ASKOS experiment for desert dust research

Outline:

- ASKOS/JATAC datasets (and how can be used for):
- Validation and Enhancement of satellite products
- Data Assimilation
- Advance knowledge on atmospheric dust processes
- Improve dust modeling

ASKOS experiment

WHERE:

Mindelo, Sao Vicente, Cabo Verde

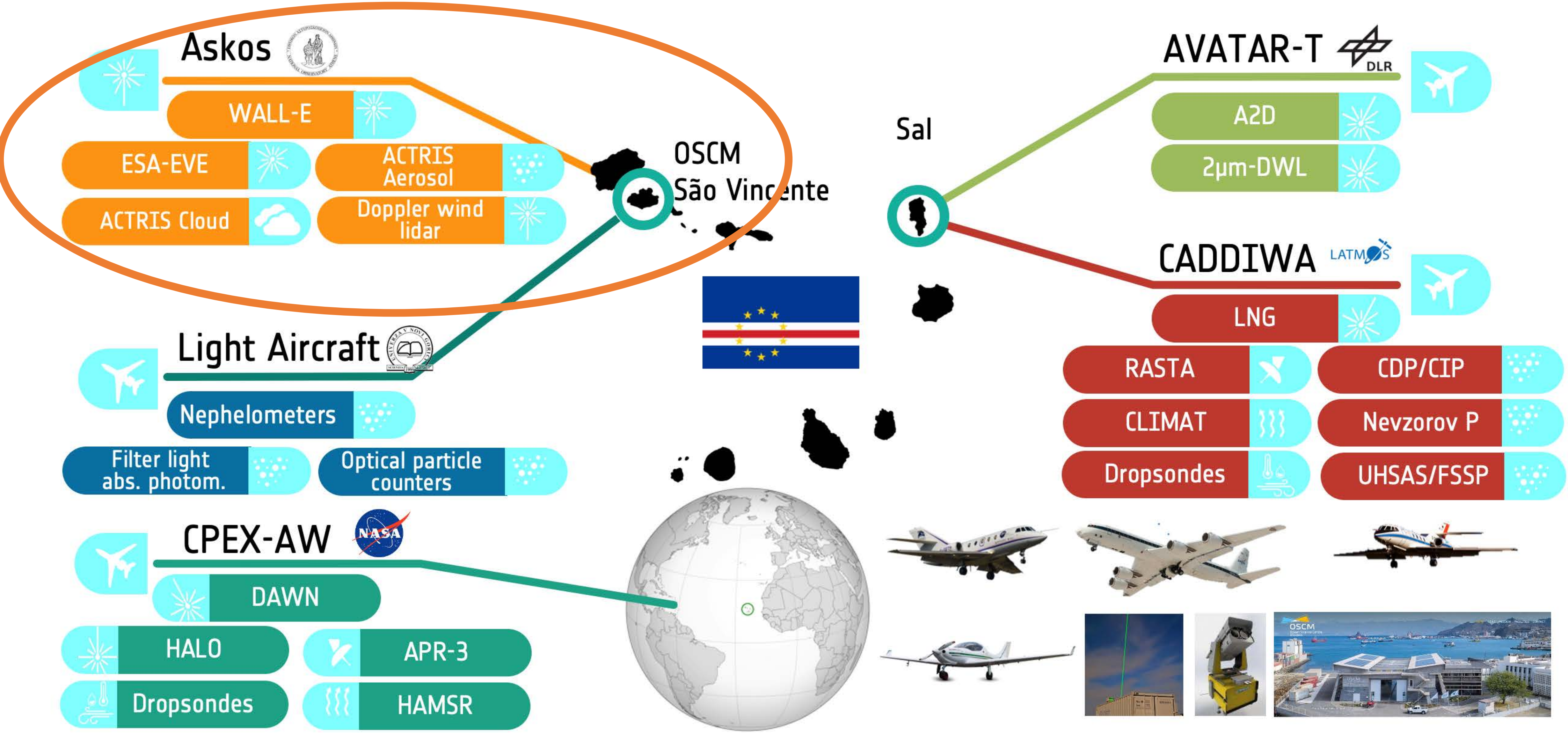
WHEN:

September 2021: Along with other experiments in the framework of **JATAC**

June 2022: Collocated with the **ERC D-TECT** experiment

September 2022: Along with **NASA CPEX** experimental campaign

JATAC experimental campaign



ASKOS Remote Sensing Facilities

ACTRIS
Exploring the Atmosphere

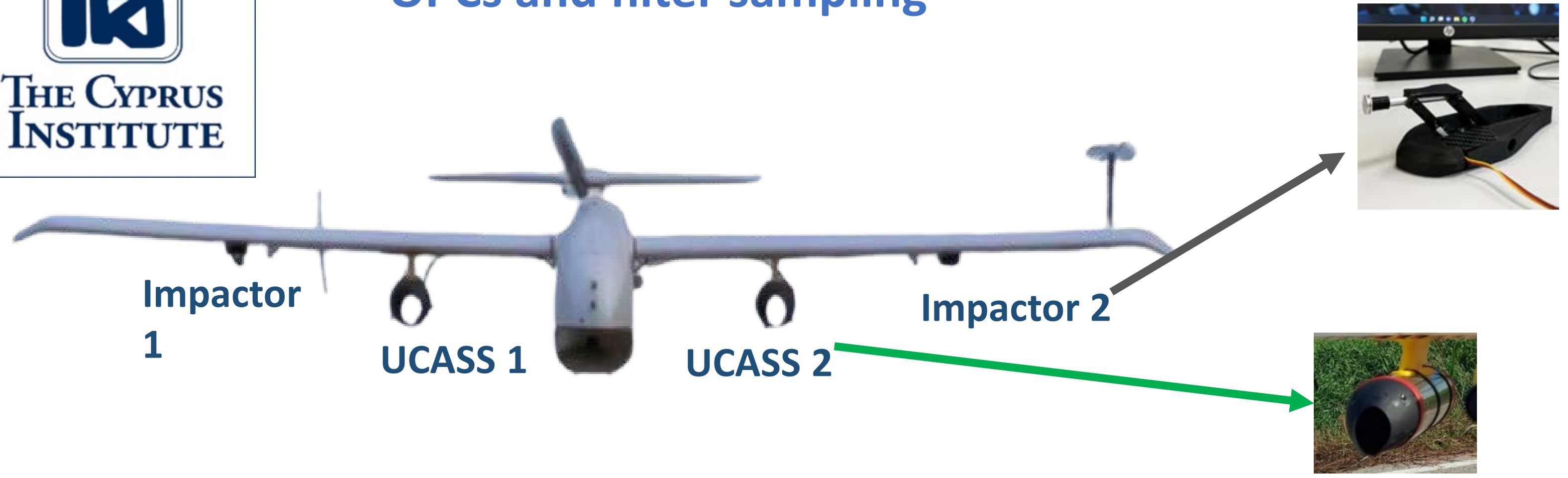
TROPOS
Leibniz Institute for Tropospheric Research

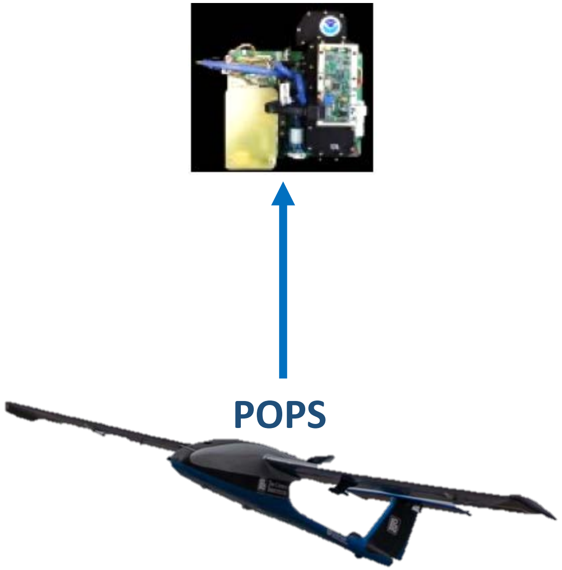
FMI

The Cyprus Institute

CyI drones

OPCs and filter sampling





COBALD – particle backscatter sensor

Trans-National Access Framework

eVe lidar for Aeolus Cal/Val

Paschou et al., AMT, 2022

The mission

Aeolus is the first satellite mission to acquire profiles of Earth's wind on a global scale. These observations are being used to improve weather forecasts and climate models. The Aeolus satellite carries just one large instrument – a Doppler wind lidar that will measure the winds sweeping around our planet.

The launch

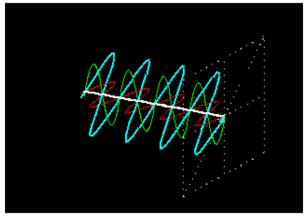
Date: 22 August 2018

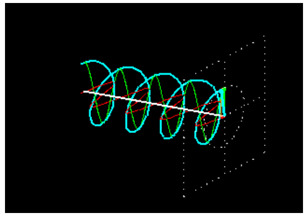
Site: Kourou, French Guiana

Rocket: Vega

Wall-E polarization lidar

Emits linearly- and elliptically-polarized light at 1064 nm

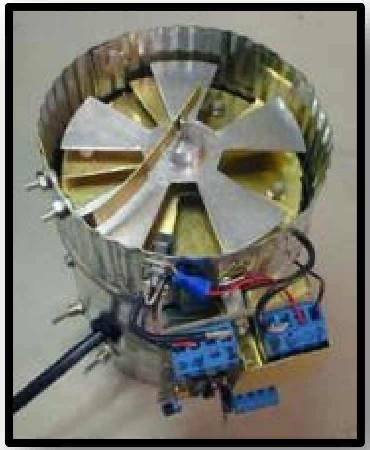


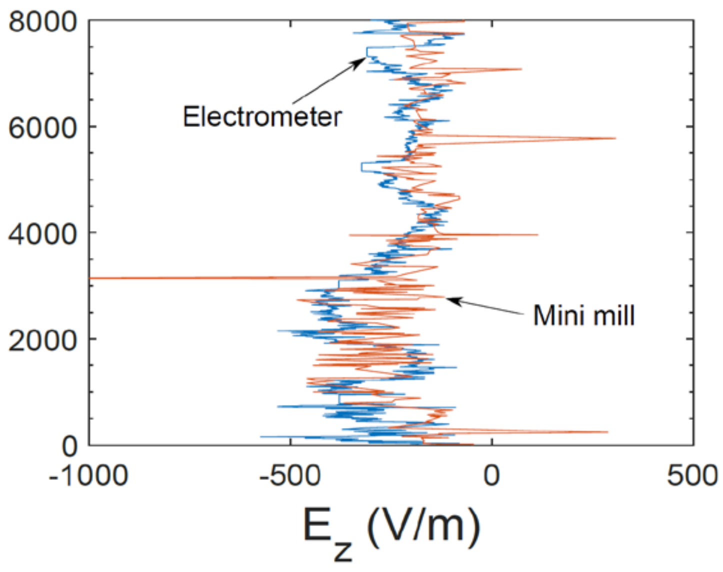


Designed to measure particle preferential orientation

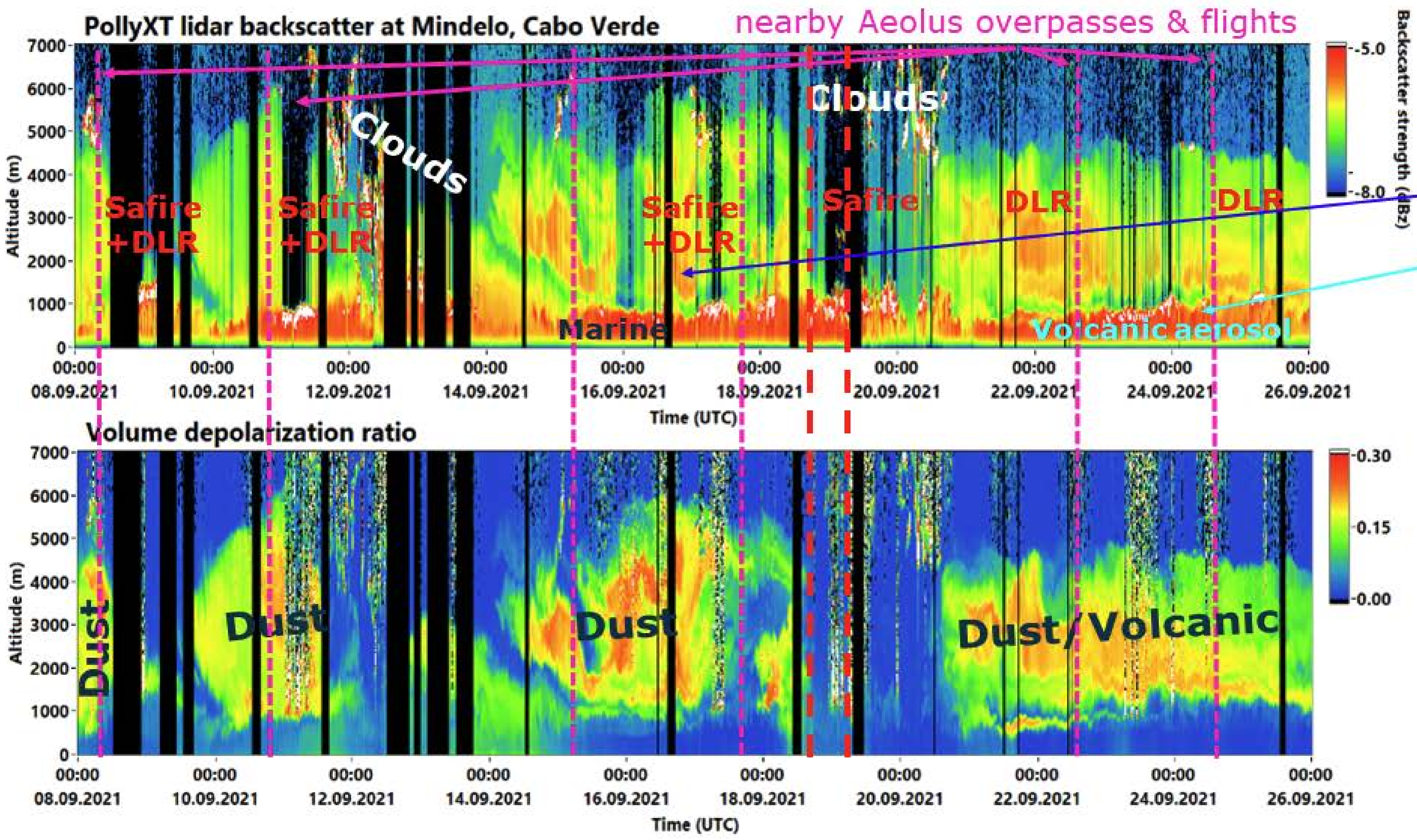
Tsekeri et al., AMT, 2021

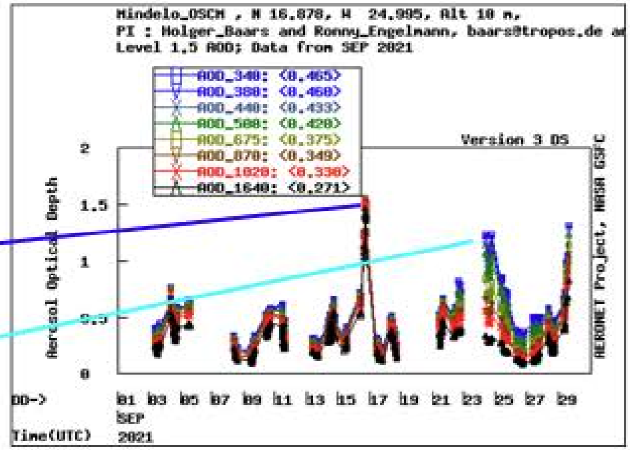
Measurements of the atmospheric electricity





ASKOS measurements - examples



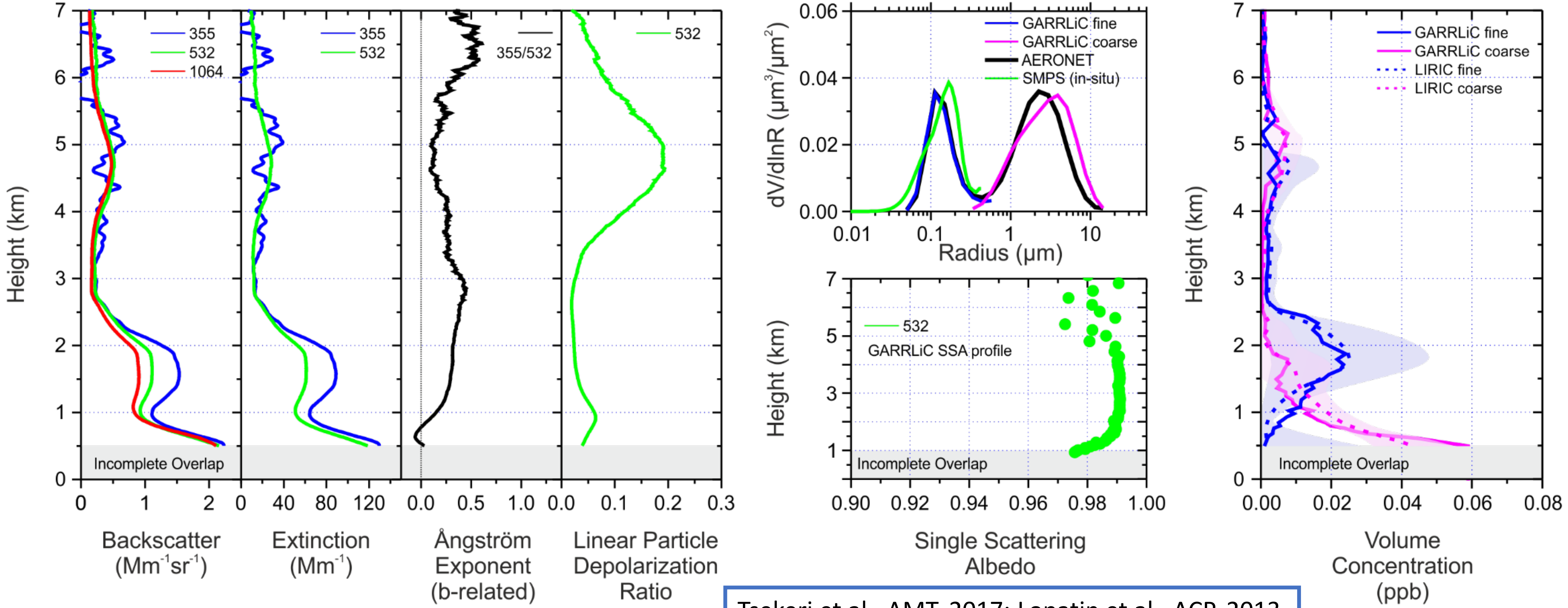


Aeronet AOD

11/9/2021 flight

ASKOS measurements - examples

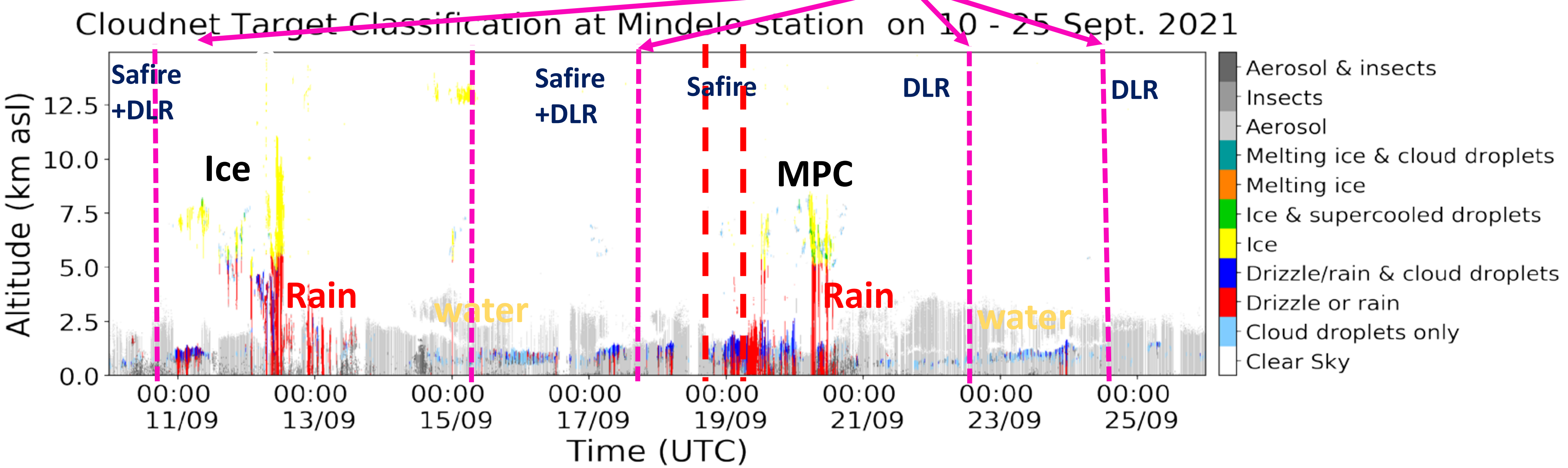
Typical aerosol lidar products and inversion retrievals

