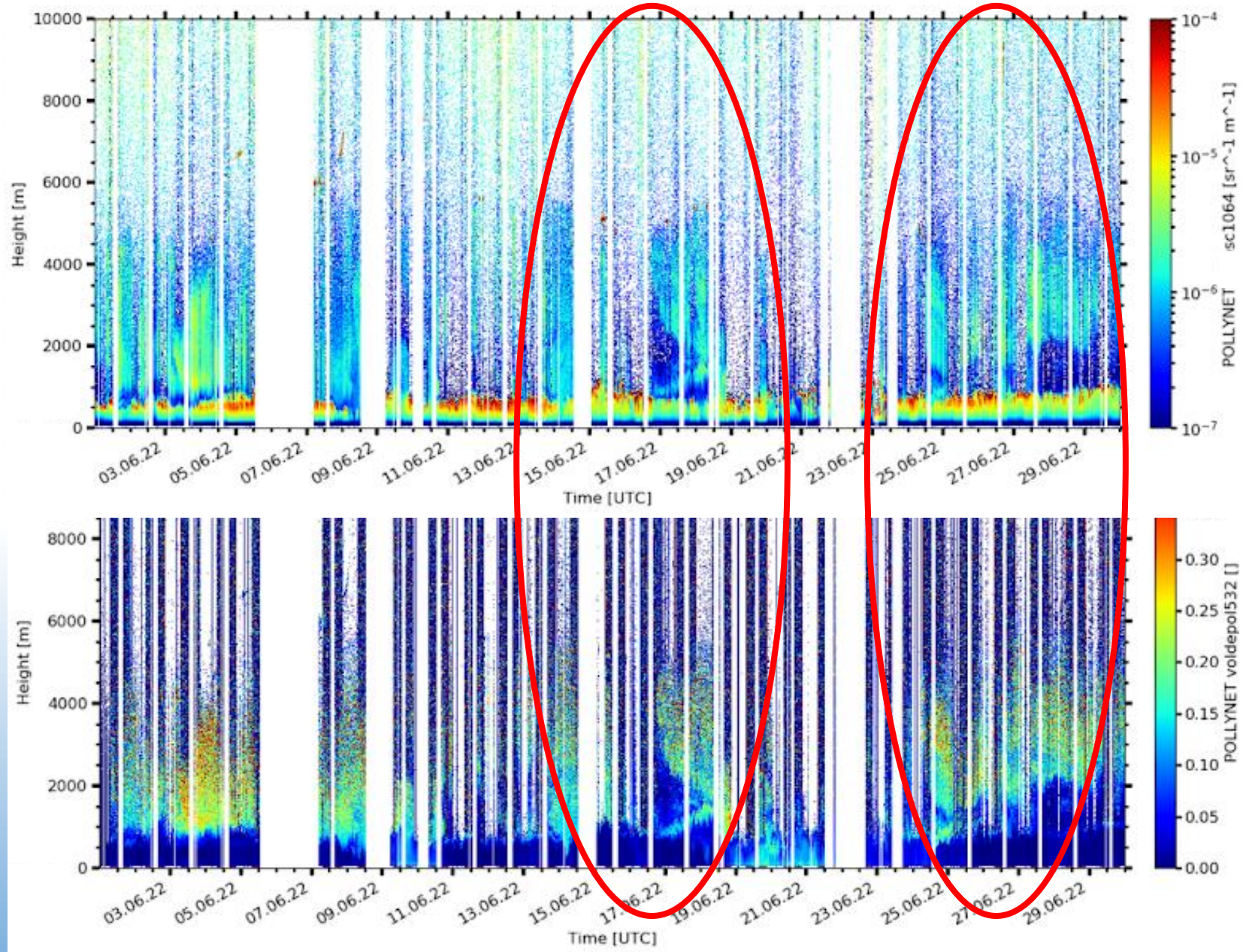
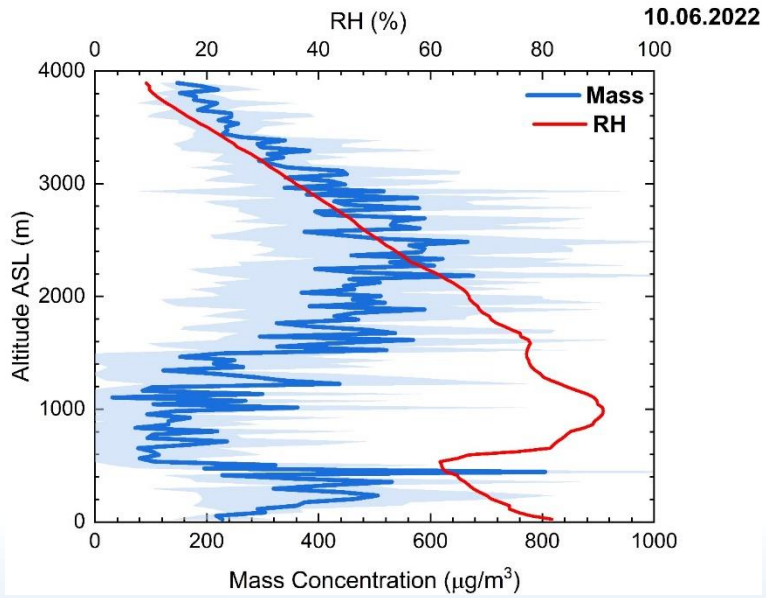


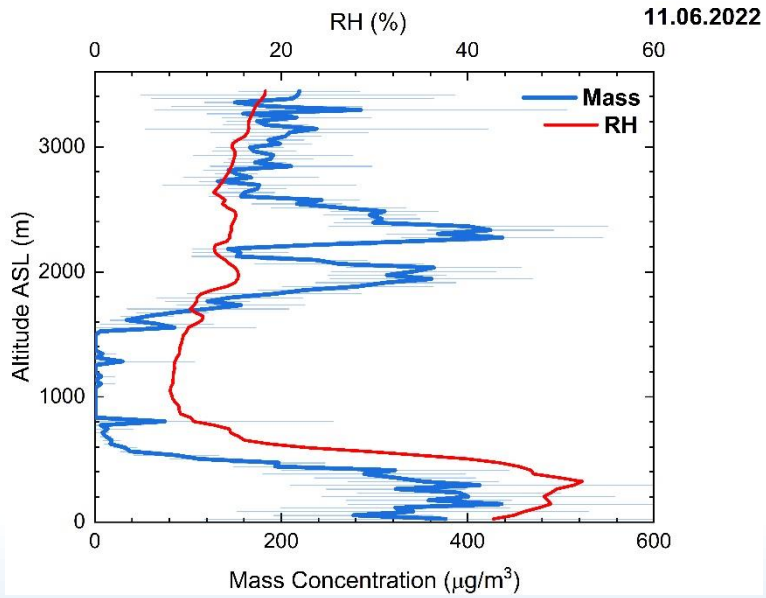
PollyXT lidar backscatter at Mindelo, Cabo Verde