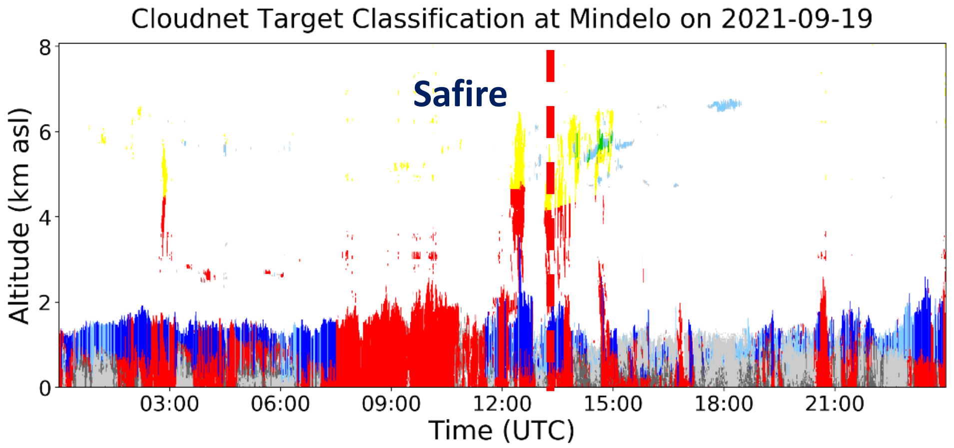


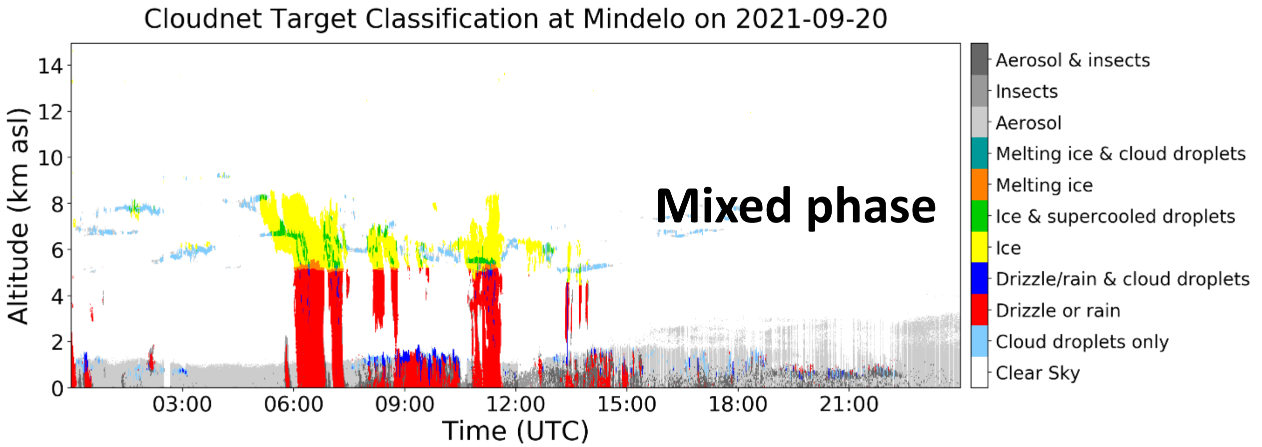
Tsekeri et al., AMT, 2017; Lopatin et al., ACP, 2013

ASKOS measurements - examples

nearby Aeolus overpasses & flights

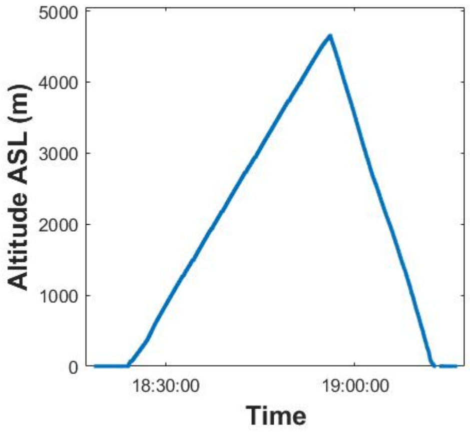


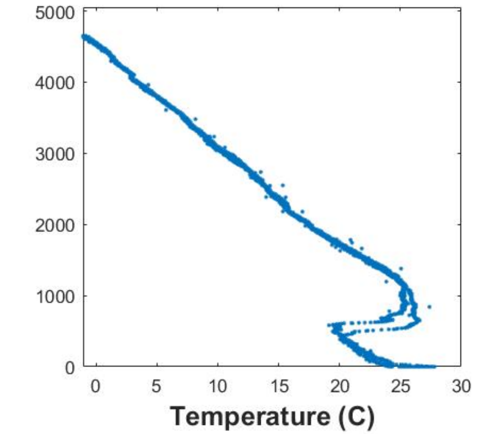


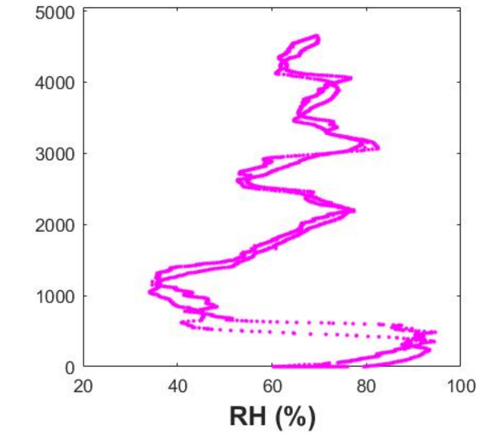


ASKOS measurements - examples

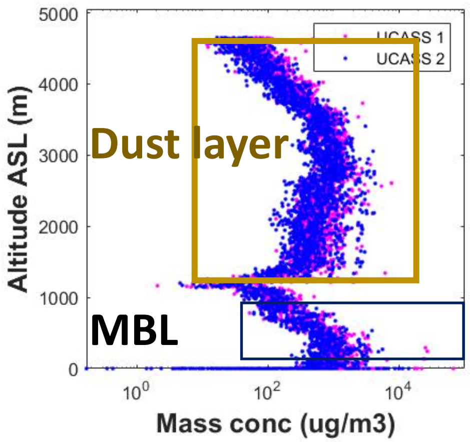
UCASS/CoBi UAV - 24.06.2022 – Simultaneous with AEOLUS overpass over CV

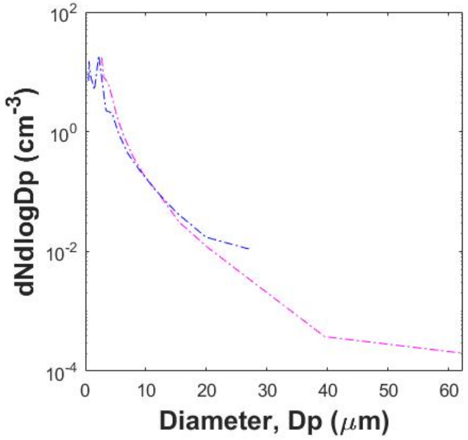


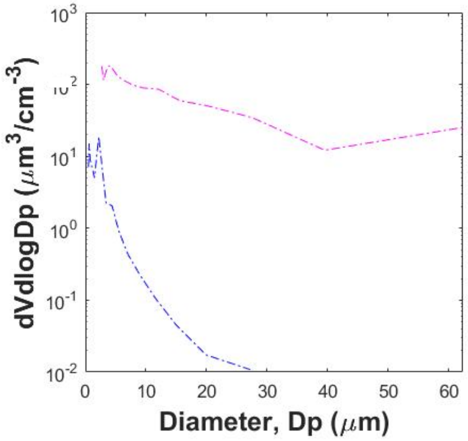


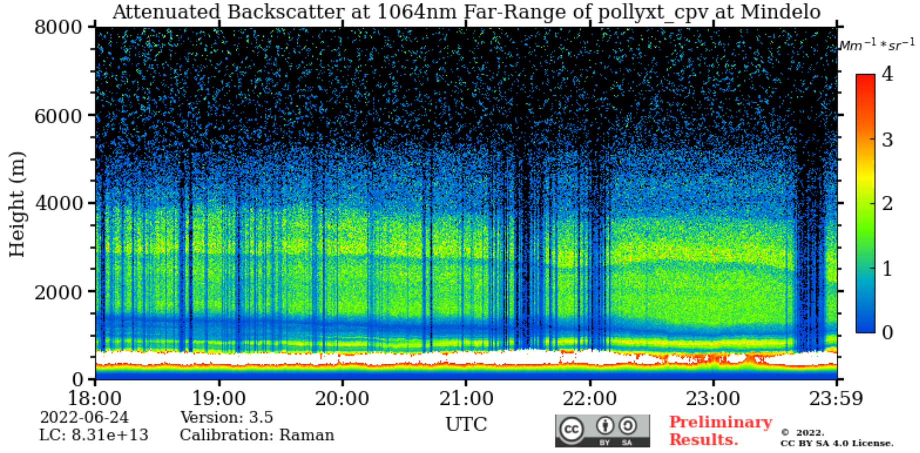


Presence of particles up to 60 μm within dust layers









Use of ASKOS-like measurements for:

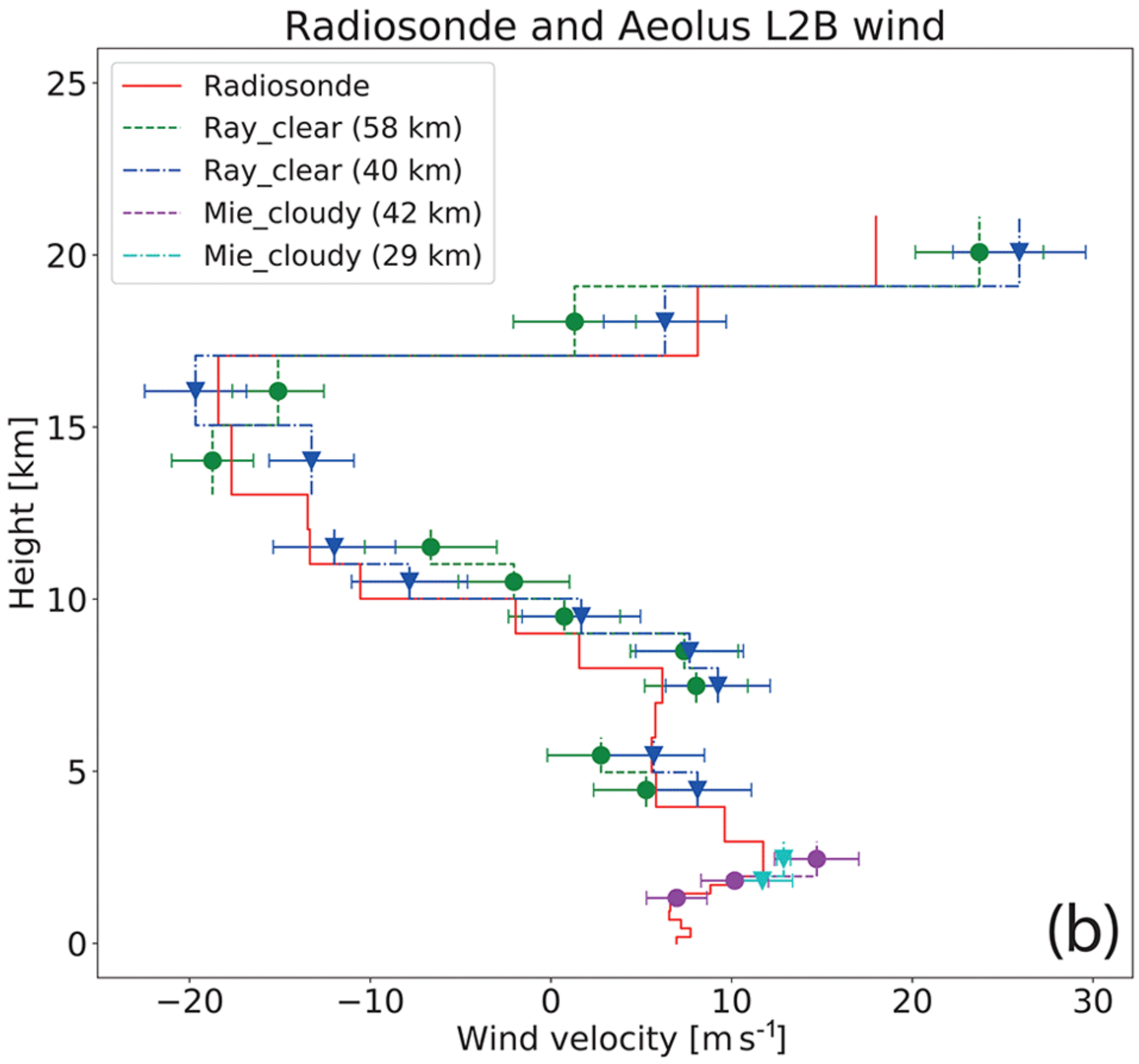
Validation and Enhancement of satellite products

Validation and enhancement of satellite products

Evaluation of satellite retrievals: eVe for Aeolus

Baars et al., 2020

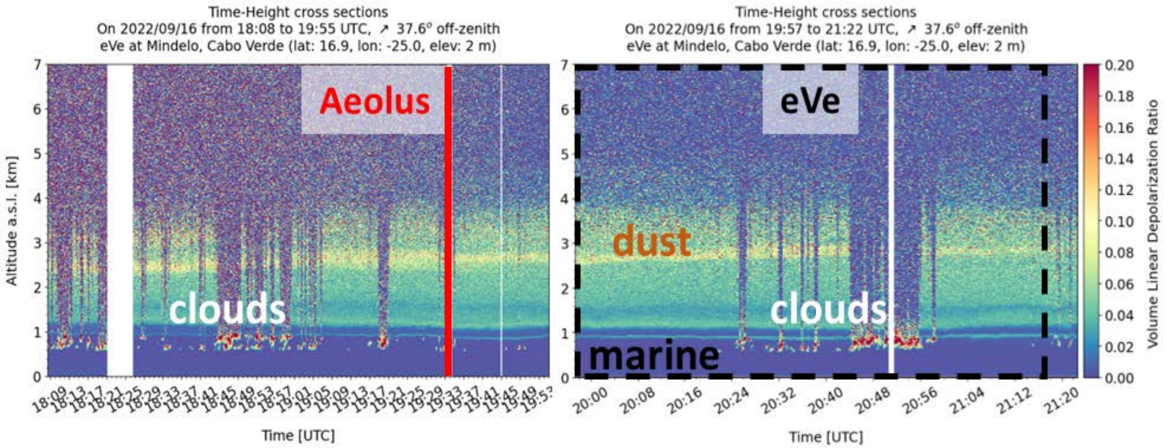
TROPOS
Leibniz Institute for Tropospheric Research

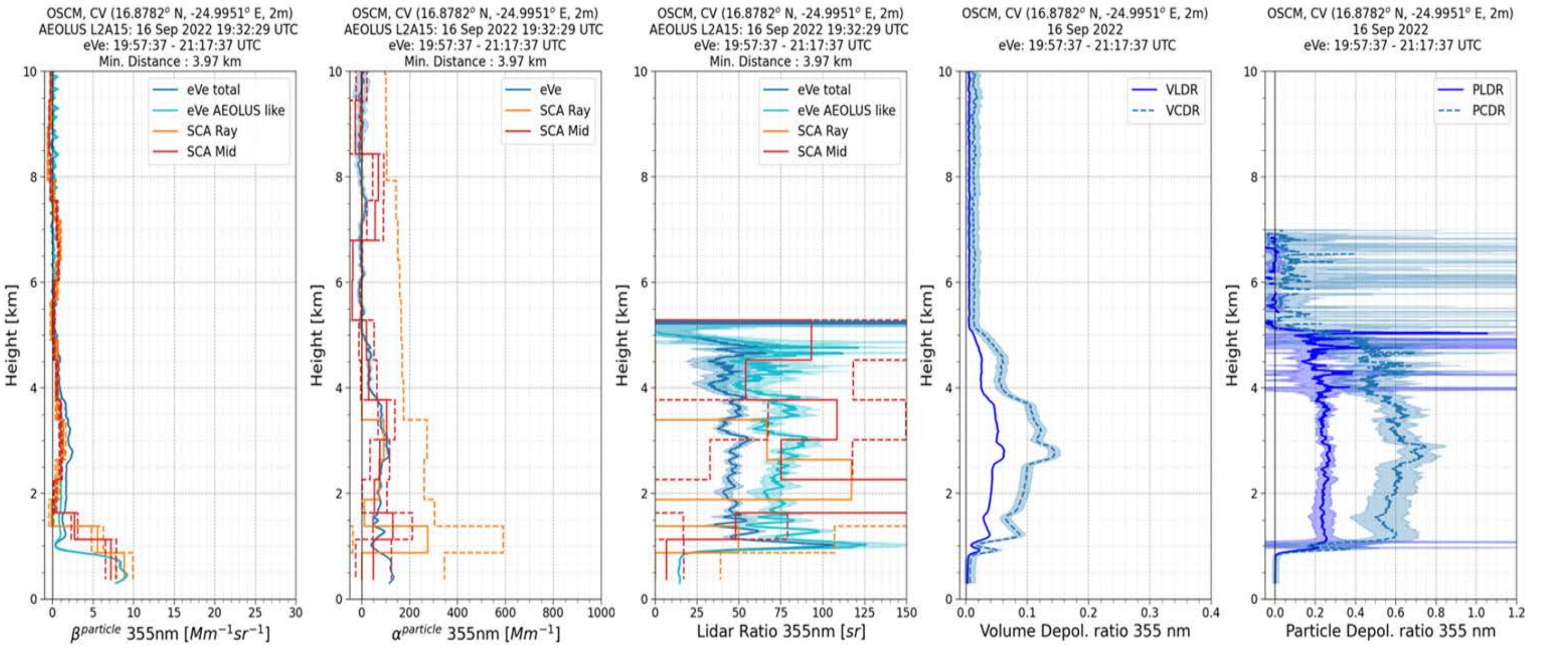


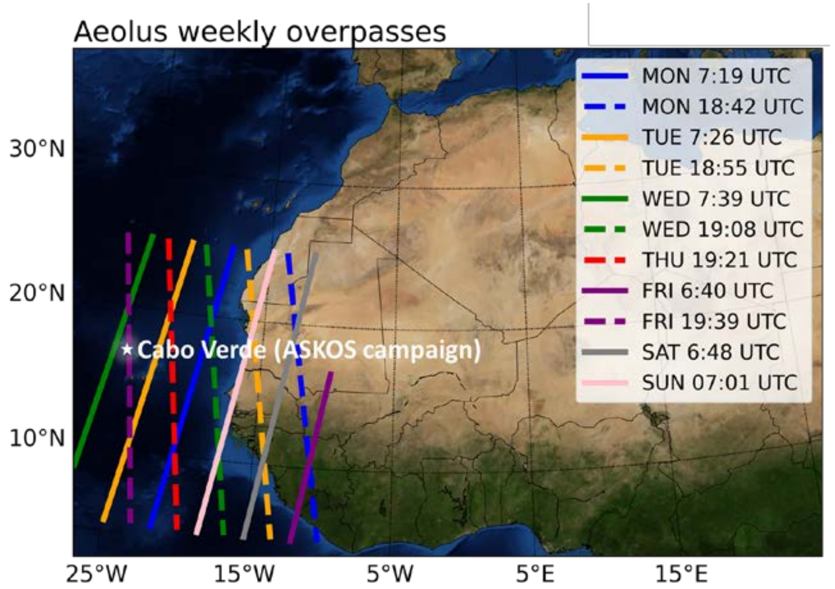
Validation and enhancement of satellite products

Evaluation of satellite retrievals: eVe for Aeolus

Paschou et al., 2022

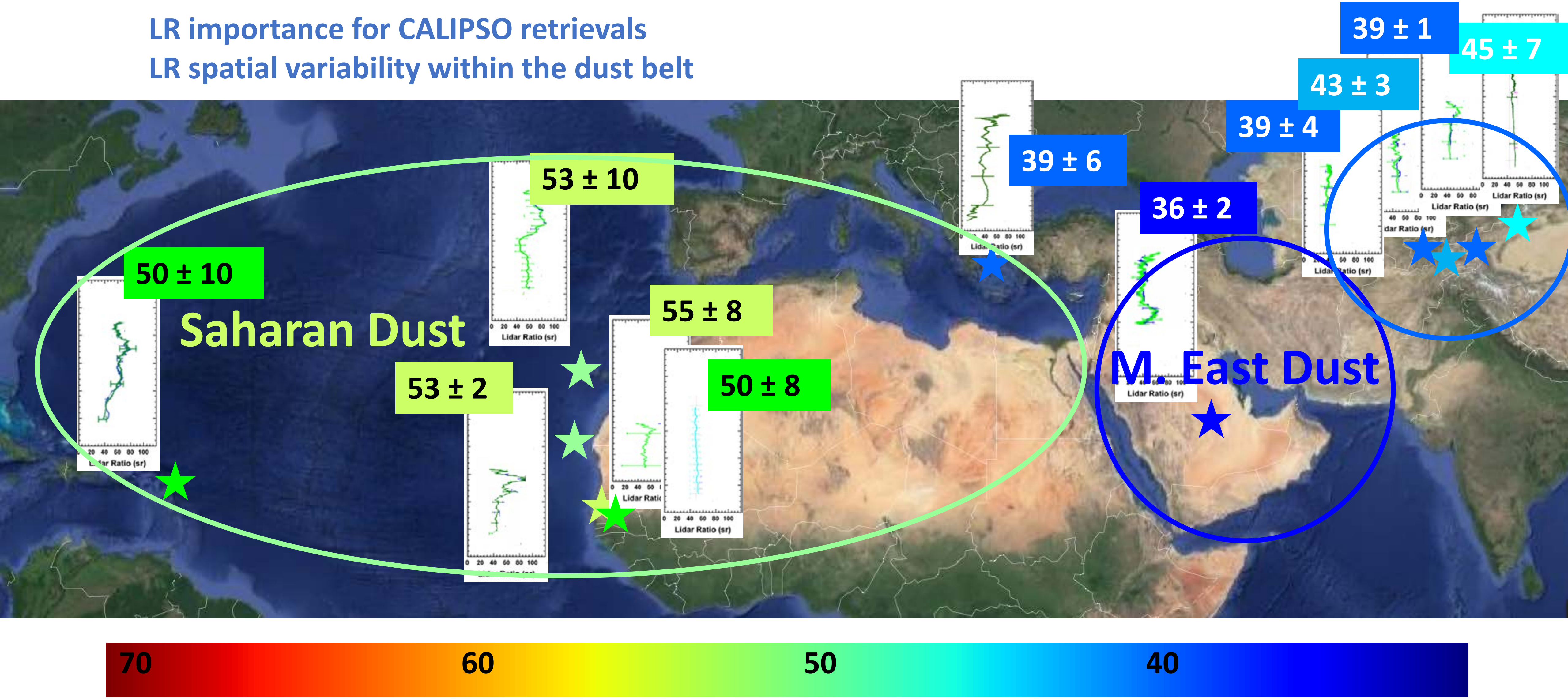






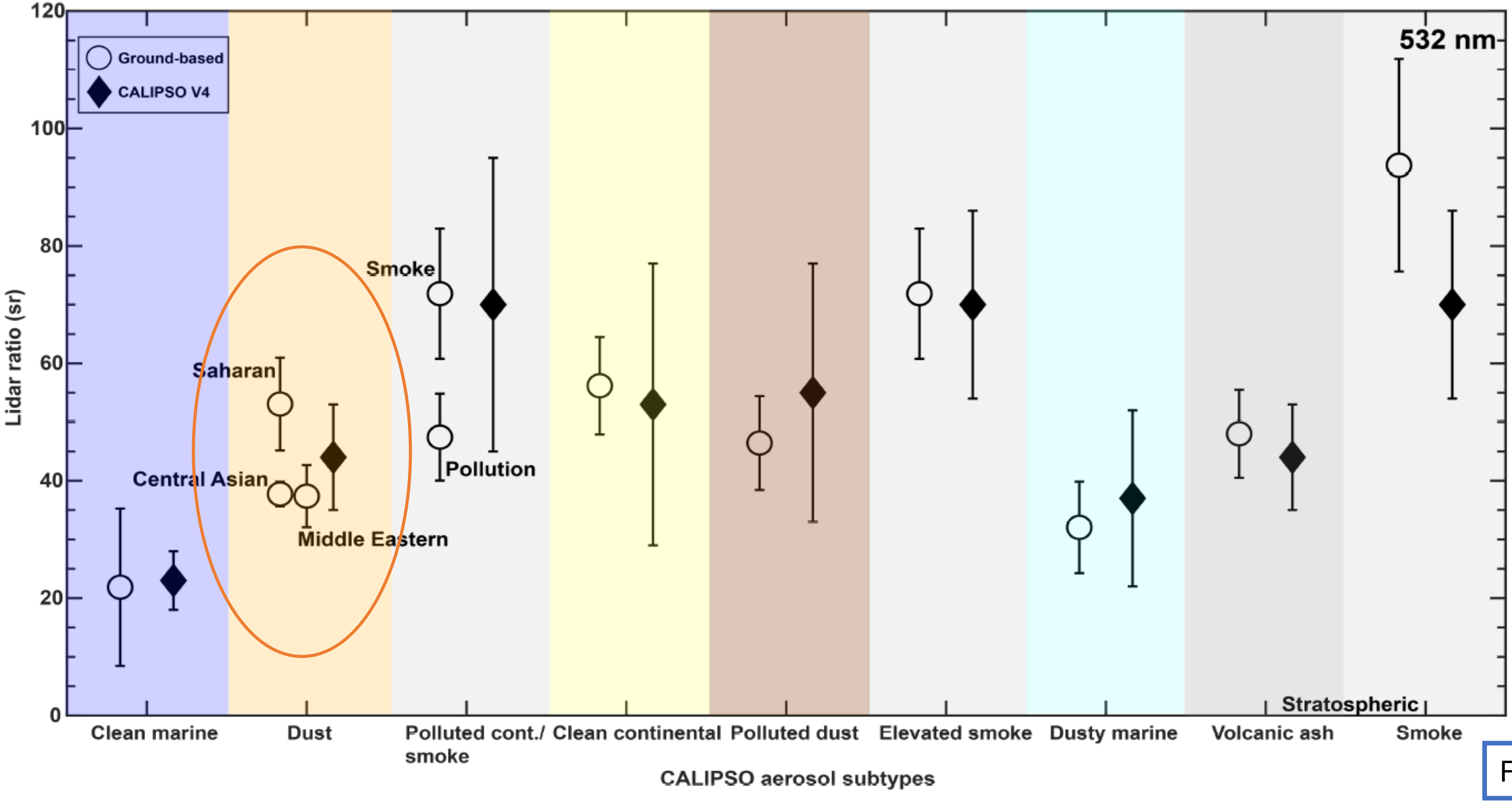
Validation and enhancement of satellite products

LR importance for CALIPSO retrievals
LR spatial variability within the dust belt



Validation and enhancement of satellite products

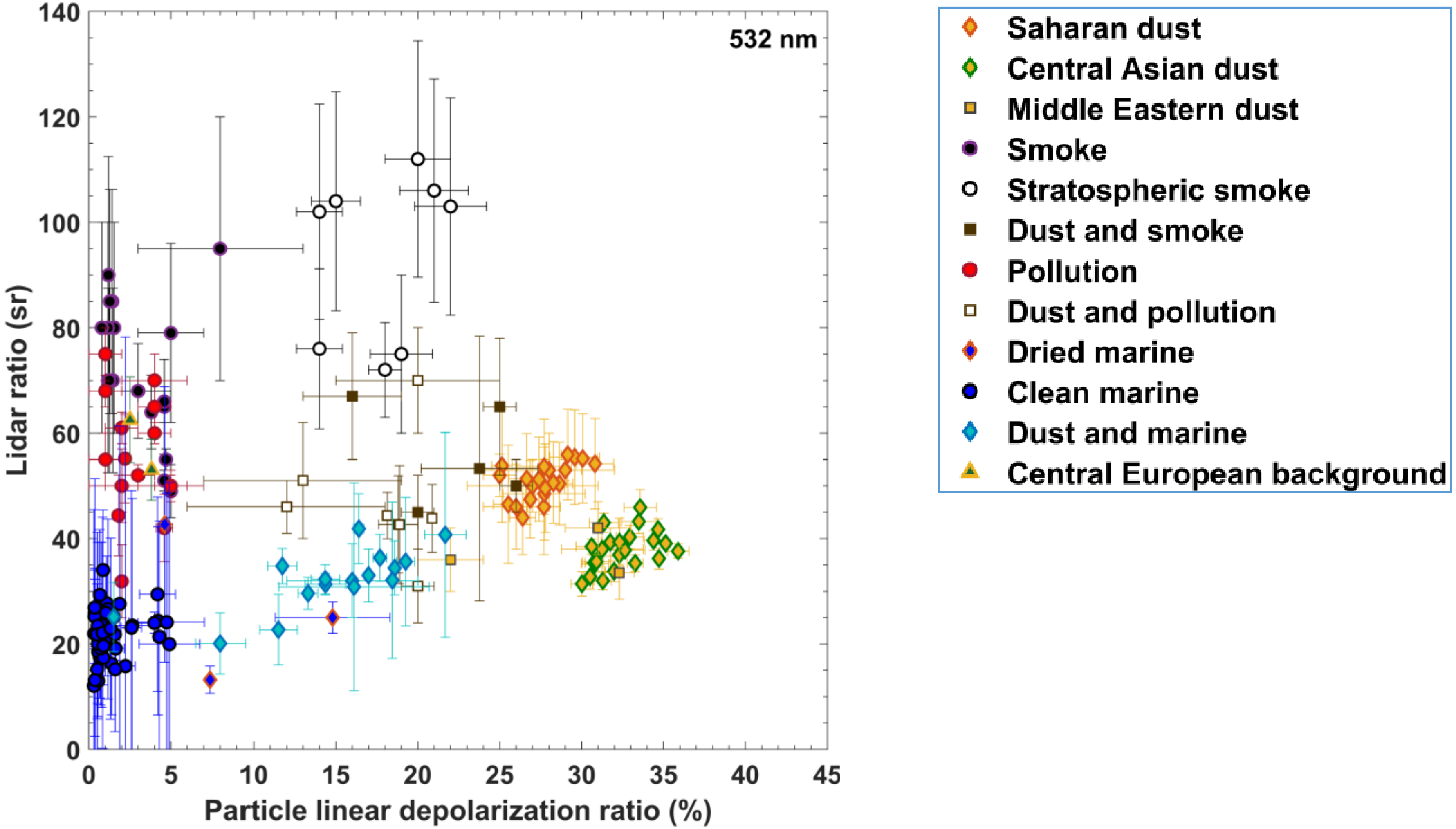
Enhancement of CALIPSO retrievals: variability of dust LR



Floutsi et al., AMT, 2022

Validation and enhancement of satellite products

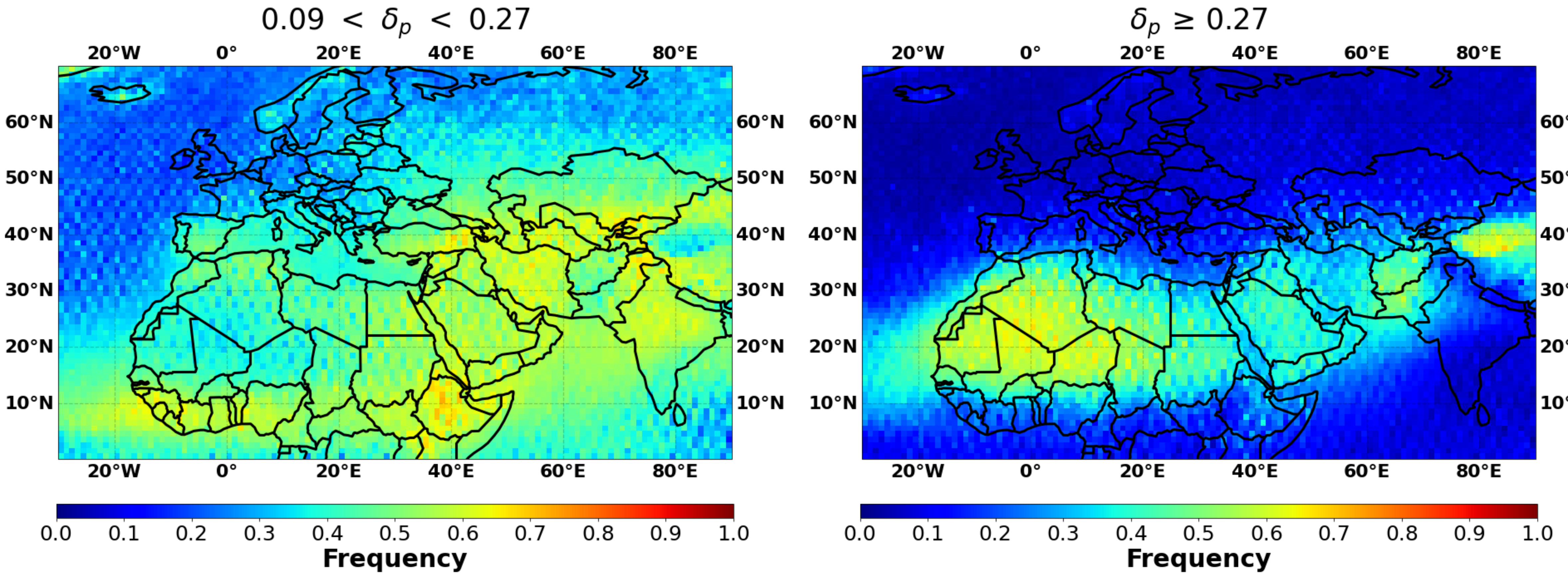
Enhancement of CALIPSO retrievals: variability of dust LR vs PLDR



Floutsi et al., AMT, 2022

Validation and enhancement of satellite products

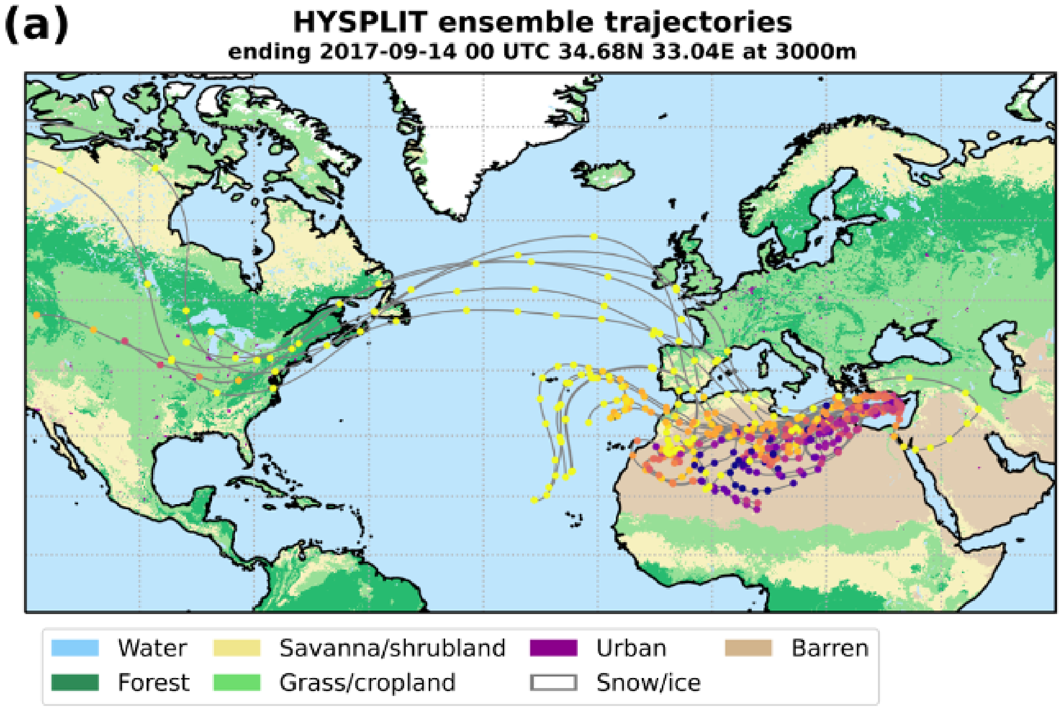
PLDR spatial variability within the dust belt

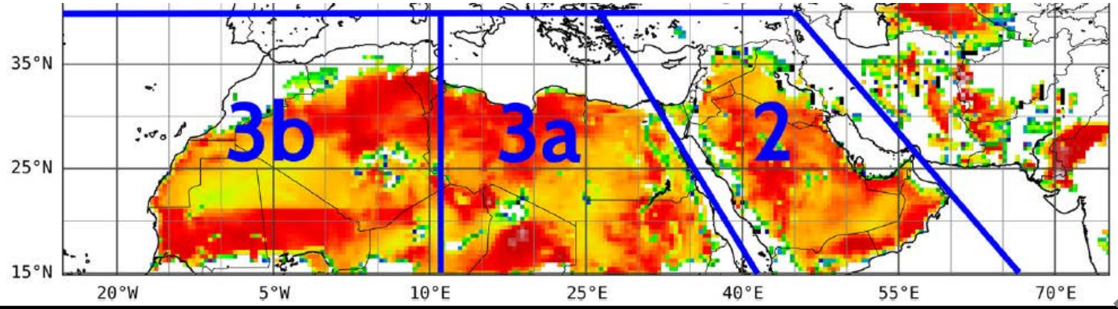


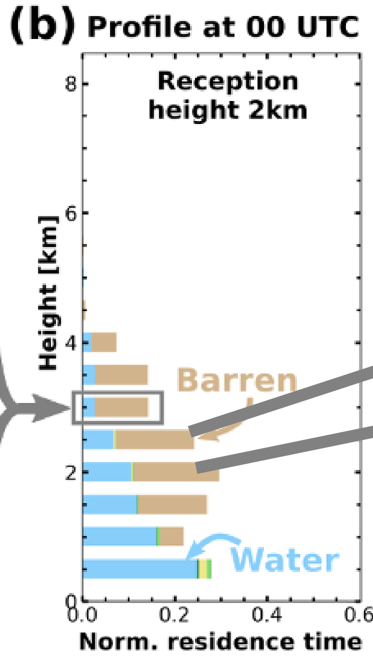
Moustaka et al., EGU, 2023

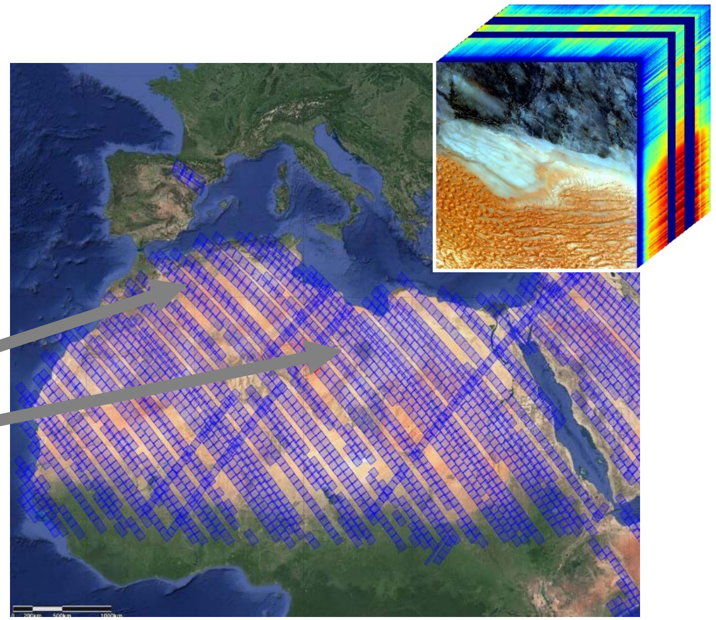
Validation and enhancement of satellite products

Spatial variability of the intensive properties could be related to the mineralogy









In anticipation of the first mineralogical maps from EMIT

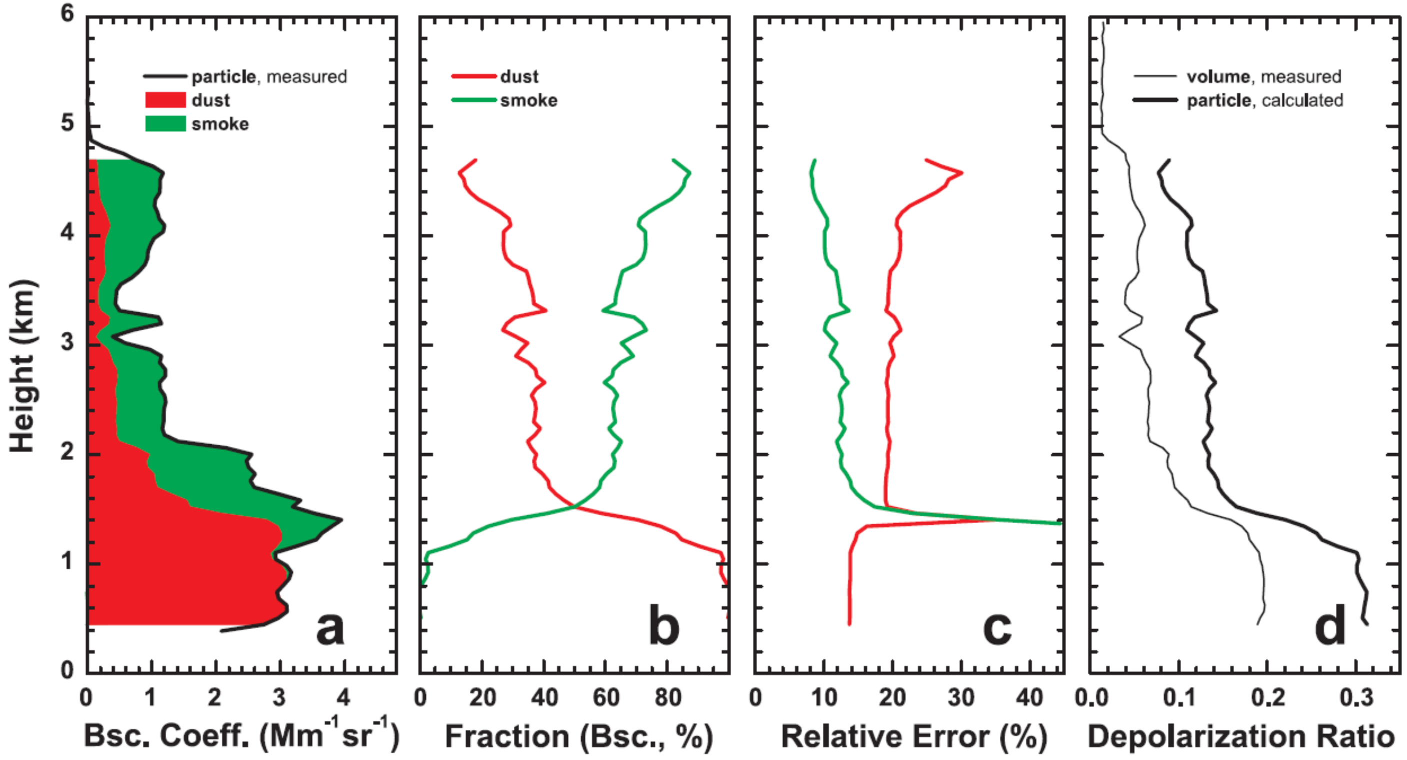
Validation and enhancement of satellite products

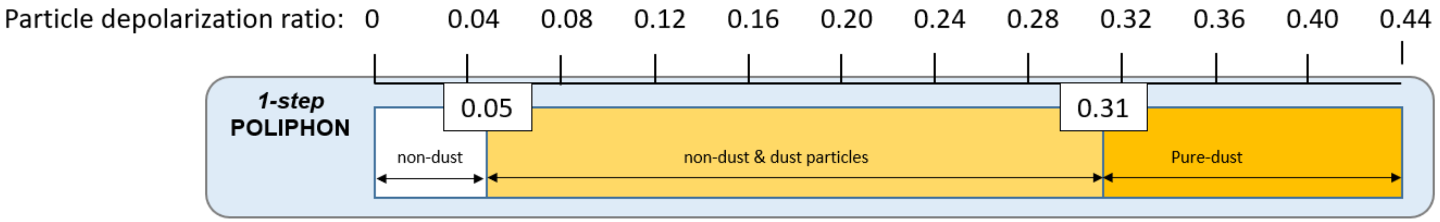
CALIPSO dust retrievals following the POLIPHON concept

POLIPHON: Polarization lidar-photometer networking technique

Discriminating the pure dust component in remote sensing observations, **under the hypothesis of external dust mixtures**

$$\beta_1 = \beta_t \frac{(\boldsymbol{\delta_p} - \delta_2)(1 + \delta_1)}{(\delta_1 - \delta_2)(1 + \delta_p)}$$