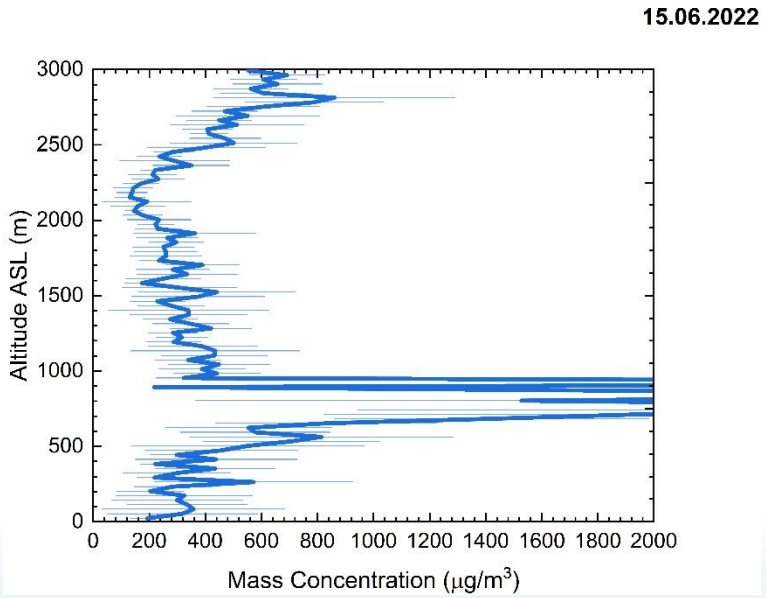
Credits: NOA, TROPOS

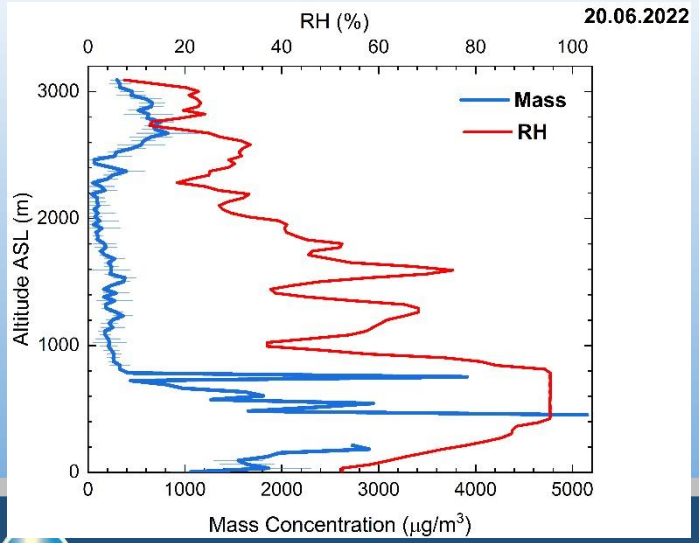
Volume depolarization ratio

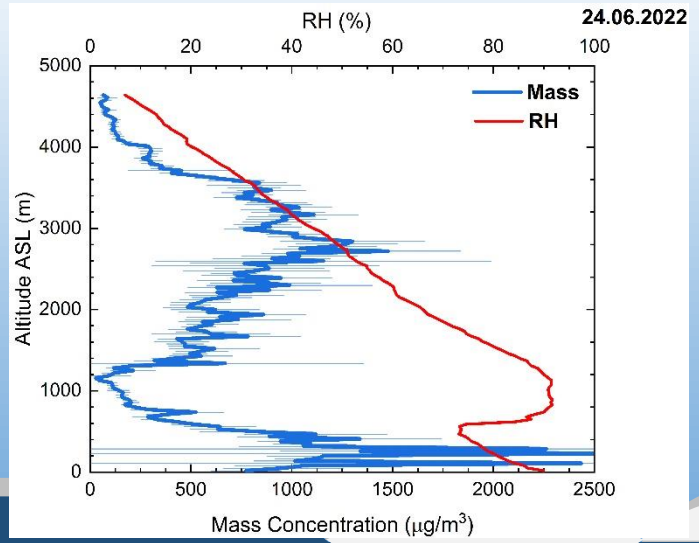
Mass Concentration Profiles - UCASS

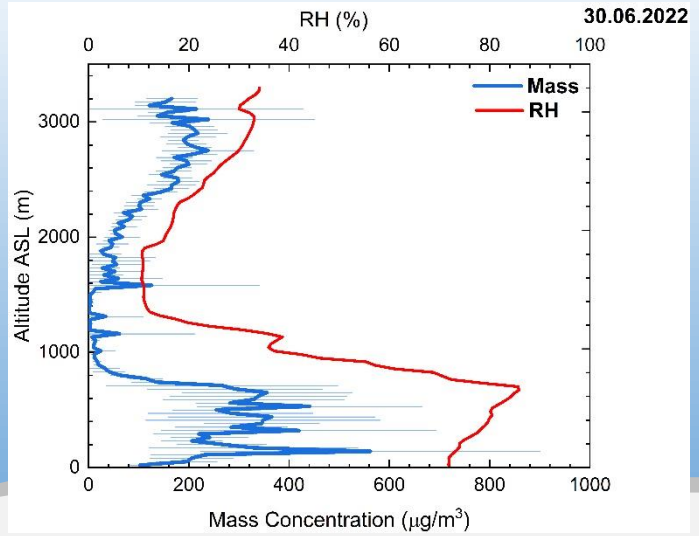








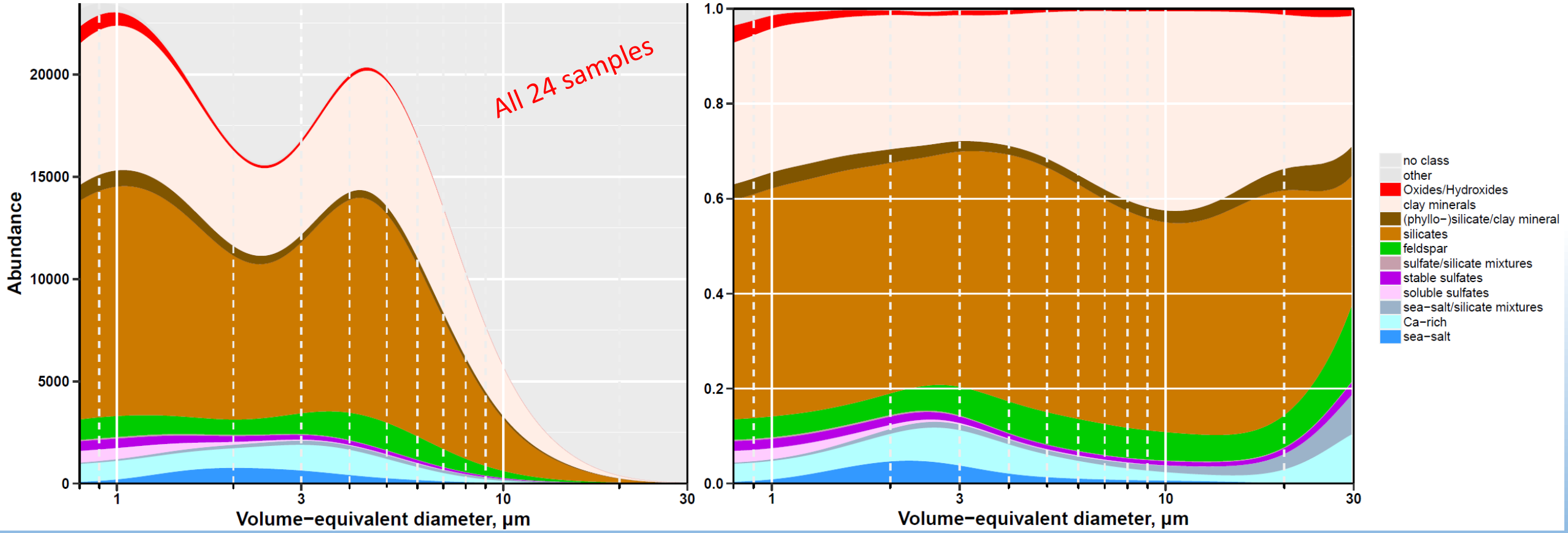




Size-resolved mineralogy (high altitude samples)

Date	Time (UTC)	Exposure (min)	Altitude (m ASL)
10/06/2022	19:25-19:29	4	1000-600
11/06/2022	18:39-18:43	4	3200-2400
11/06/2022	18:45-18:47	2	2200-1800
15/06/2022	12:37-12:40	3	3126-2389
15/06/2022	12:41-12:45	4	2081-1255
17/06/2022	18:15-18:20	5	3384-2499