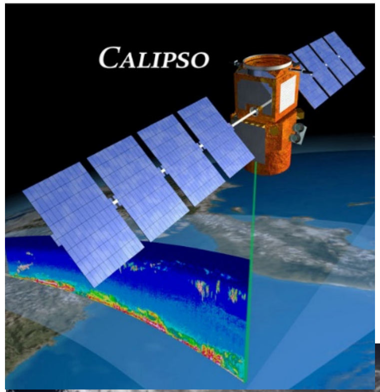




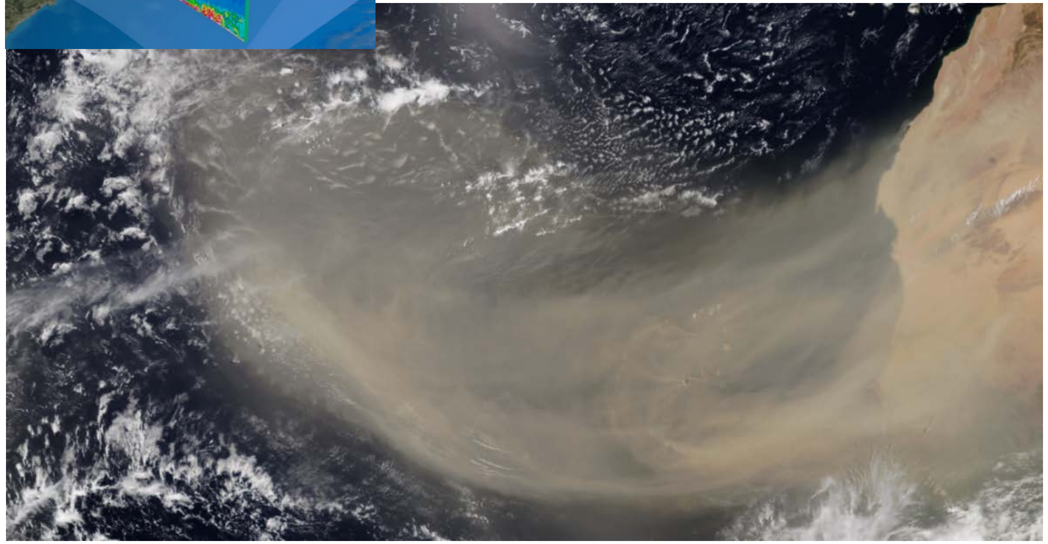
Tesche et al., JGR, 2009
Mamouri et al., AMT, 2017
Ansmann et al., AMT, 2019
Amiridis et al., ACP, 2013

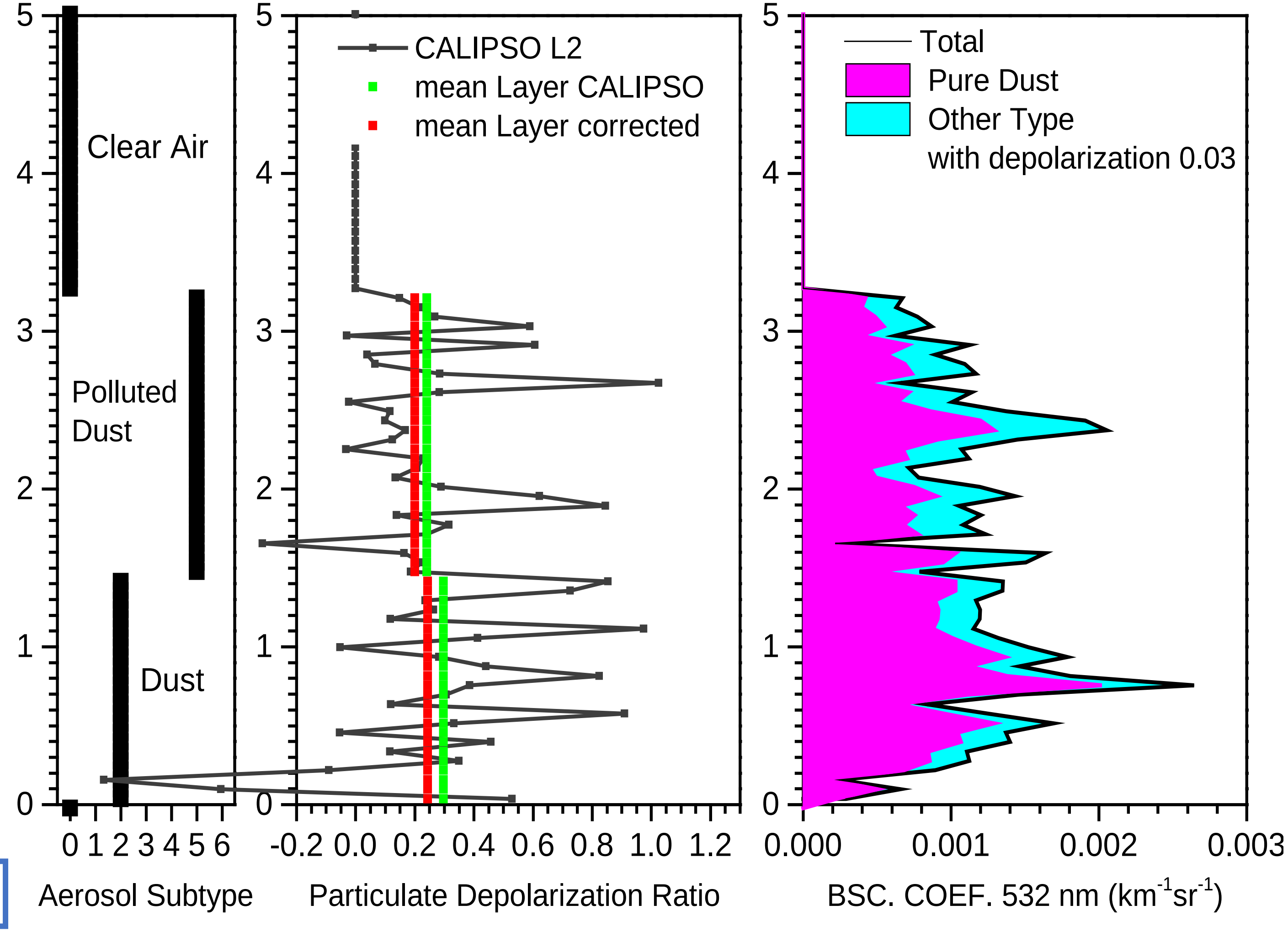
Validation and enhancement of satellite products

CALIPSO dust retrievals following the LIVAS concept



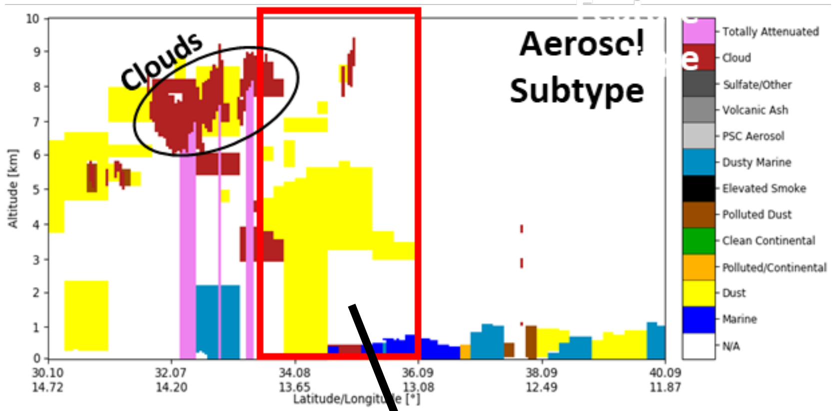
LIVAS:
1. 4D and multiwavelength - aerosol.
2. Pure-Dust including fine/coarse mode components.
3. Pure-Dust related IN/CCN (ongoing).



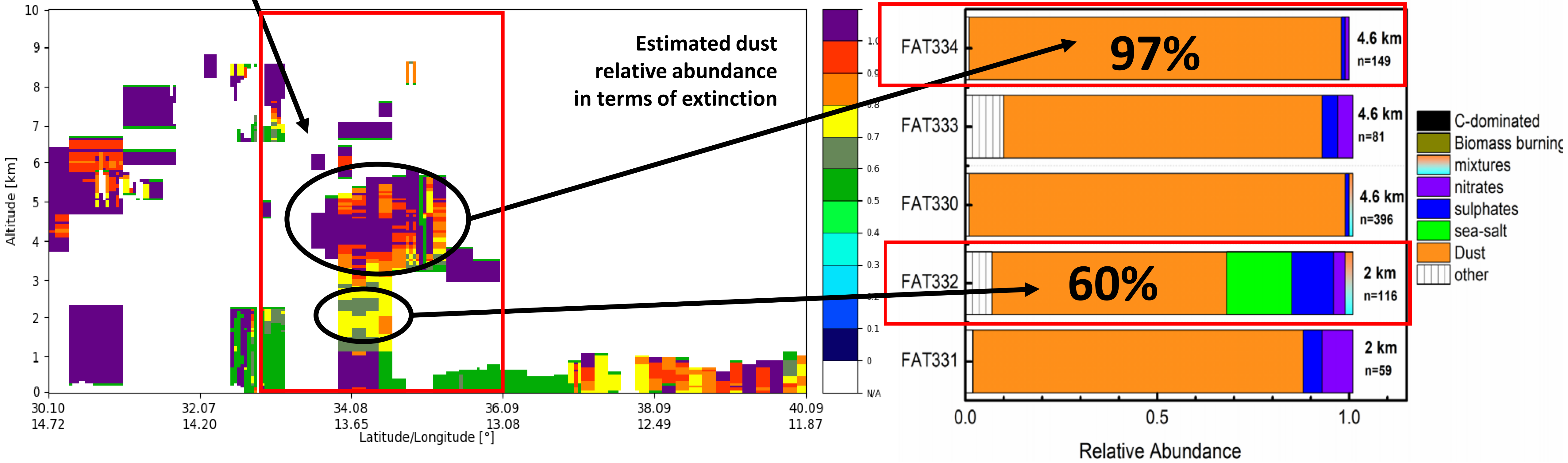


Amiridis et al. 2013; Marinou et al. 2019; Proestakis et al. 2017

Validation and enhancement of satellite products

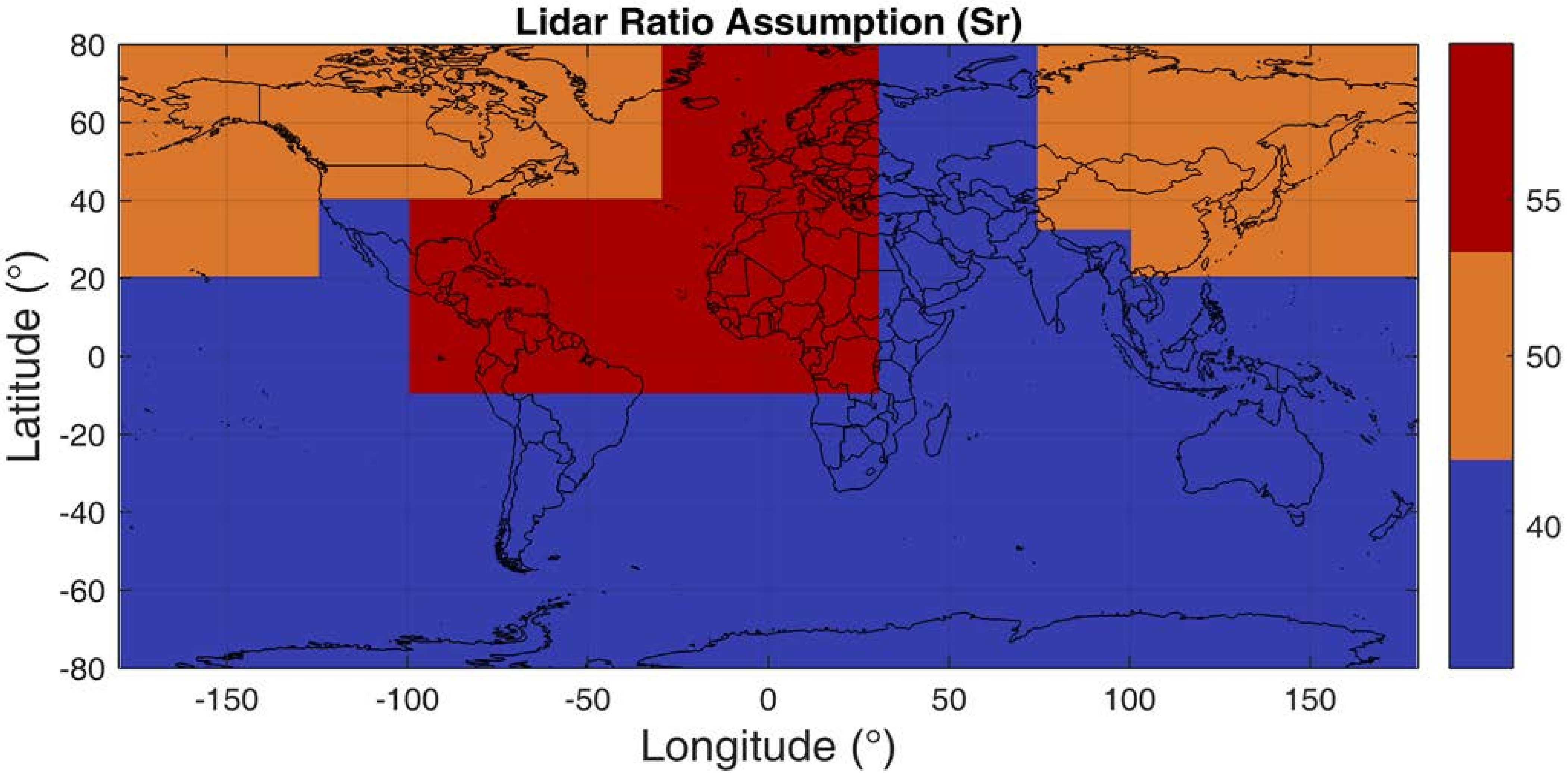


Reasonable Consistency with analysis of airborne samples



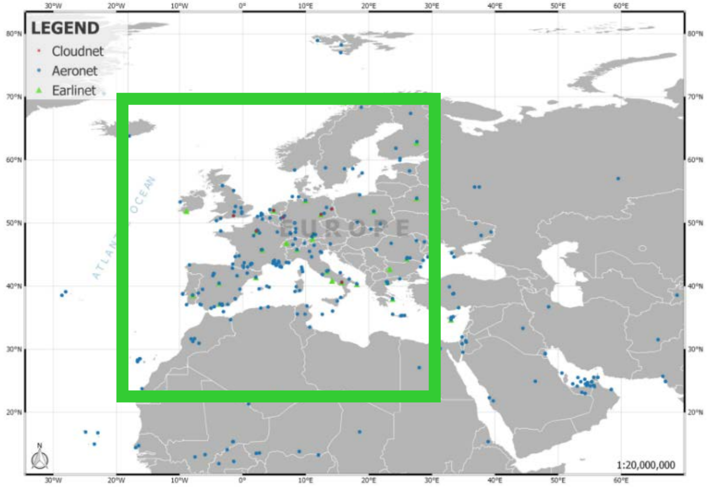
Validation and enhancement of satellite products

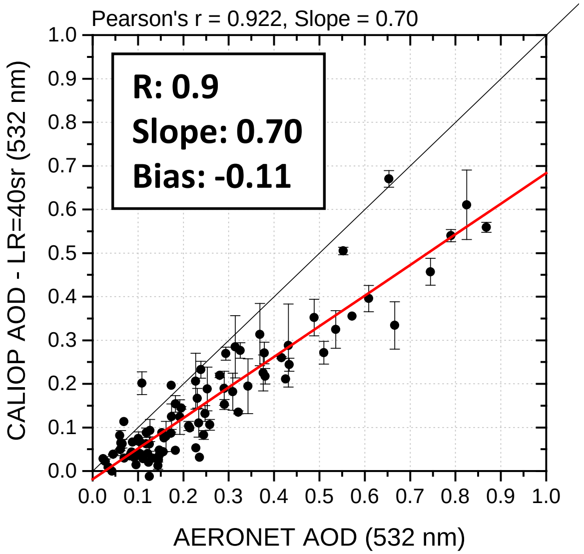
Enhancement of CALIPSO retrievals using regionally-dependent LRs

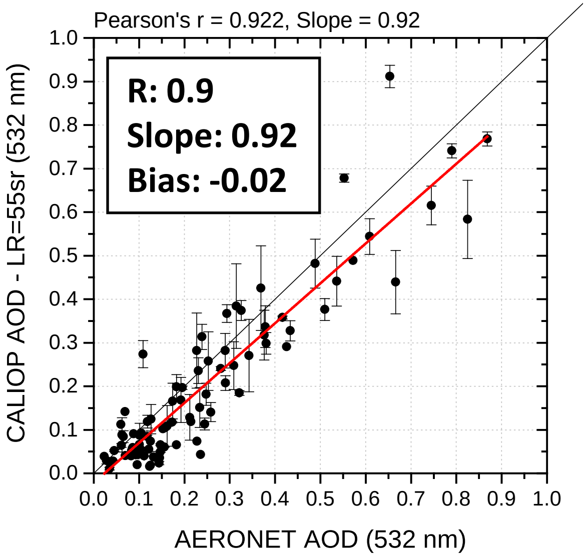


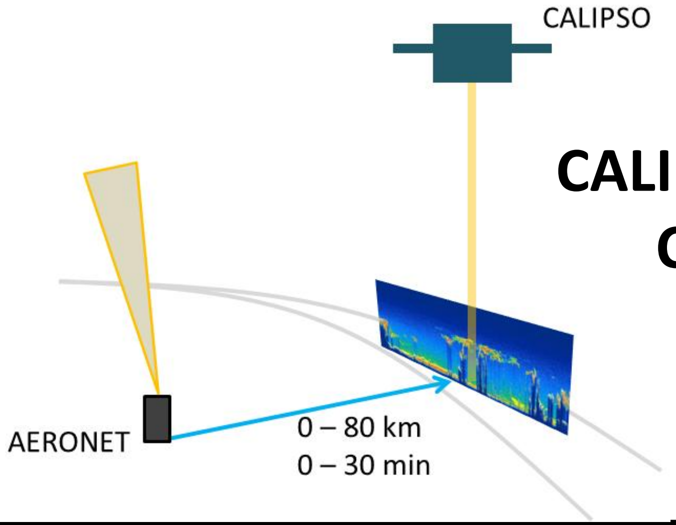
Validation and enhancement of satellite products