17/06/2022	18:24-18:29	5	1892-1068
19/06/2022	18:33-18:36	3	2399-1550
19/06/2022	18:38-18:40	2	503-73
20/06/2022	5:25-5:27	2.4	3025-2278
23/06/2022	18:05-18:10	5	3139-2097
23/06/2022	18:12-18:14	2	1573-1062
24/06/2022	18:56-19:01	5.5	4789-3142
24/06/2022	19:03-19:07	4	2640-1596
26/06/2022	04:27-04:33	5.5	4990-3151
26/06/2022	04:33-04:38	4	2894-1784
28/06/2022	12:10-12:15	5	900-897
28/06/2022	12:33-12:37	4	3053-2308
29/06/2022	03:45-03:50	5	966-980
30/06/2023	04:31-04:36	5	3126-2079

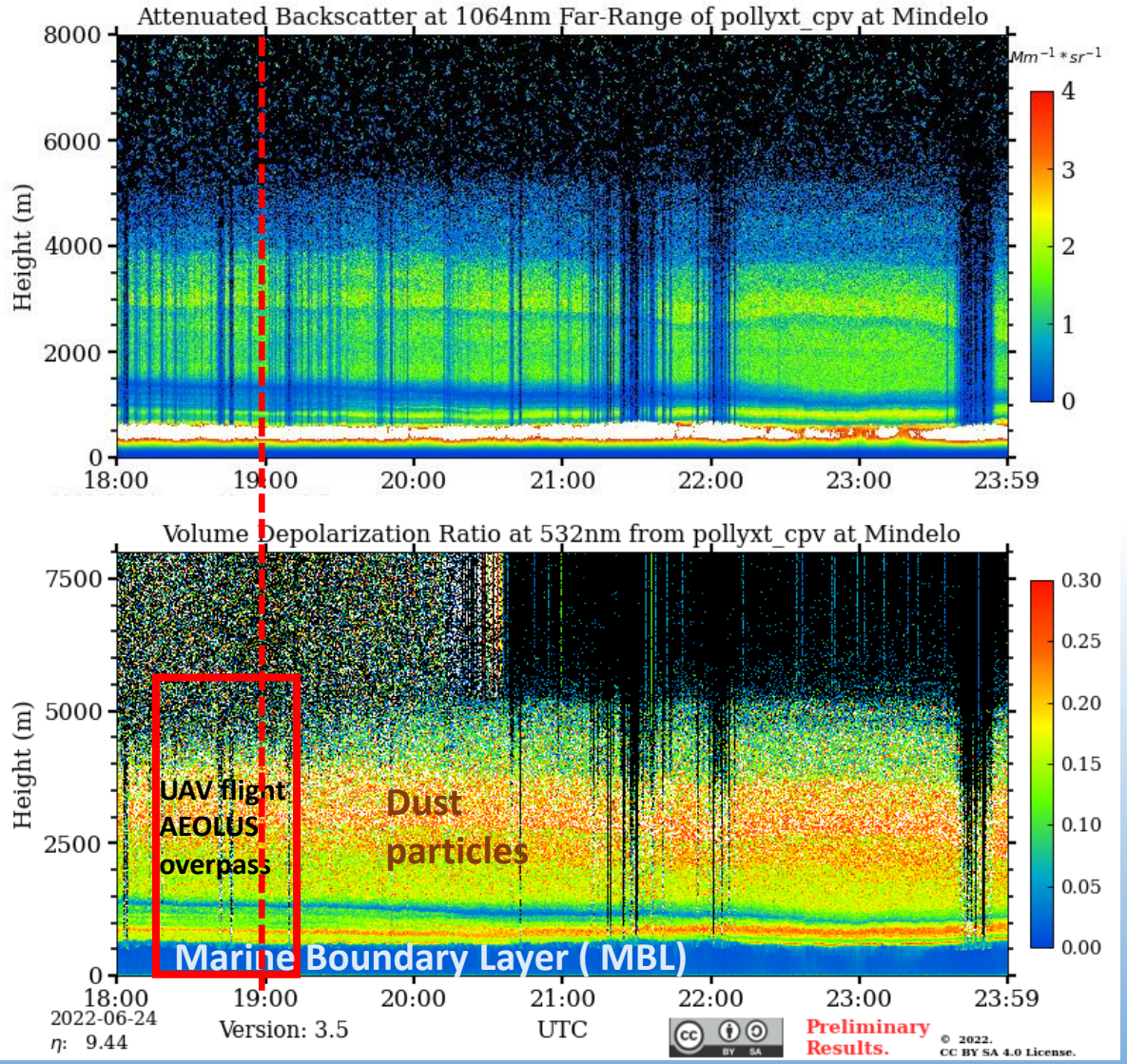
Size-resolved mineralogy (high altitude samples)