CALIPSO dust retrievals following the LIVAS concept









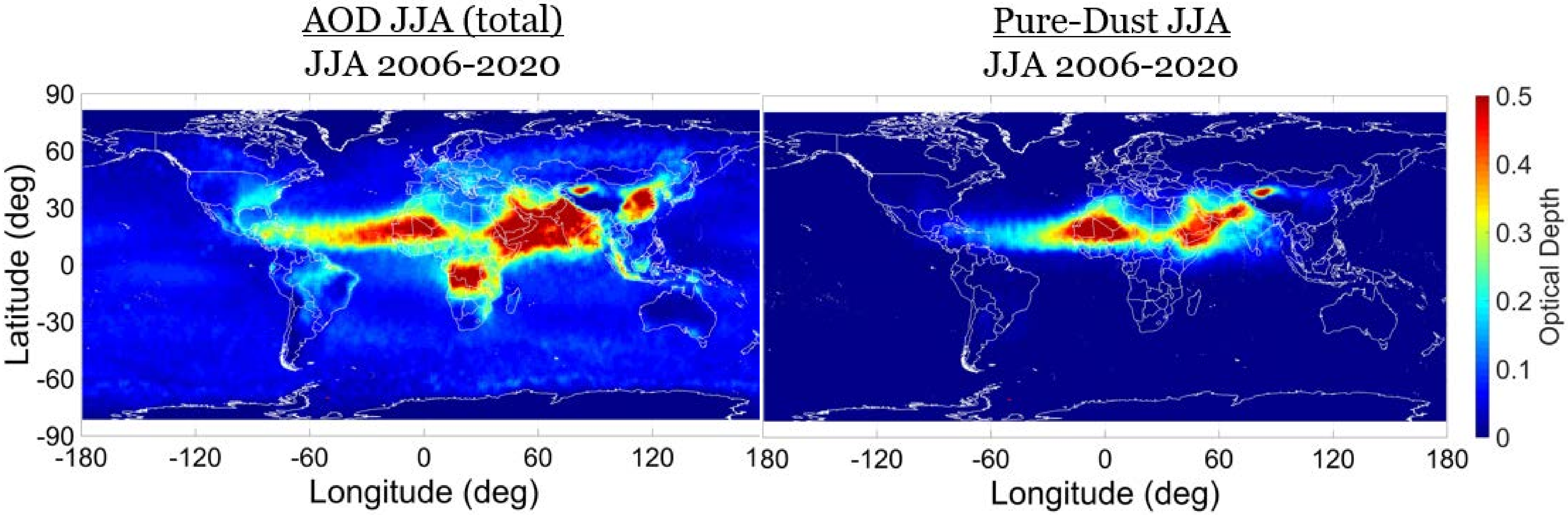
CALIPSO-AERONET Collocation

For pure dust cases according to CALIPSO depolarization over AERONET stations

Amiridis et al., 2013

Validation and enhancement of satellite products

CALIPSO dust retrievals following the LIVAS concept

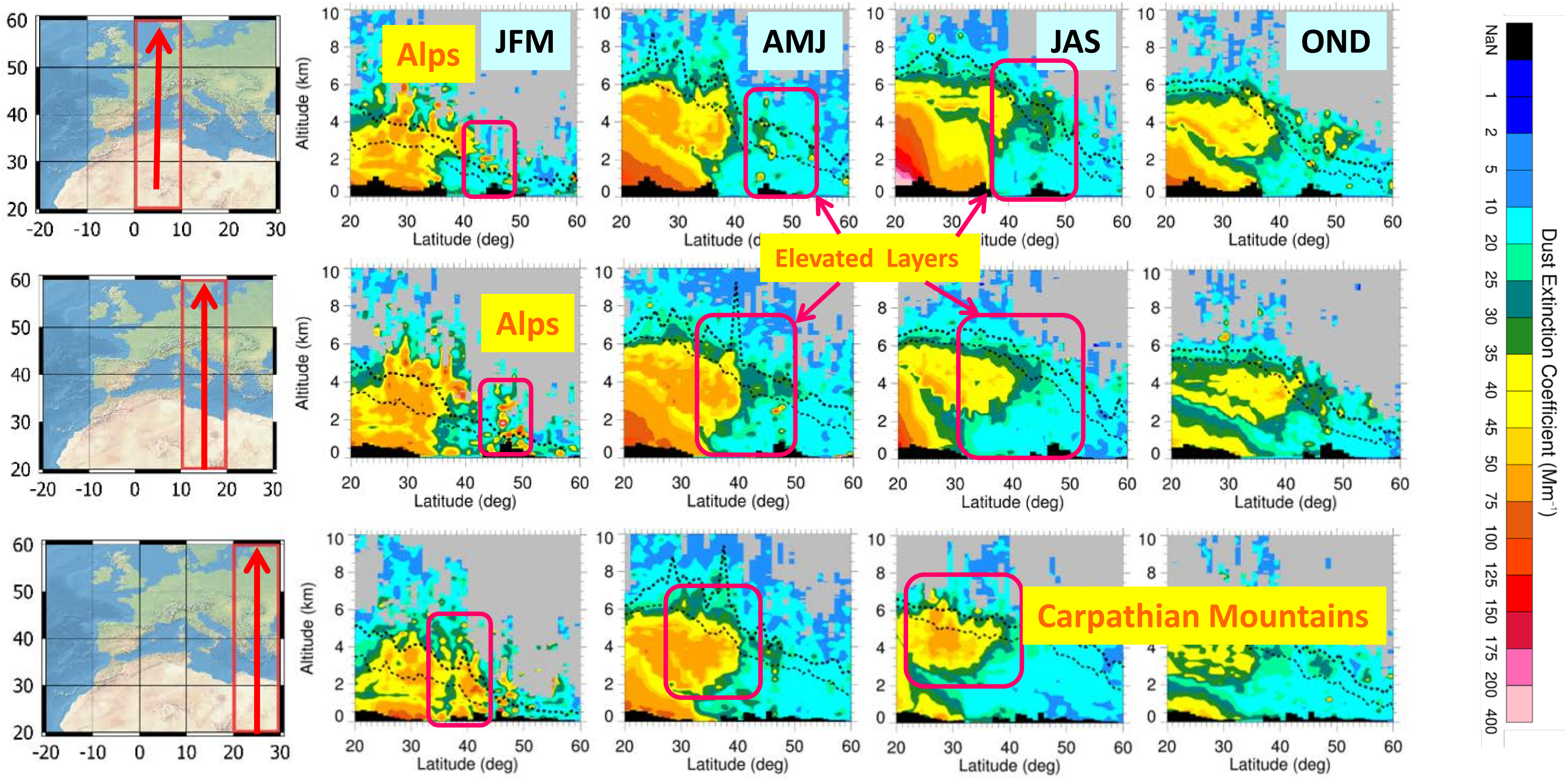


Proestakis et al., ACP, 2017

Validation and enhancement of satellite products

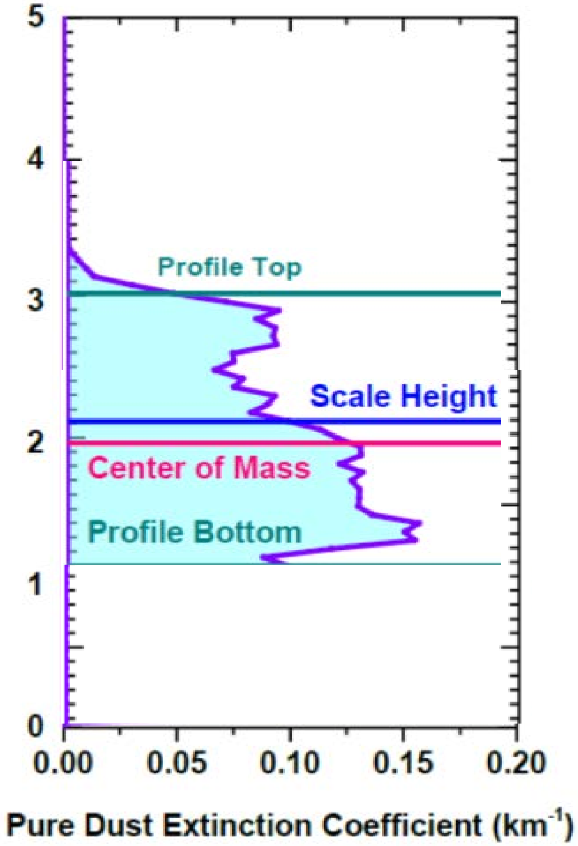
CALIPSO dust retrievals following the LIVAS concept

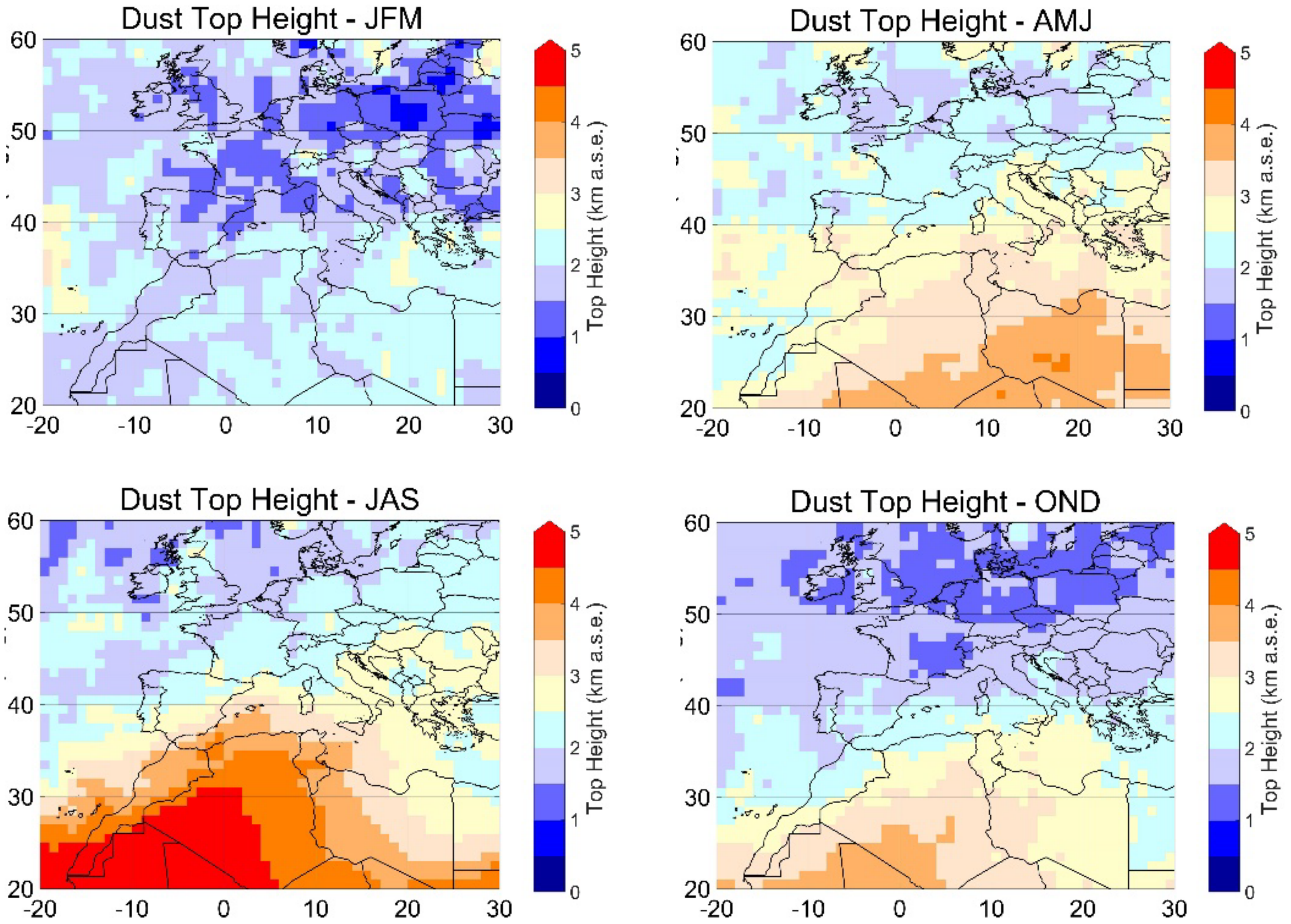
Latitudinal cross-sections of dust transport



Marinou et al., ACP, 2017

CALIPSO dust retrievals following the LIVAS concept

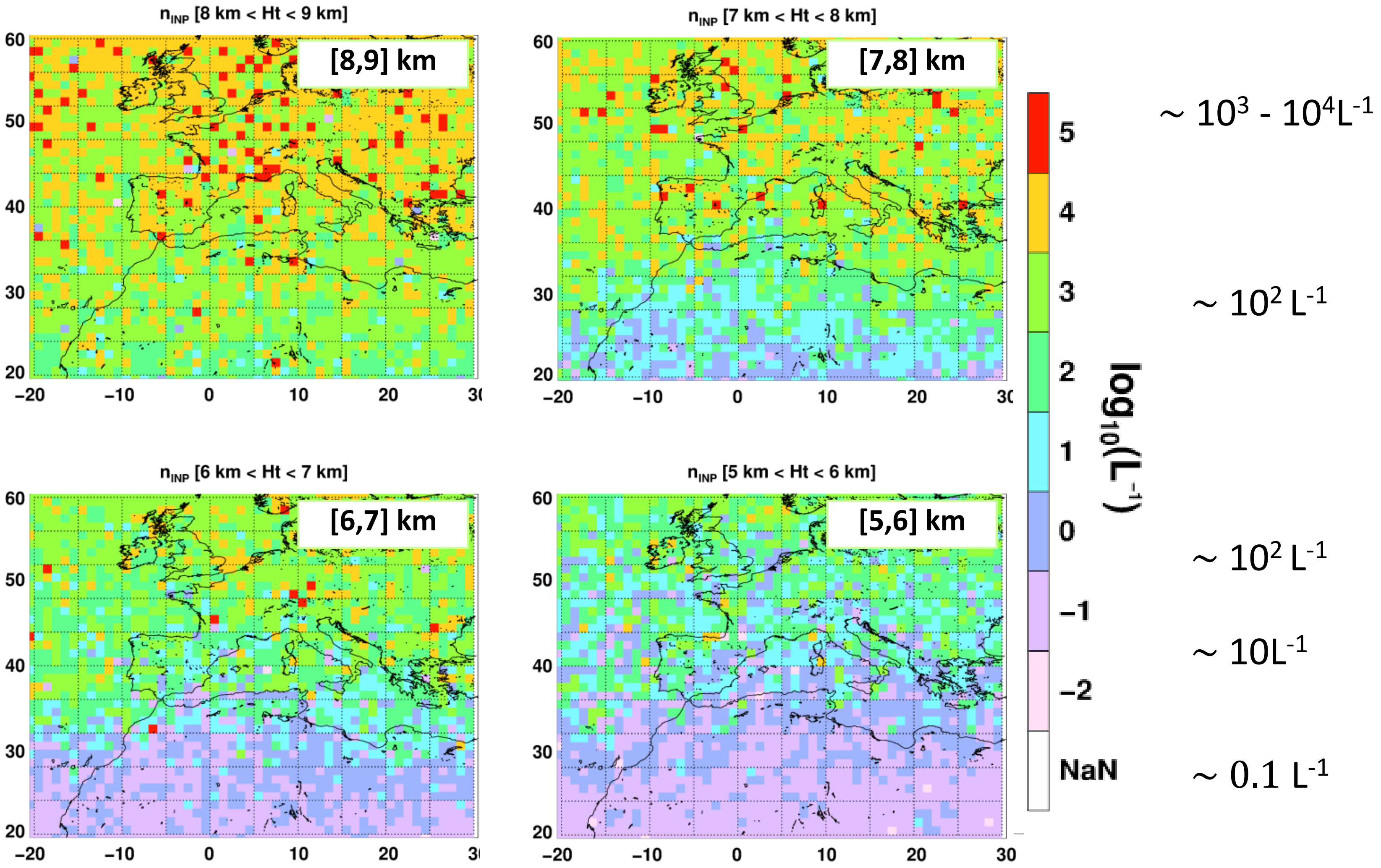




Marinou et al., ACP, 2017

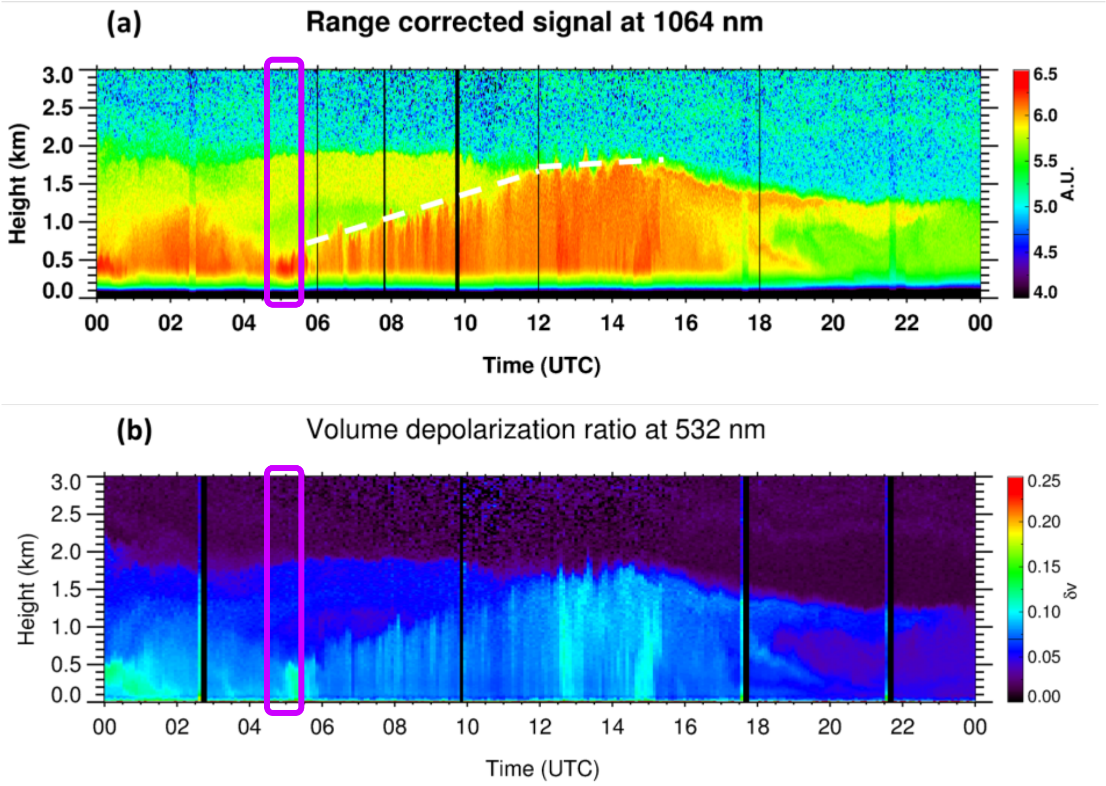
Validation and enhancement of satellite products

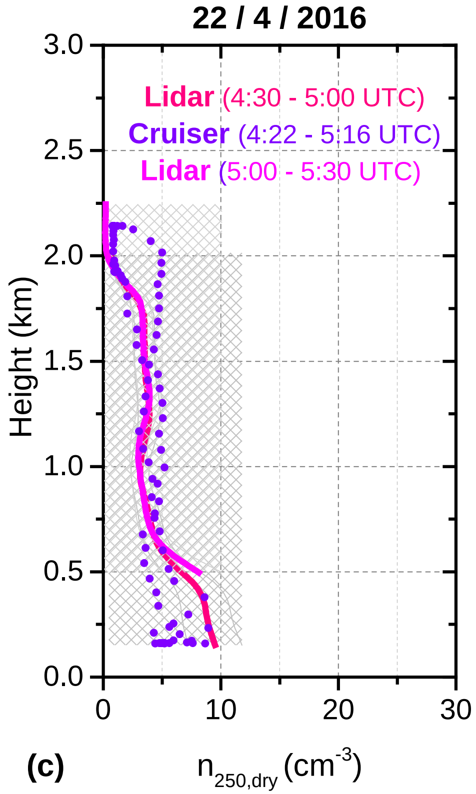
CALIPSO dust IN retrievals following the LIVAS concept



Validation and enhancement of satellite products

CALIPSO dust IN retrievals following the LIVAS concept





photograph by Kjell-Sture Johansen

Good agreement between the in-situ and lidar-derived $n_{250,d}$ within the lidar uncertainties

Differences observed are attributed to the spatiotemporal variability of the scenes

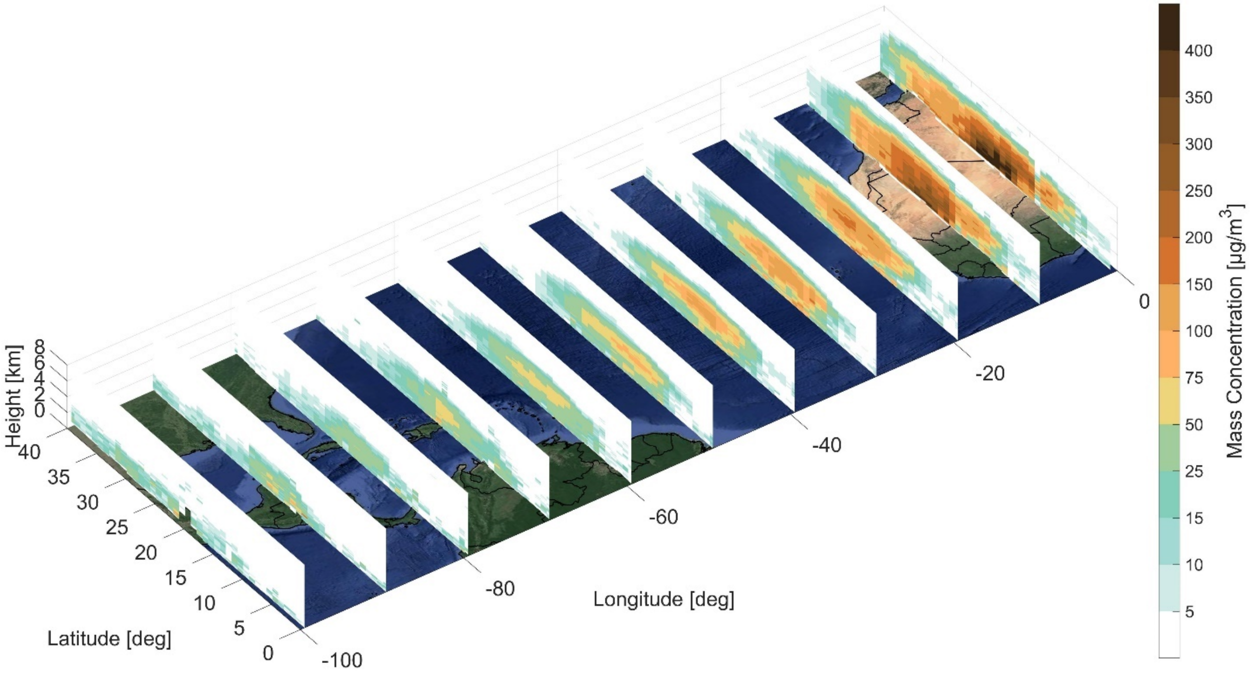
Mamouri et al.,2017
Marinou et al., 2019

Validation and enhancement of satellite products

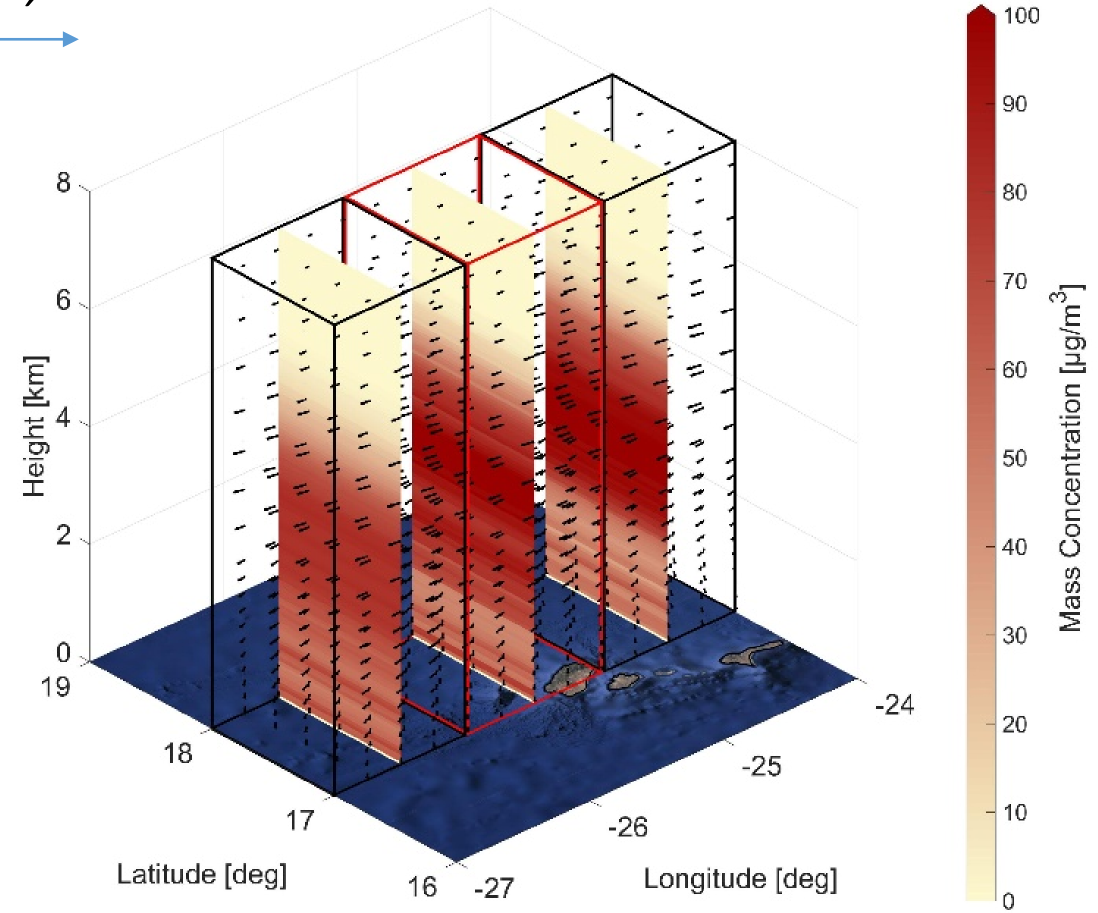
CALIPSO dust deposition retrievals following the LIVAS concept

DOMOS ESA Study
PI: A. Benedetti
NOA: E. Proestakis

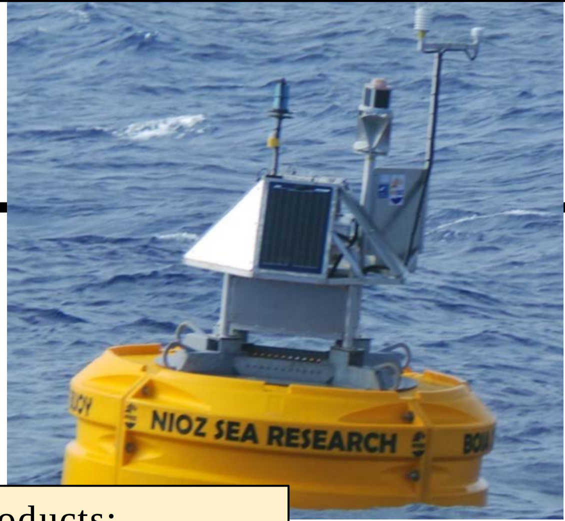
LIVAS Pure-Dust Mass Concentration
JJA 2006-2020



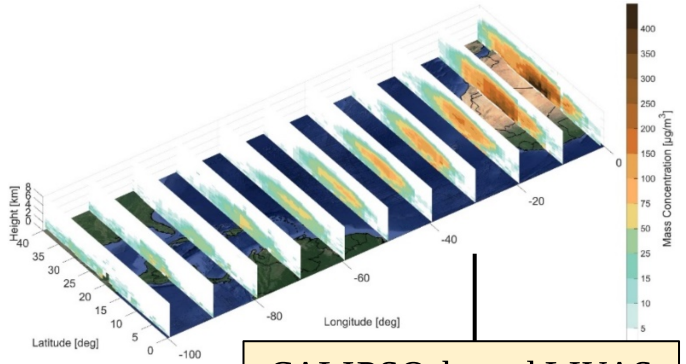
+ ERA5 u, v, w.