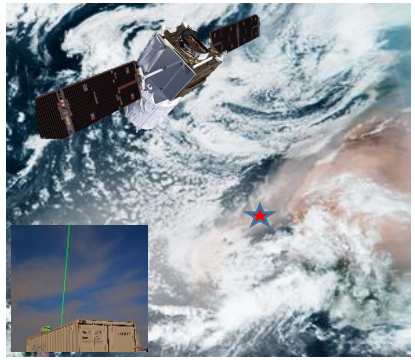
Case study: 24.06.2022

Case study: 24.06.2022

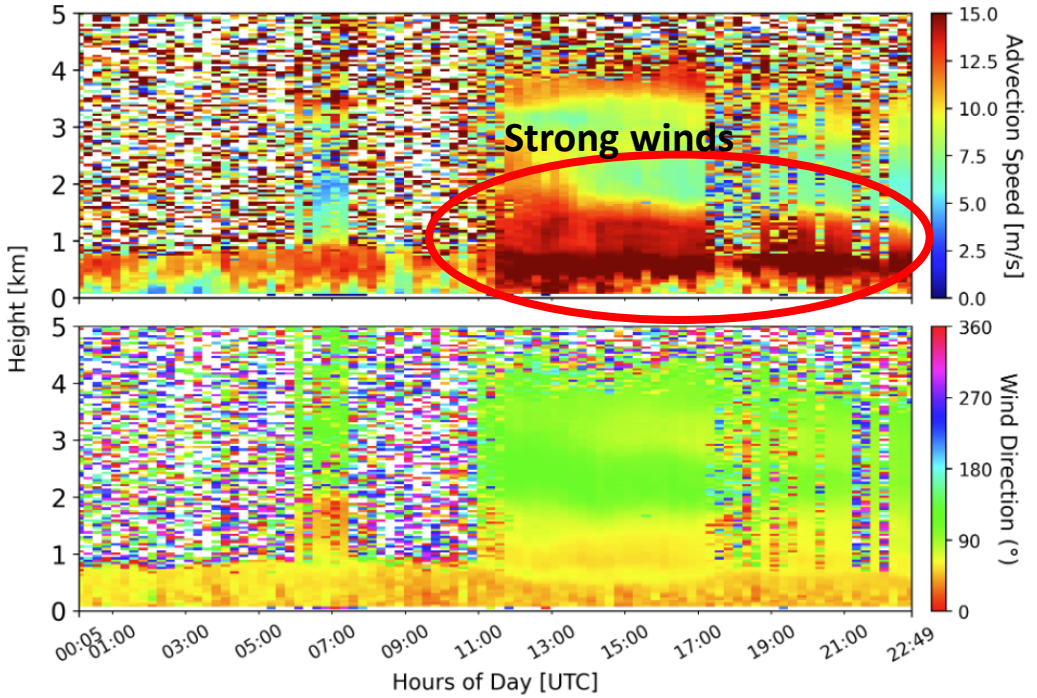
PollyXT lidar



AEOLUS overpass over Cape Verde



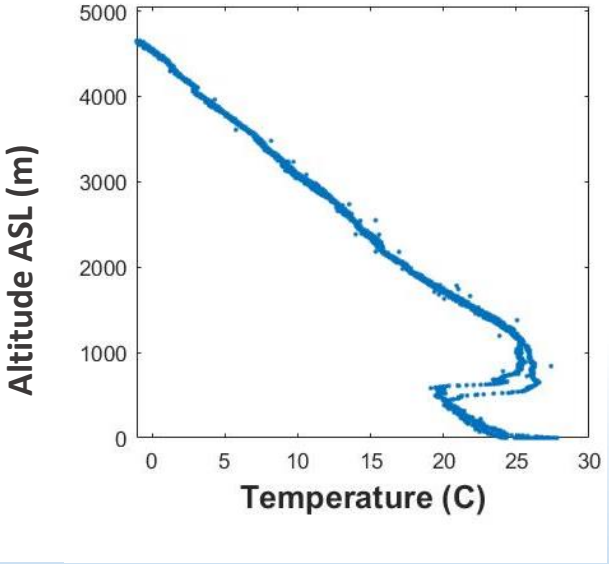
Halo wind

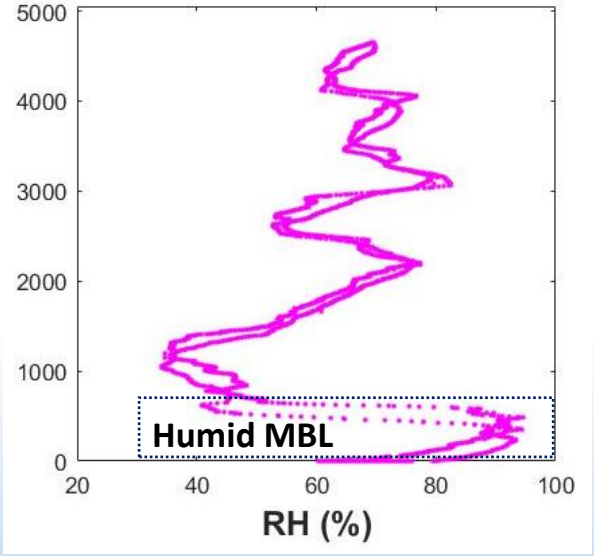


Credits: National Observatory of Athens (NOA)