Validation and enhancement of satellite products



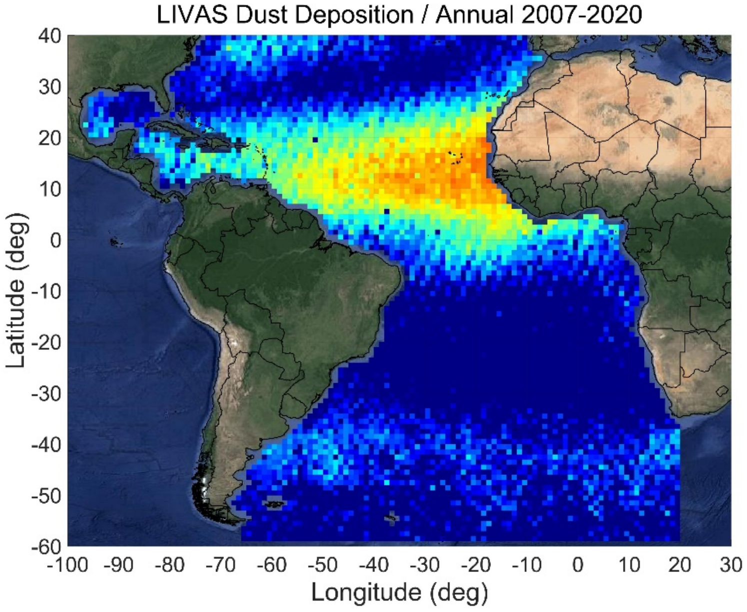
CALIPSO dust deposition retrievals following the LIVAS concept

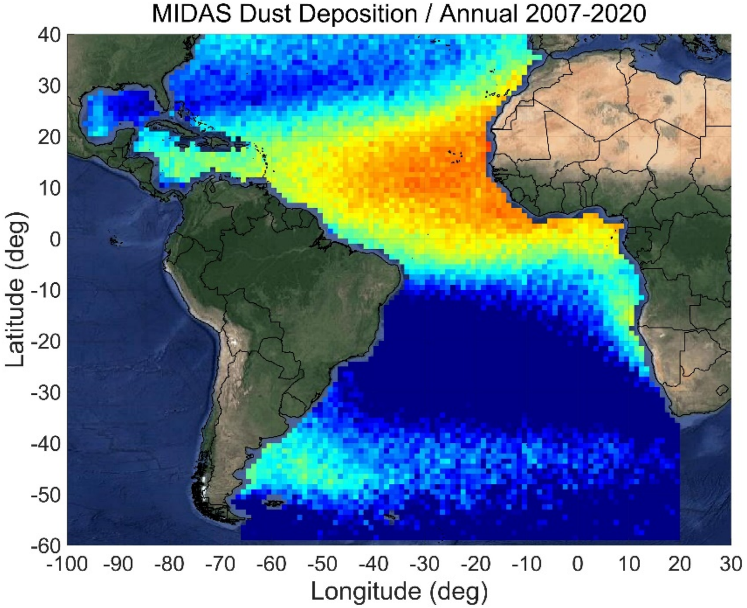


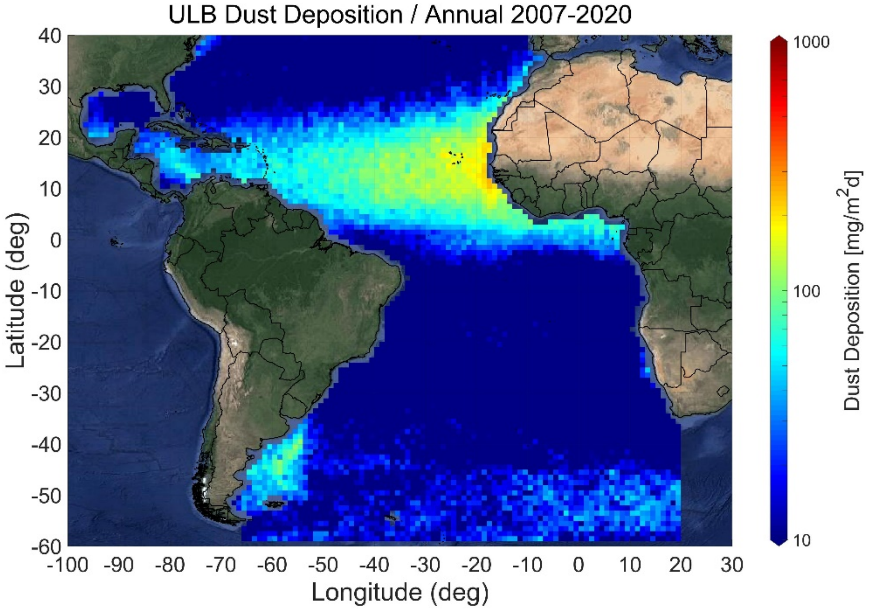
CALIPSO-based LIVAS

<u>Synergy of dust products:</u>
CALIPSO-based LIVAS
And
MIDAS

<u>Synergy of dust products:</u>
CALIPSO-based LIVAS
And
Metop-IASI-ULB

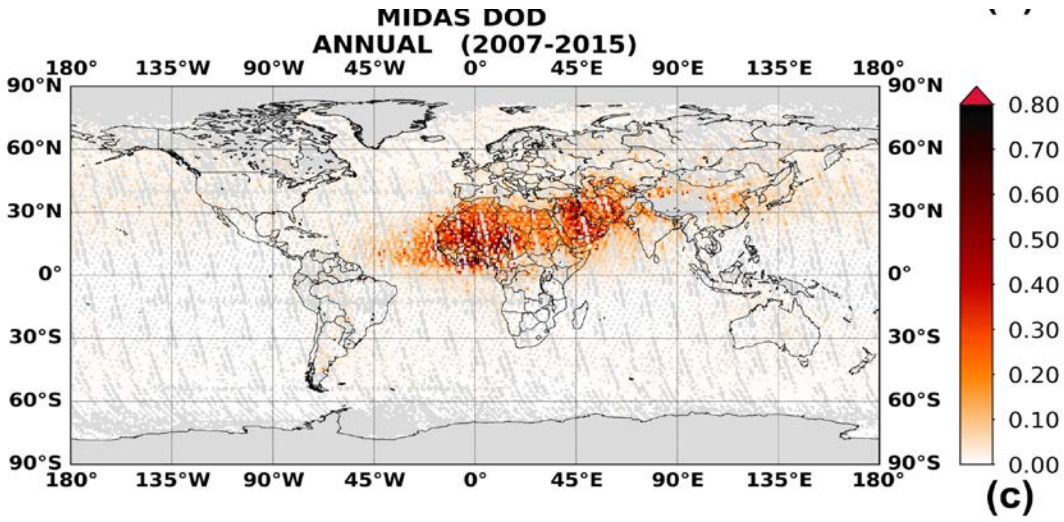






Validation and enhancement of satellite products

LIVAS and MIDAS

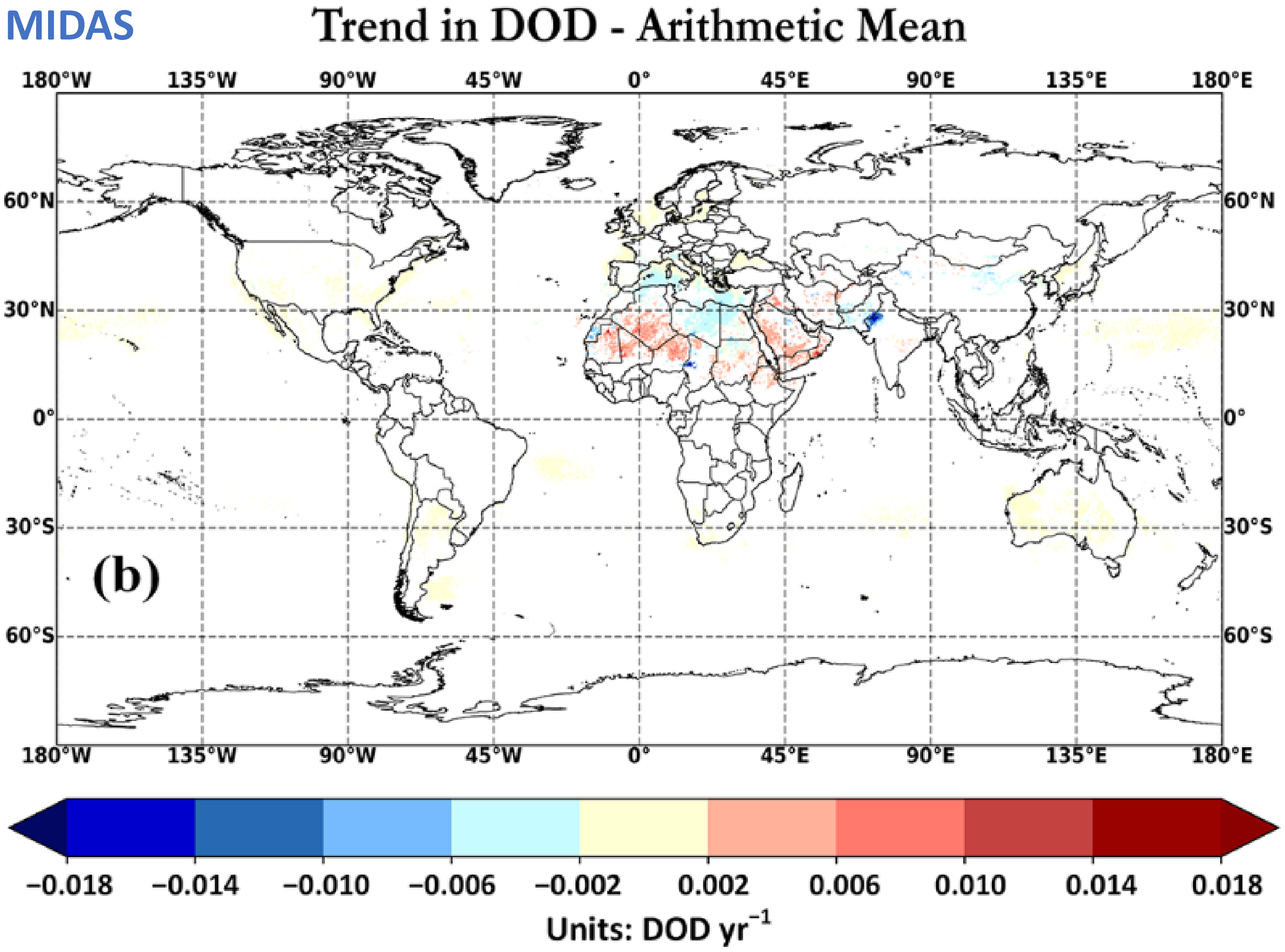


Spatial resolution: 0.1° x 0.1°
Spatial coverage: Global
Temporal resolution: Daily
Temporal availability: 2003 – 2017
Access: https://zenodo.org/record/4244106#.Y8EJwhVBwtw
Project: DUST-GLASS [(H2020-MSCA-IF-2016)]

Gkikas et al., AMT, 2021; 2022

Validation and enhancement of satellite products

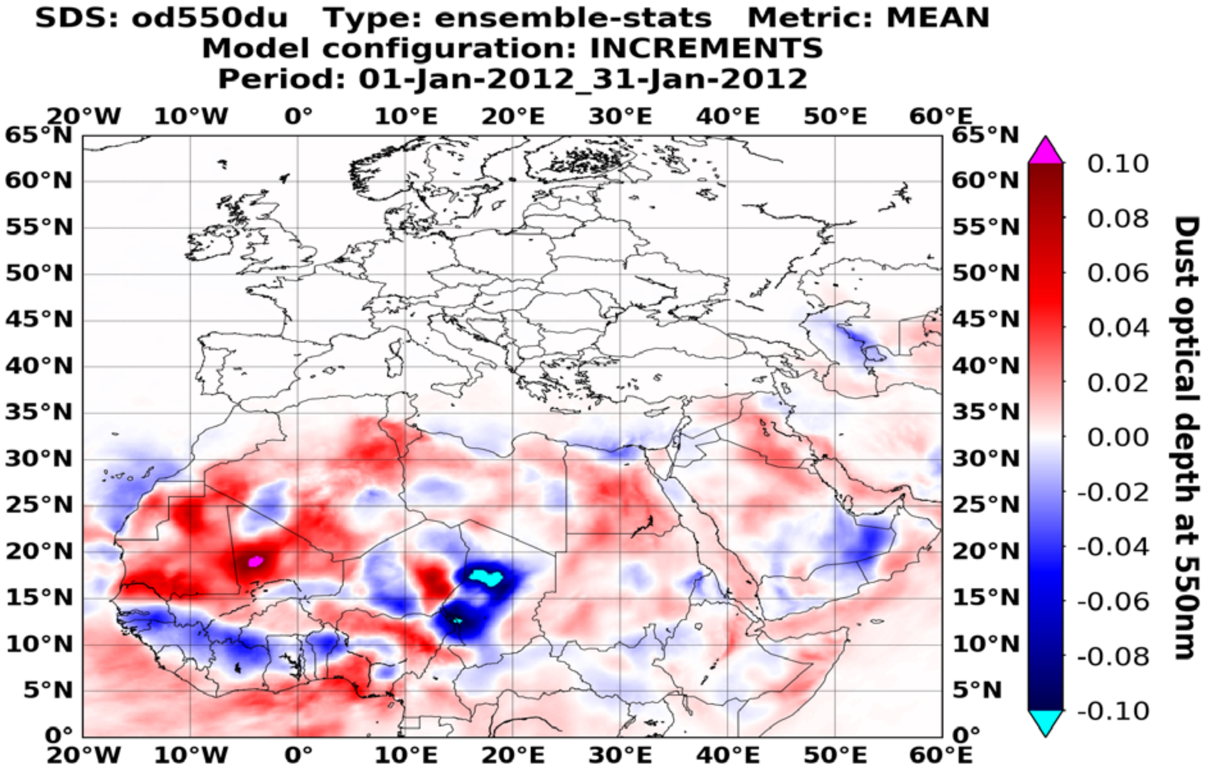
LIVAS and MIDAS

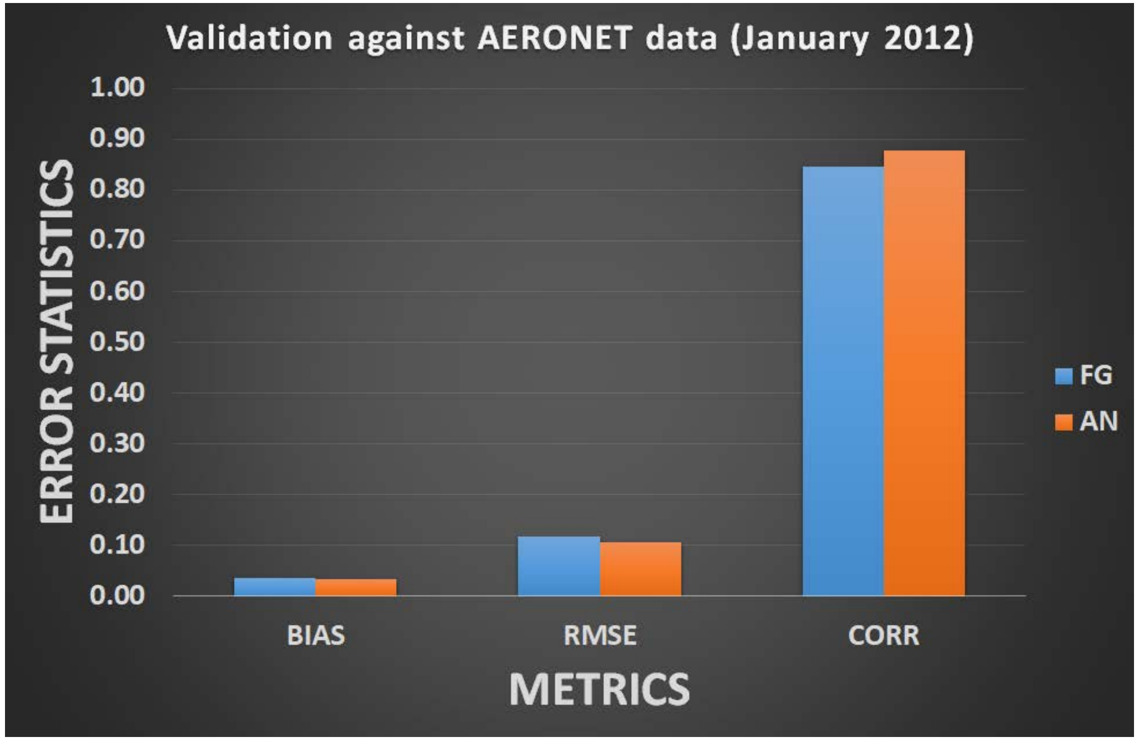


Logothetis et al., 2021

Validation and enhancement of satellite products

MIDAS for DA



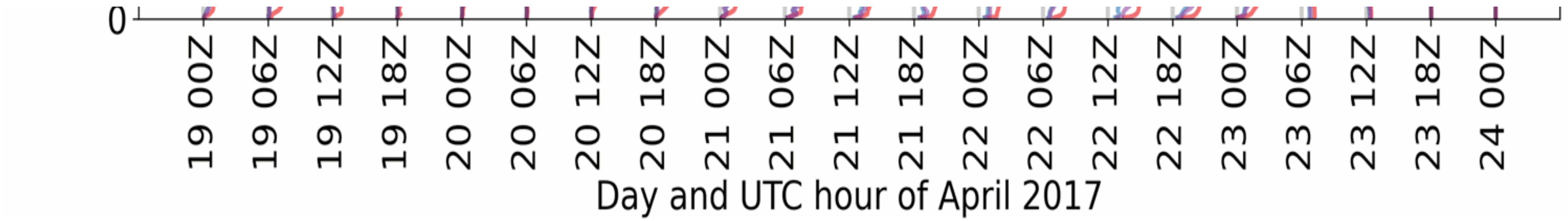


Use of ASKOS-like measurements for:

Data Assimilation and related Operators

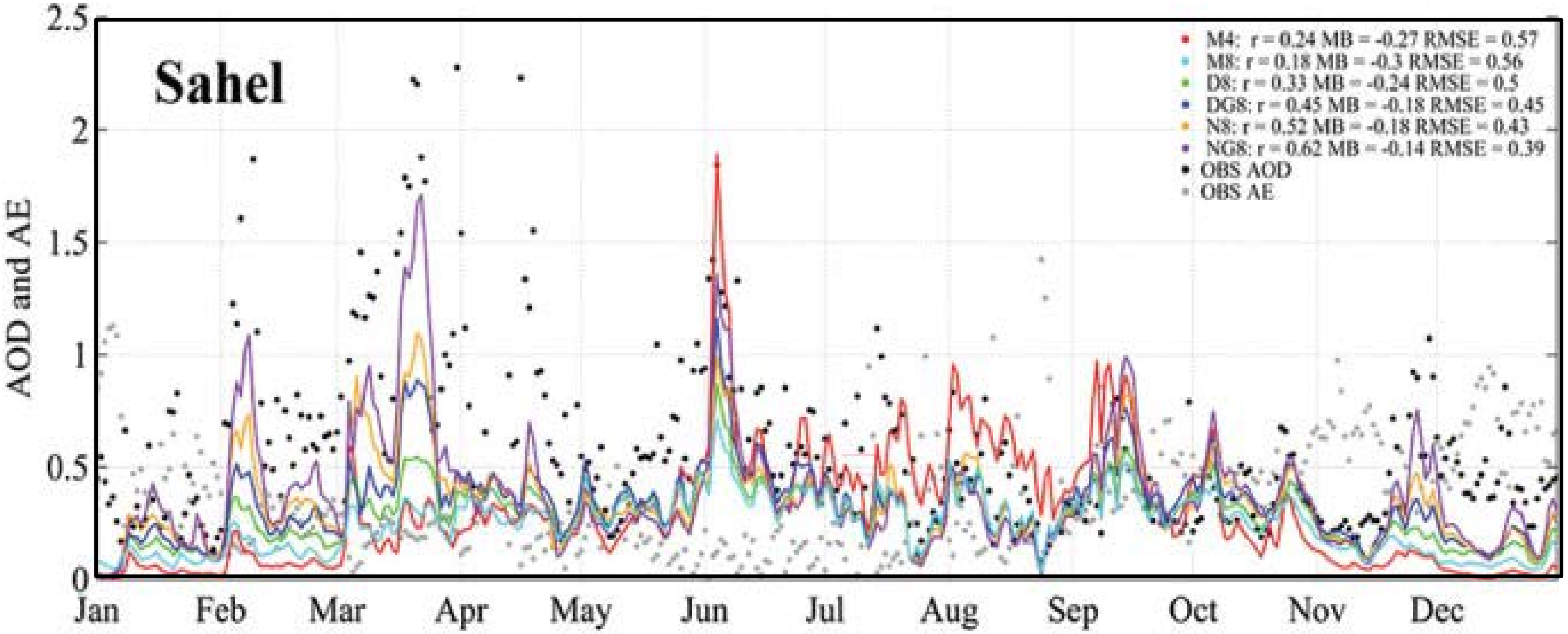
Data Assimilation

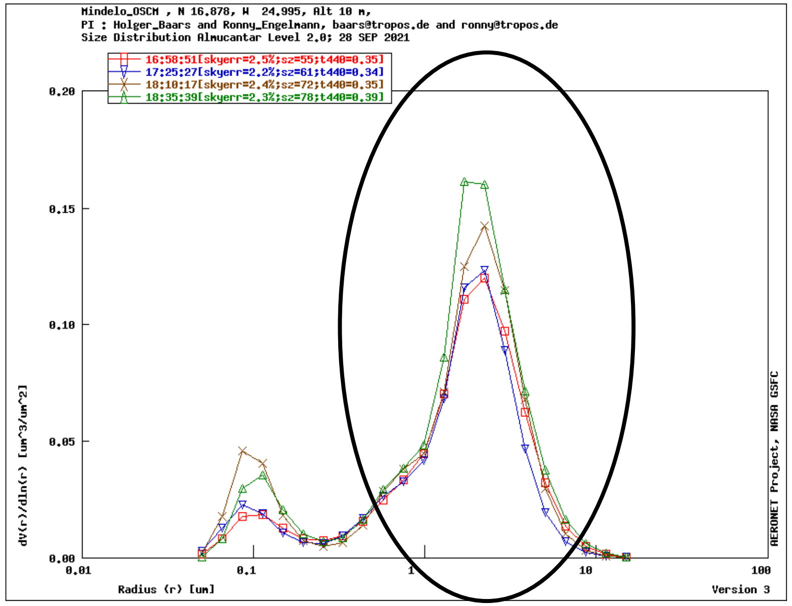
Dust transport model MONARCH: forecast improvement through LIVAS assimilation



Escribano et al., ACP, 2022

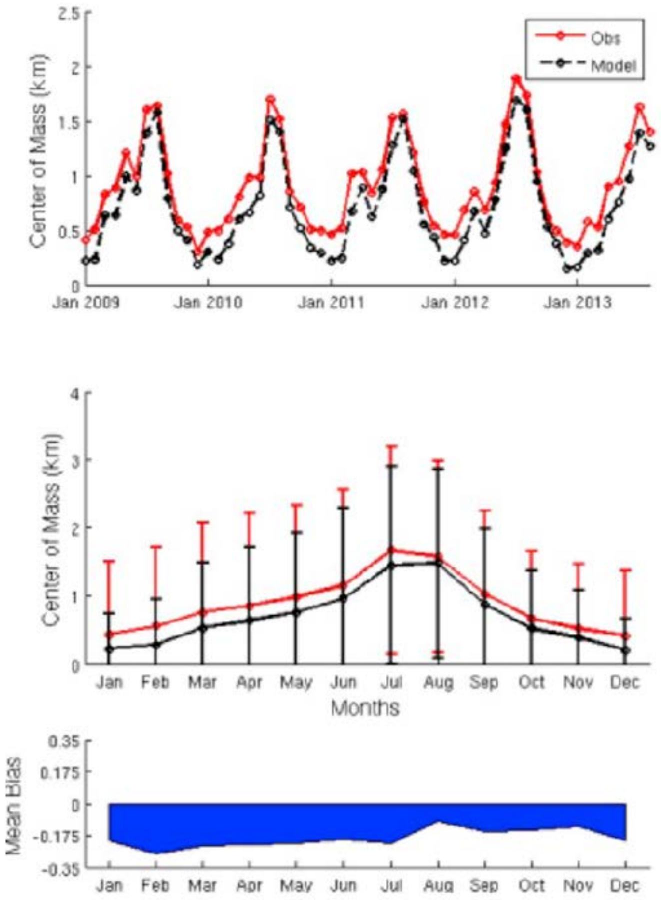
Dust transport models: how we test the impact against observations?



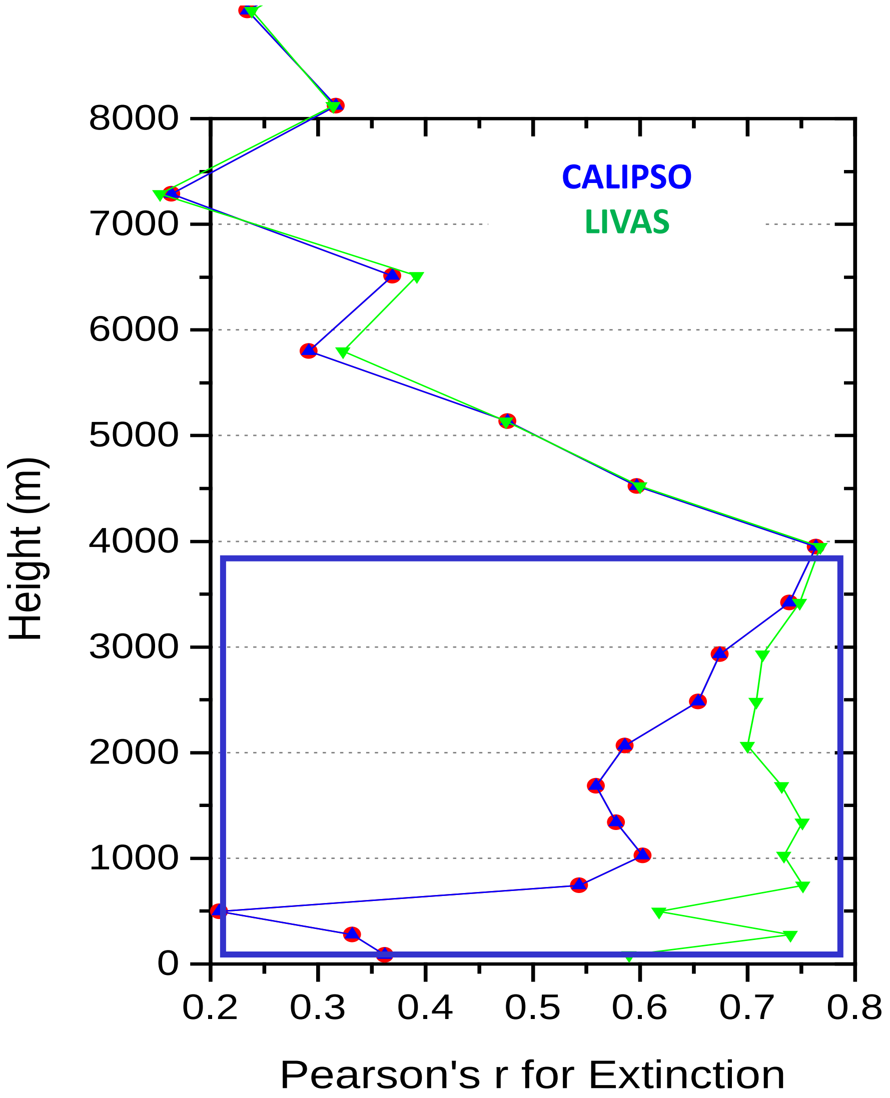


Basart et al., CPM, 2012

Dust transport models: DREAM vs LIVAS for NAMEE



Konsta et al., 2018

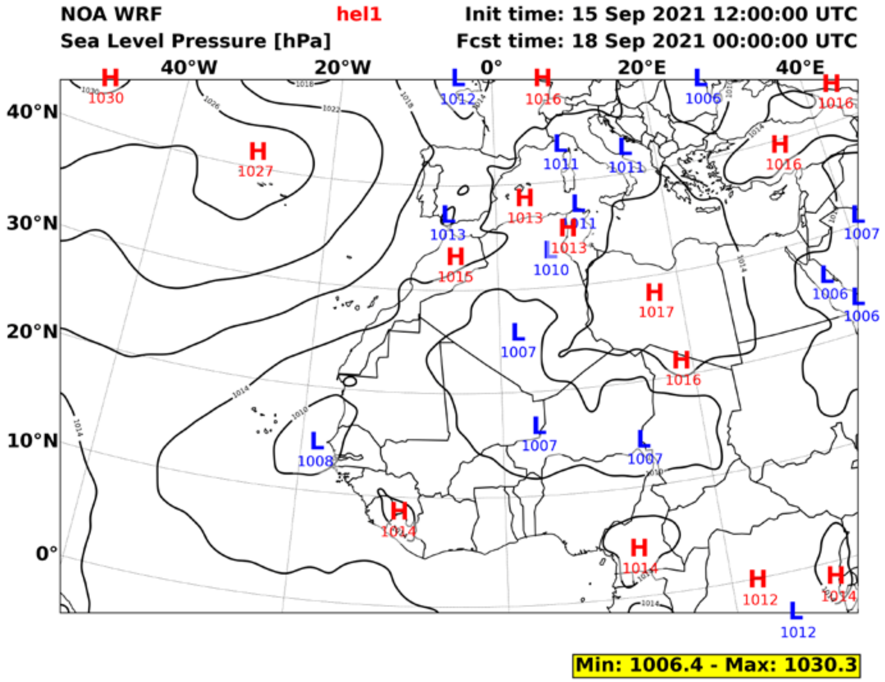


Amiridis et al., ACP, 2013

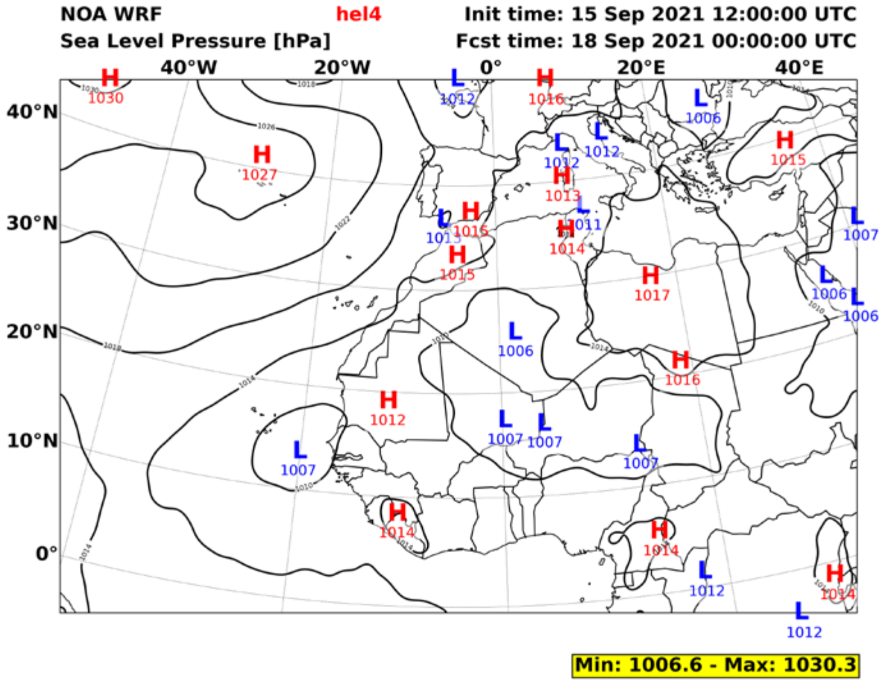
Aeolus impact on dust transport models

Deepening of the low-pressure system, centered eastwards of Cape Verde, in the hel4 run

hel 1 [without Aeolus assimilation]



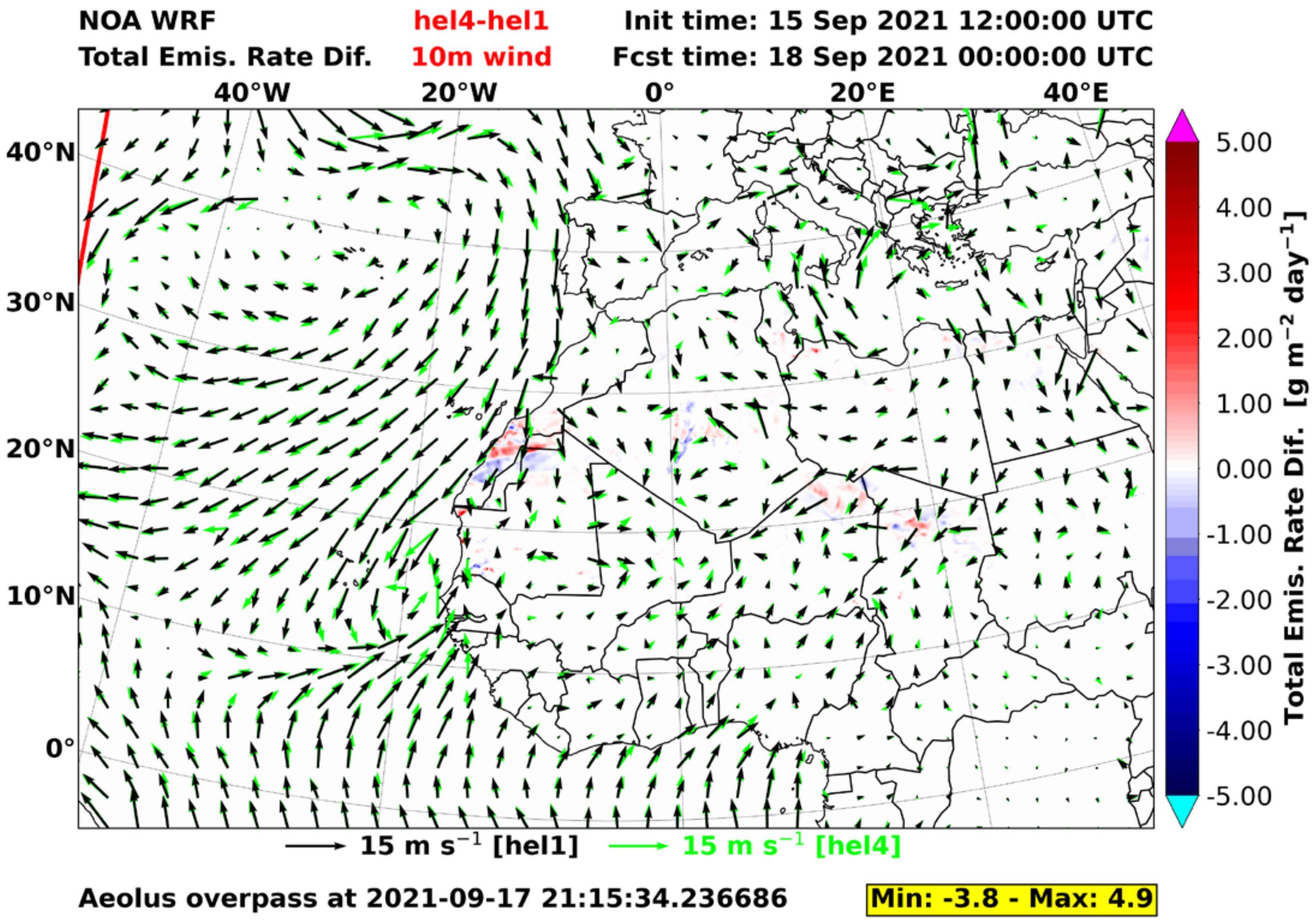
hel 4 [with Aeolus assimilation]



Data Assimilation

Aeolus impact on dust transport models

hel4 – hel1



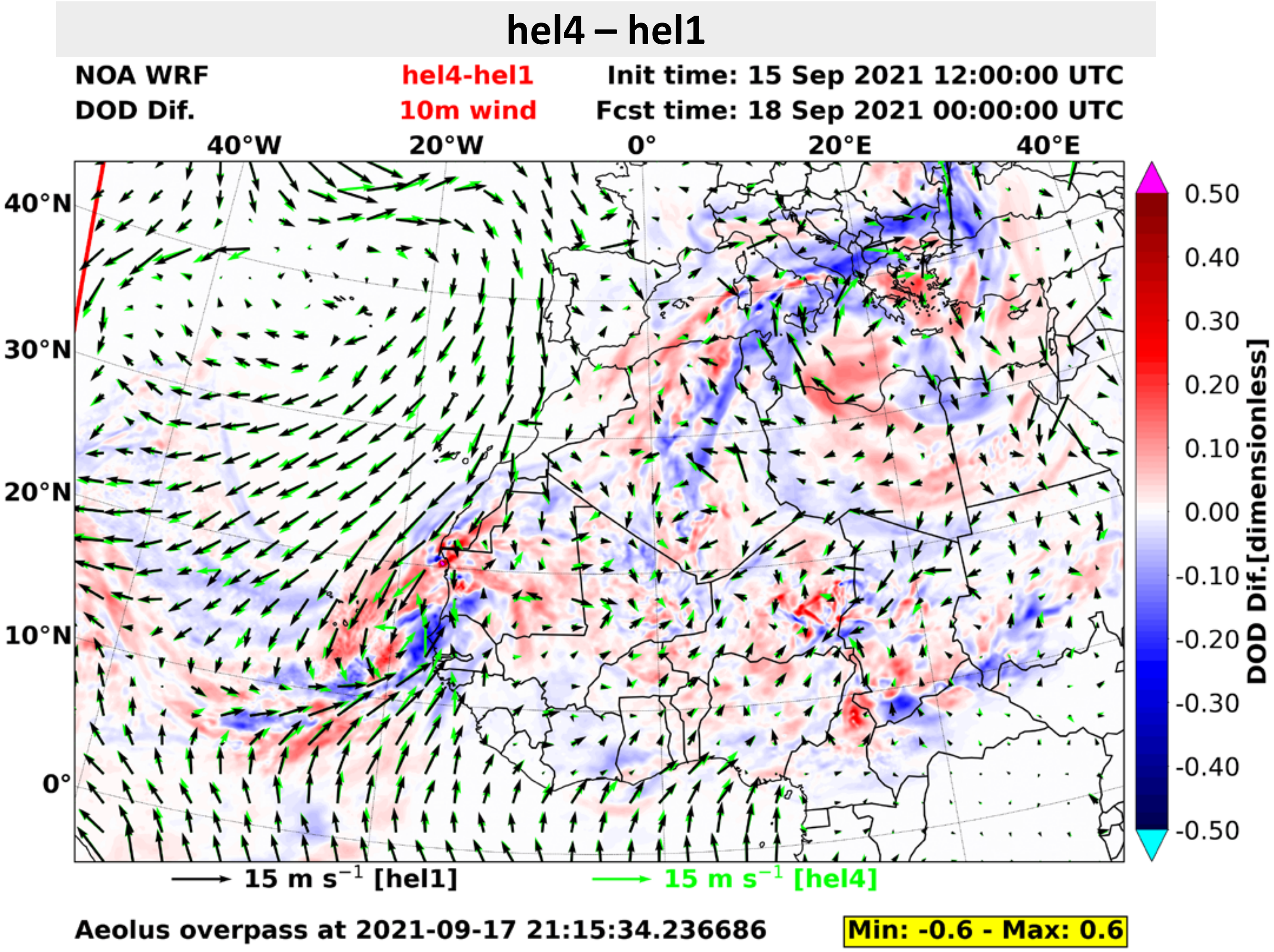
NEWTON & L2A+ ESA Studies

- ❑ Large deviations of the dust emission rates in the main Saharan dust sources
- ❑ Departures on dust emission rates become more evident at lead times close to Aeolus overpass