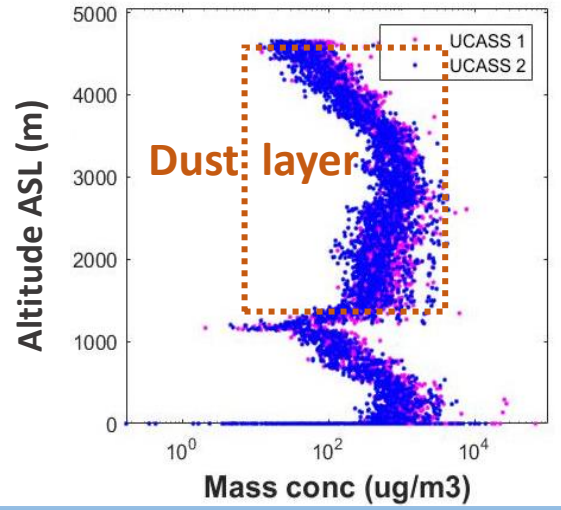
Preliminary results – OPC/CoBi UAV flight

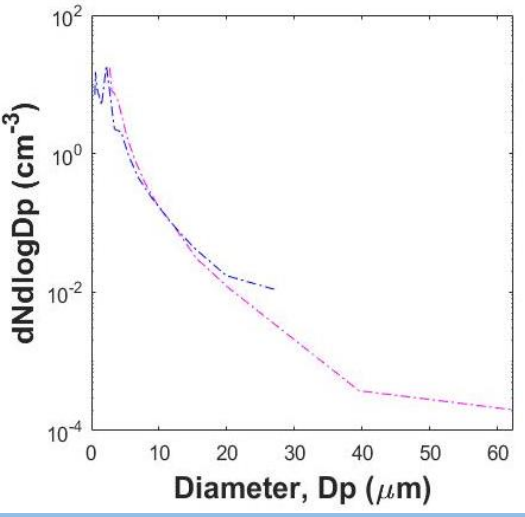
Case study: 24.06.2022C → **Simultaneous flight with AEOLUS overpass over Cape Verde**





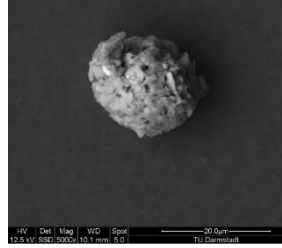
UCASS 1 – Size range: 0.4 – 32.0 µm
UCASS 2 – Size range: 2.5 – 77.0 µm

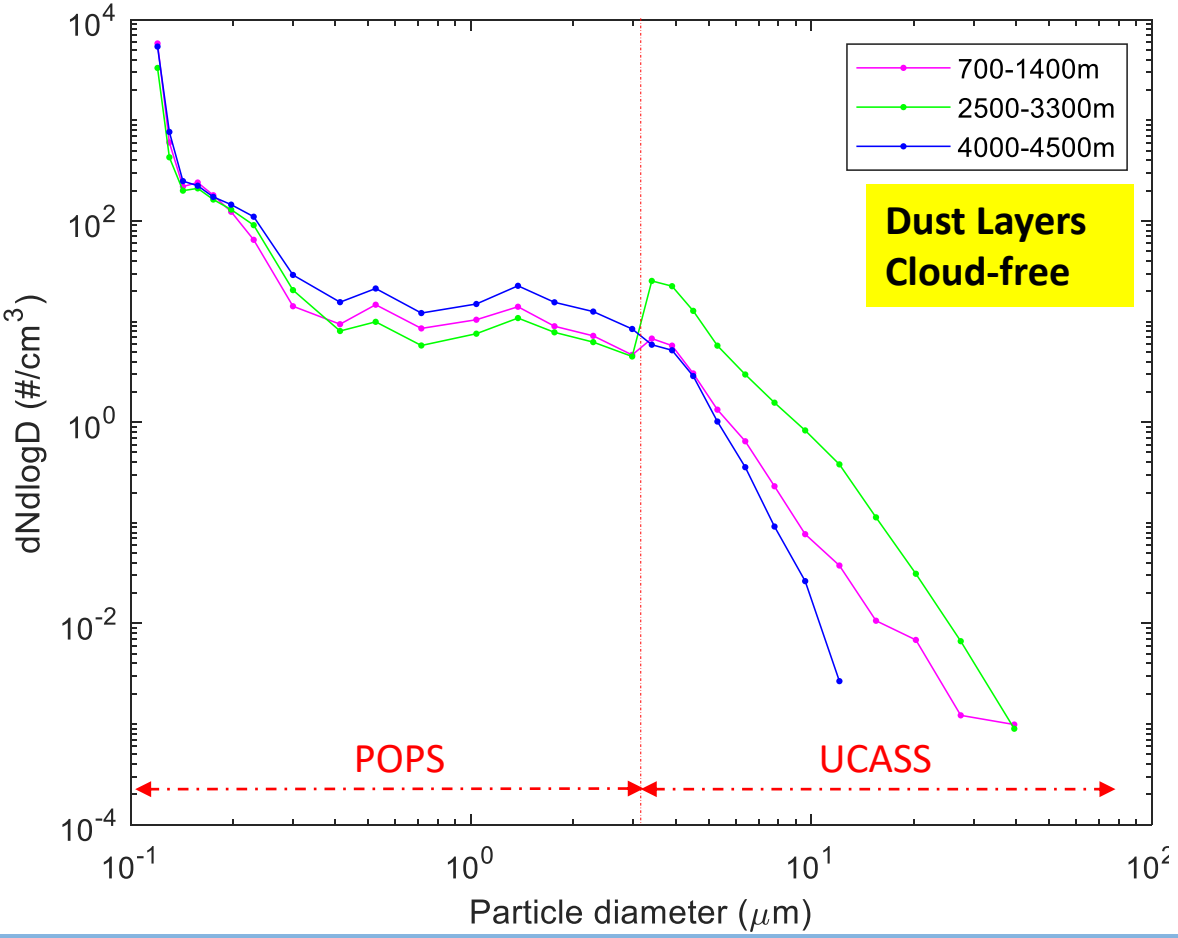


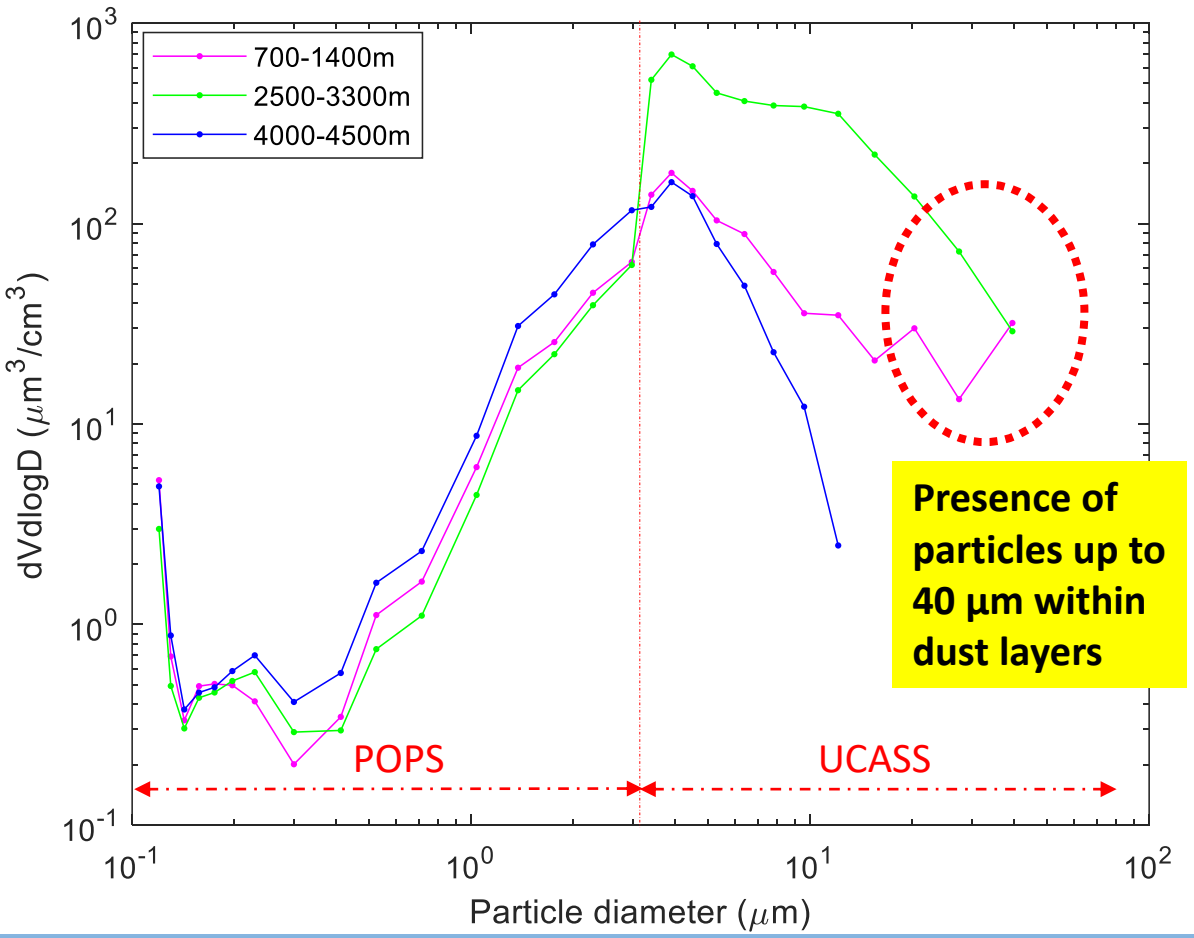


Size Distributions from OPCs

Case study: 24.06.2022



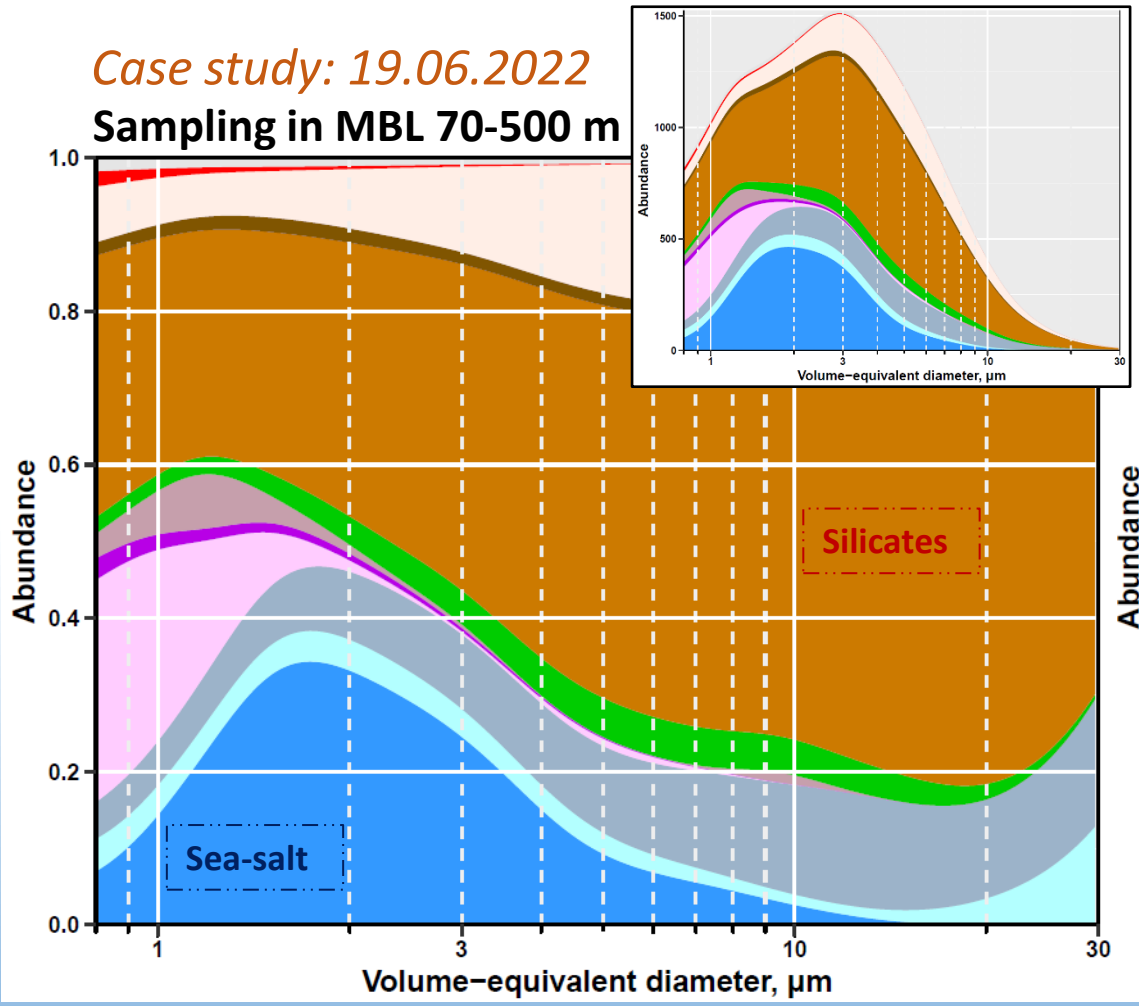




Composition of samples collected on-board

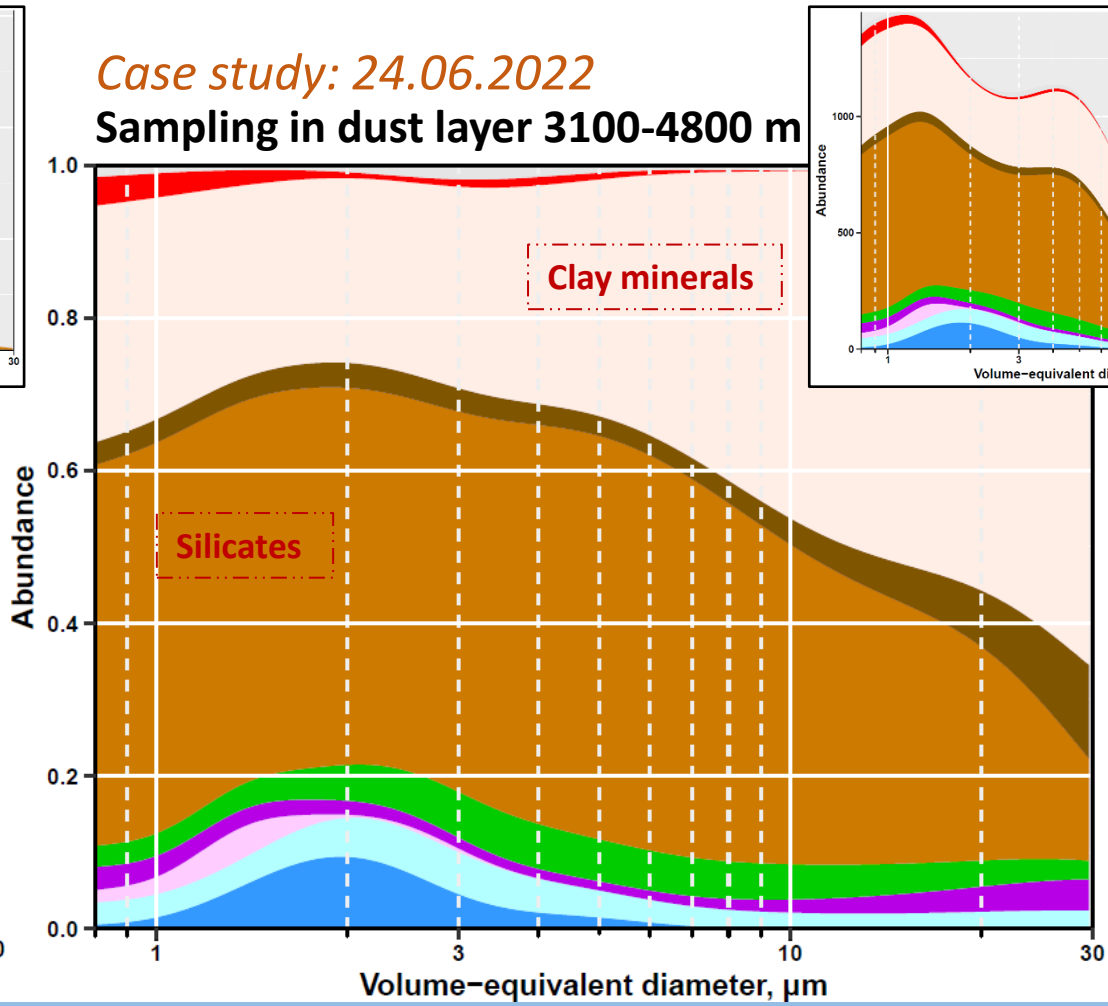
Case study: 19.06.2022

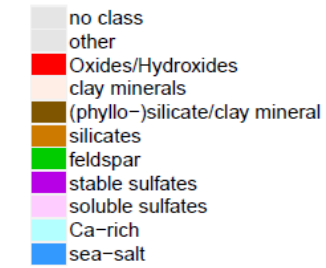
Sampling in MBL 70-500 m



Case study: 24.06.2022

Sampling in dust layer 3100-4800 m

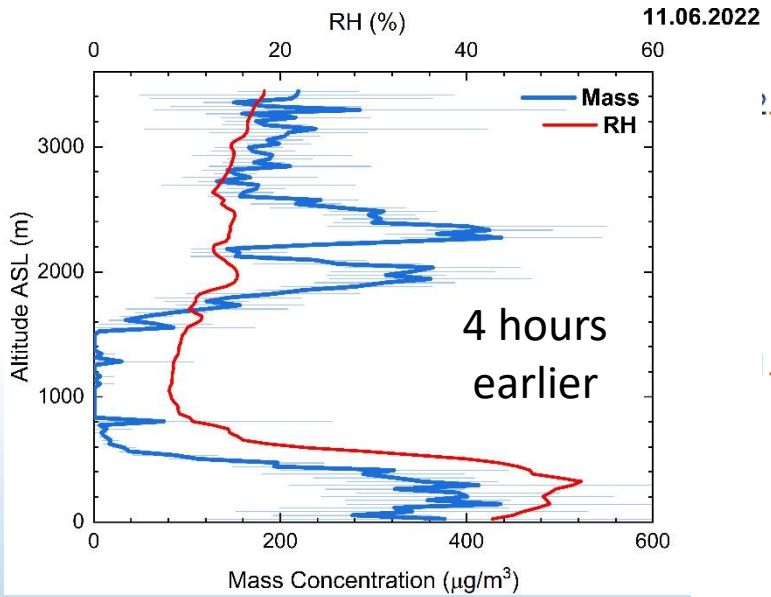


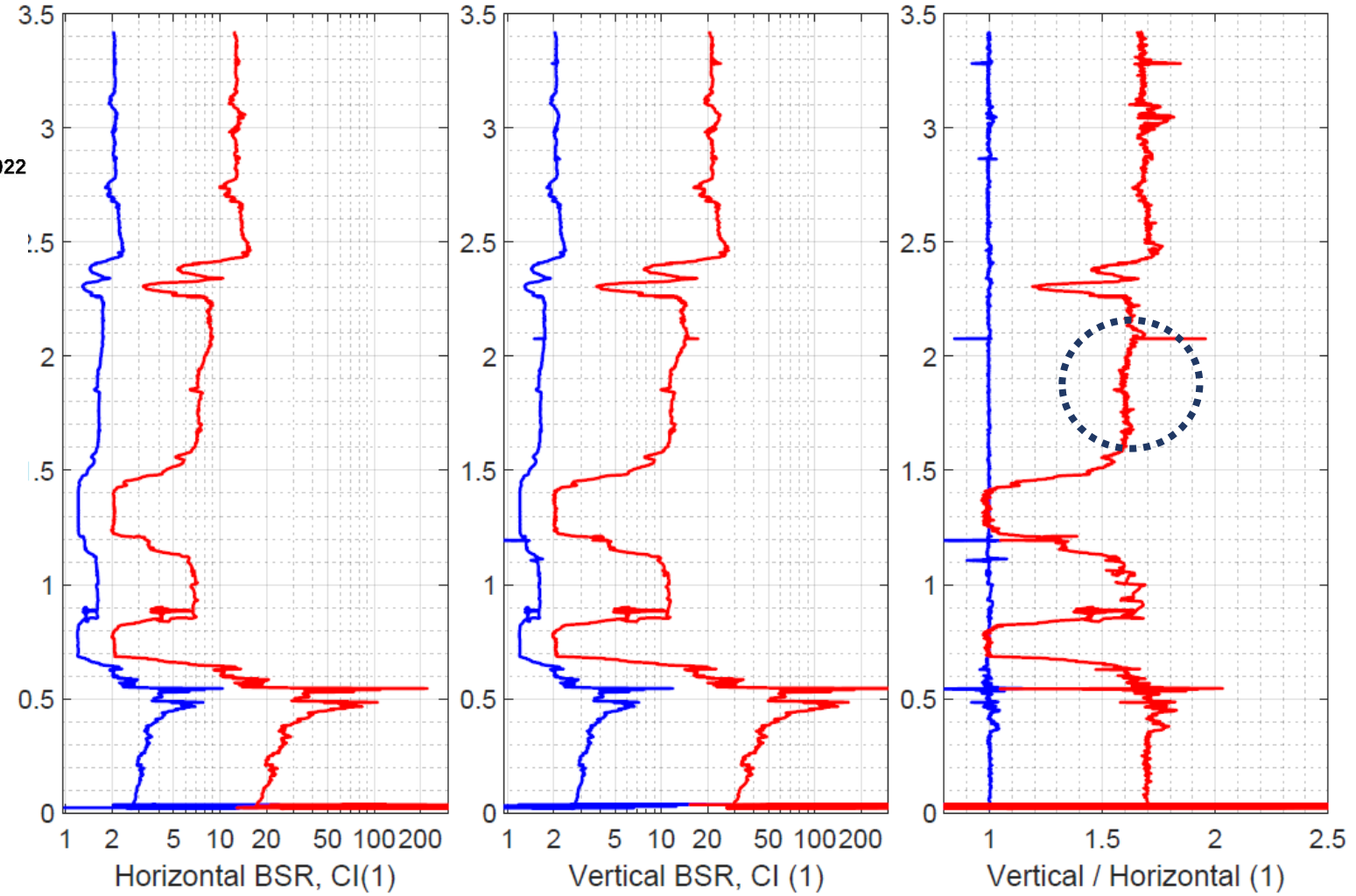


Credits: K. Kandler

Indication of dust orientation - COBALD

Case study: 11.06.2022





Credits: F. G. Wienhold

Summary

- Measurements in the full particle size range and overlap by POPS and UCASS (0.1-77.0 µm)
- Particles up to 40 µm: from ground up to at least 3,500 m ASL
- Particles up to 15 µm: in higher-up layers - up to 5,300 m ASL
- MBL – presence of dust particles in addition to sea salt
- Dust layers – dominated by clay minerals and silicates

Ongoing work

- Investigate properties of Sahara dust using height-resolved UAV measurements (OPCs, samples)
- Evaluate the AEOLUS L2A aerosol products
- Investigate the diurnal cycle of the Saharan Air Layer size-distribution for the first time - DAZSAL project (U. Reading)
- Correlate airborne in-situ observations with ground-based remote-sensing
- Examine particle orientation with COBALD-UAV vertical profiles and WALL-E lidar observations

Thank you

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 856612 and the Cyprus Government. If approved, DAZSAL will be supported under Horizon 2020 through the ATMO-ACCESS Integrating Activity under grant agreement No 101008004.

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Many thanks to the Cesaria Evora International Airport and the Ocean Science Centre Mindelo for their support, which has been decisive for the success of this campaign.