Data Assimilation

Aeolus impact on dust transport models

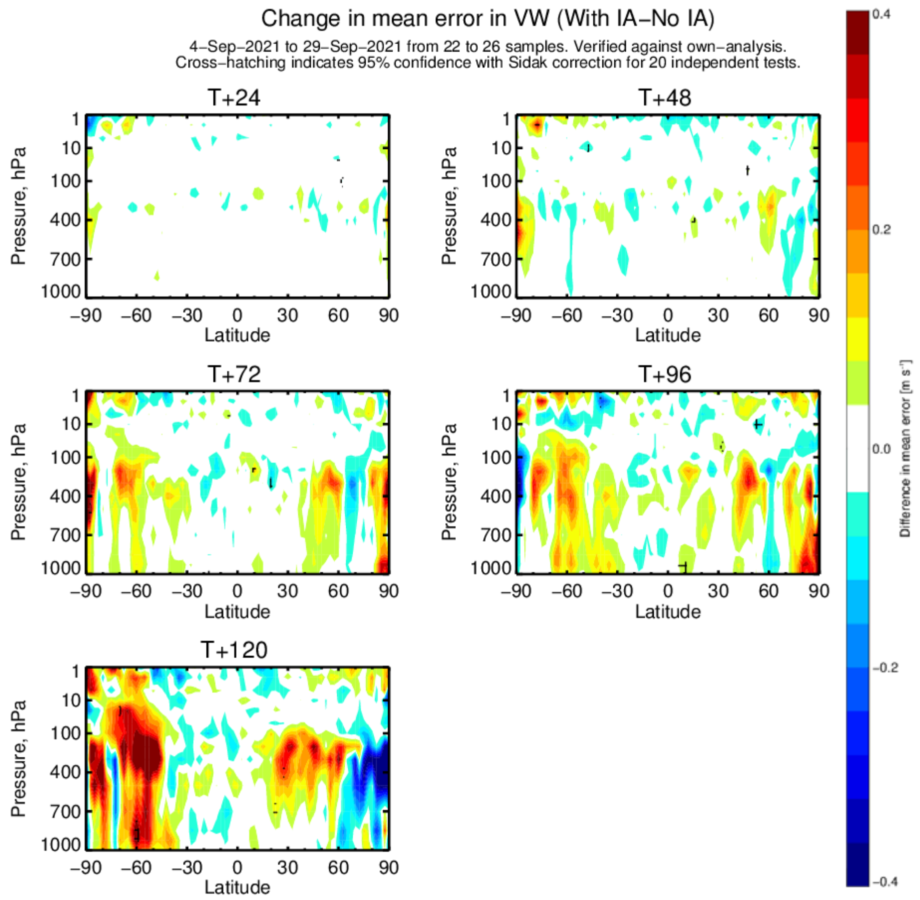
NEWTON & L2A+ ESA Studies



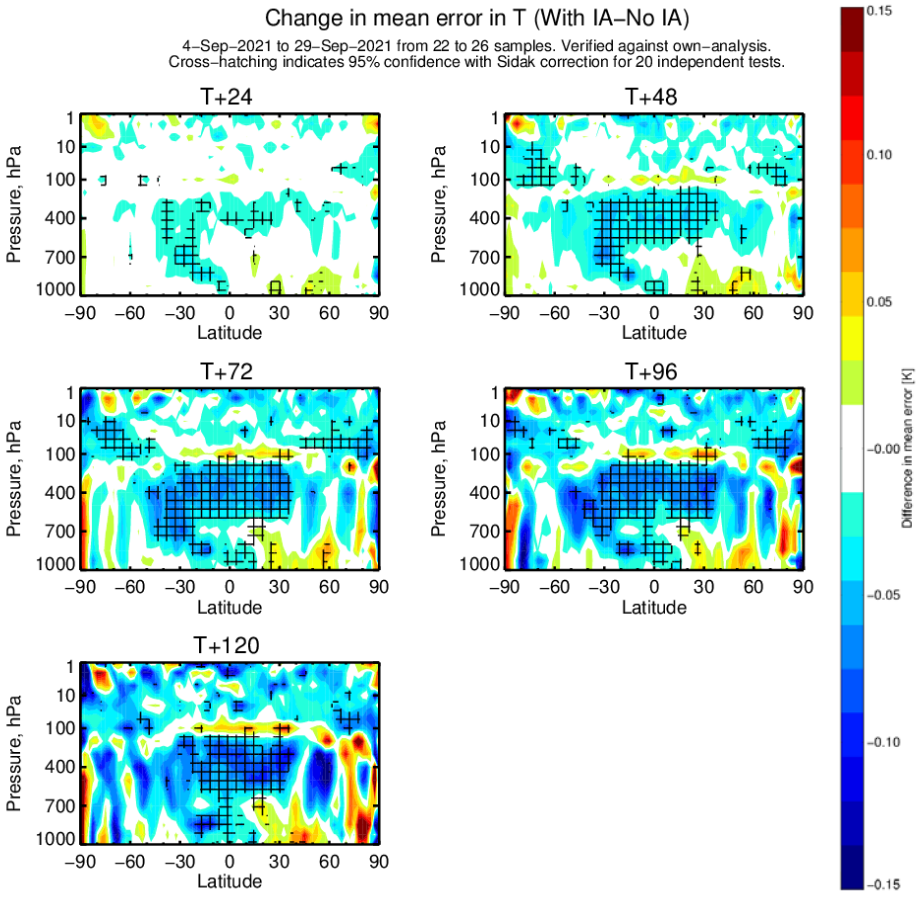
- Variations on wind speed and direction drive the Saharan outflows patterns
- DOD differences up to 0.4, in absolute terms, are evident in downwind areas

Data Assimilation

Winds



Temperature



ADD-CROSS EUMETSAT Study

- The blue shaded areas indicate a better performance of the experiment with interactive aerosols
- The cross-hatched areas indicate statistical significance at 95% confidence level

L2A+ ESA Study: Examine the impact of both Aeolus wind and aerosol fields on DA

Data Assimilation

Operators and dust radiative properties

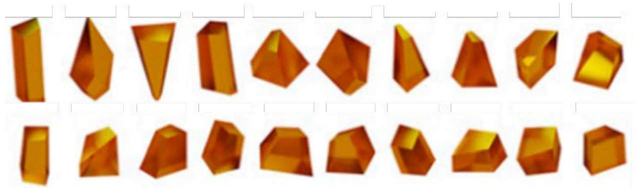
- Dust particles modeled as spheroids

Dubovik et al., 2006

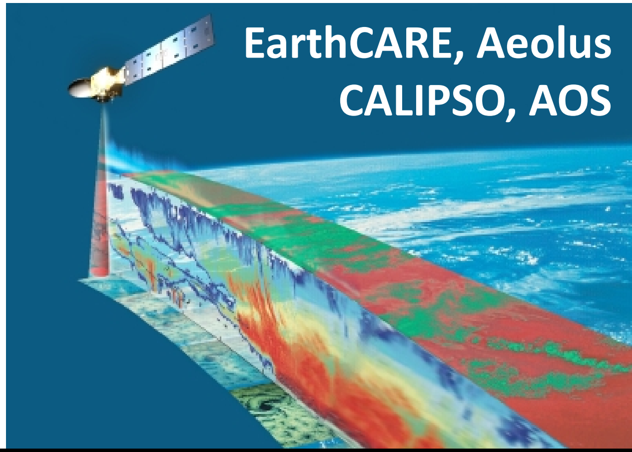
- Dust particles modeled as ellipsoids

Huang et al., 2022

- TAMUdust2020: dust particles modeled as irregular hexahedrals



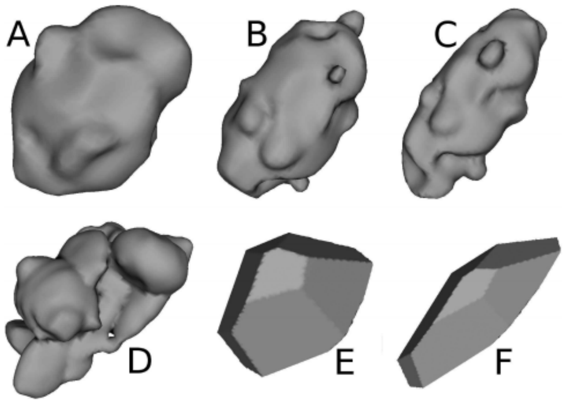
Saito and Yang, 2021



Although the above databases reproduce well the optical properties of dust at non backscattering angles, **they do not manage to reproduce (all) backscattered properties** (LR, depol)

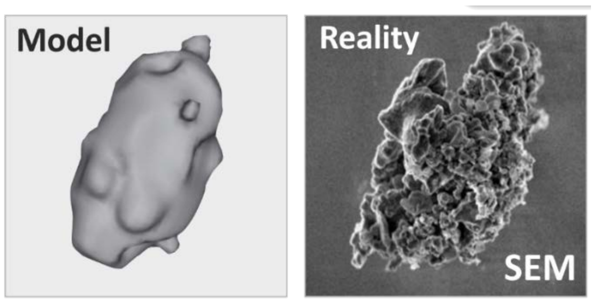
Data Assimilation

Operators and dust radiative properties



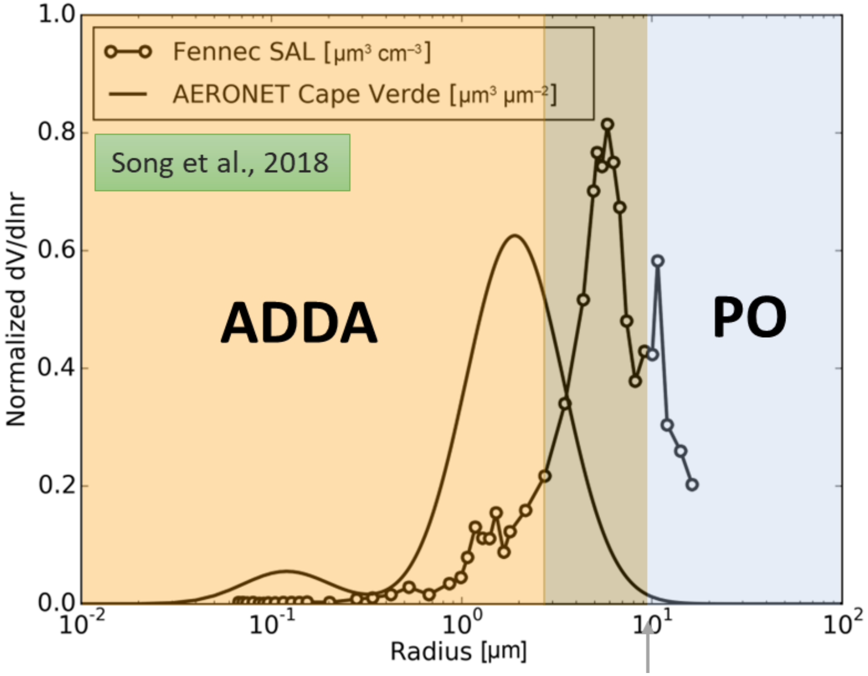
- Dust particles modeled using the irregular shapes proposed in Gasteiger et al., show **promising results for reproducing the backscatter properties of dust**
- Limited size and refractive index range due to costly calculations (size parameter up to 60, real part of RI 1.6 and 1.48, imaginary part of RI 0 and 0.002)

Gasteiger et al., 2011



Scattering calculations with ADDA for irregular particles and **super-coarse mode** are under way

work in progress at NOA (contact: Alexandra Tsekeri)



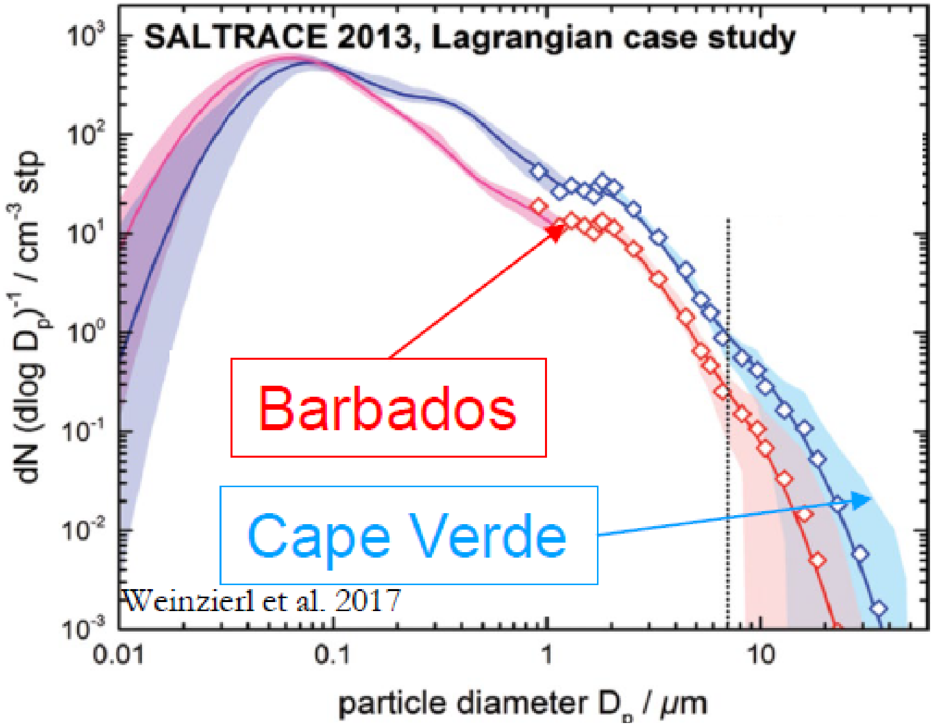
ADDA: Advanced Discrete Dipole Approximation (Yurkin and Hoekstra, 2011)
PO: Physical Optics approximation (Konoshonkin et al., 2016)

Physical Processes

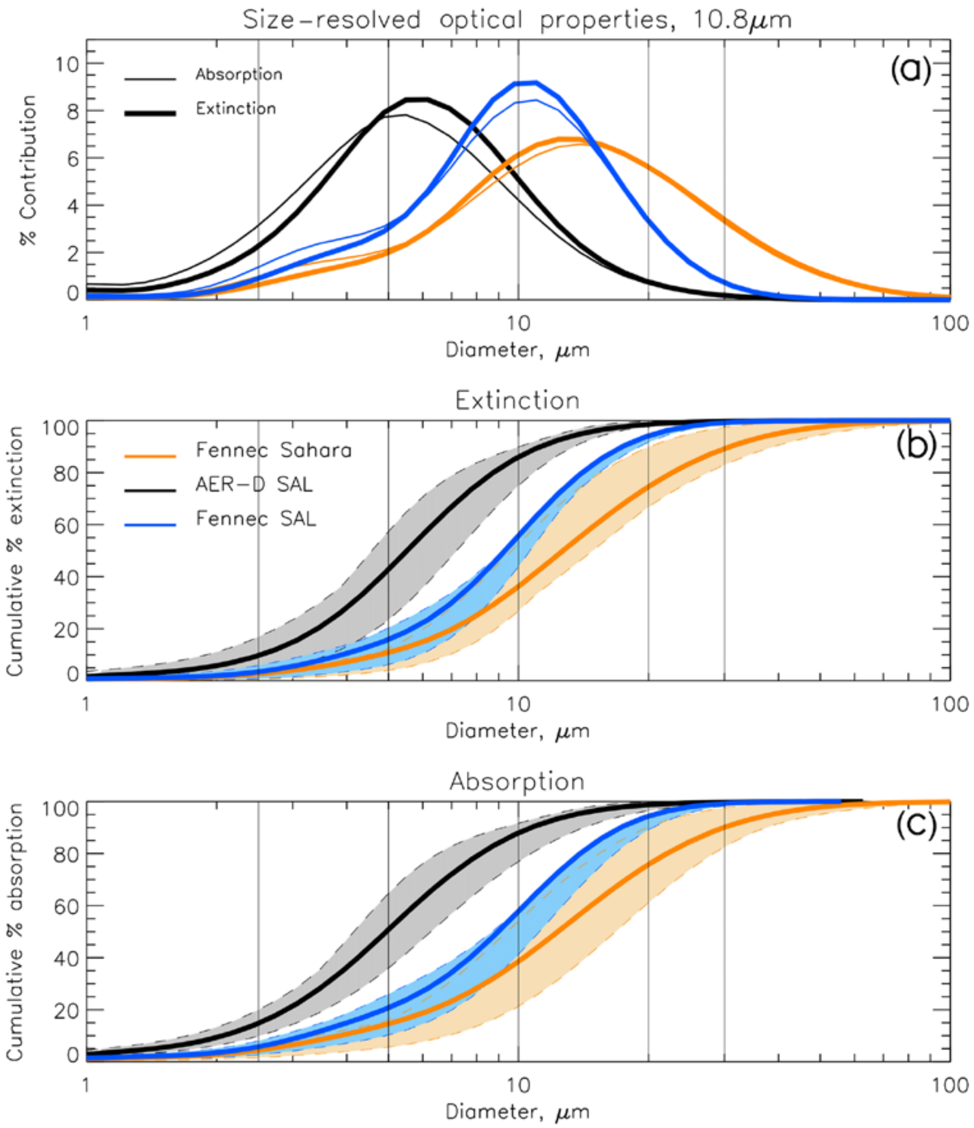
Super-coarse mode and radiation

Super-coarse dust particles are found at greater distances than anticipated from model simulations

Weinzierl, 2017; Ryder et al., 2018

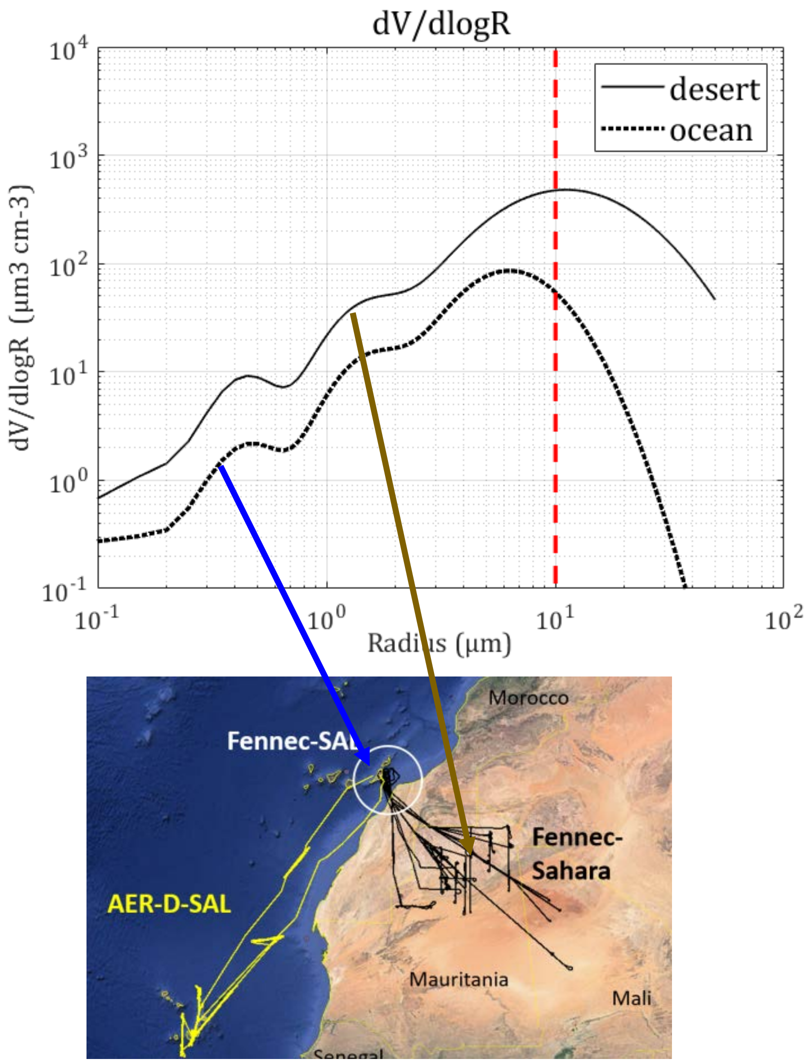


Ryder et al., 2019



Physical Processes

Super-coarse mode and radiation

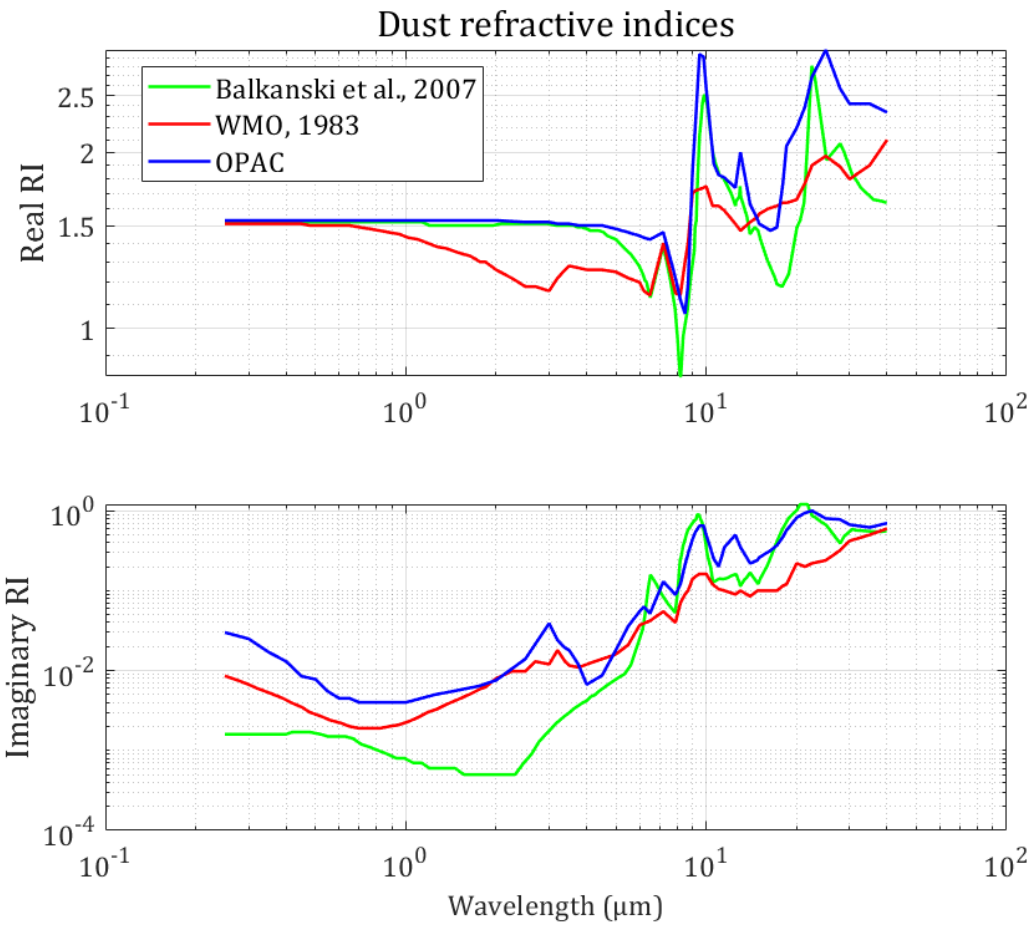


Dust size distributions acquired from measurements above Sahara (“desert”) and SAL (“ocean”), during the Fennec campaign

Max dust size used in models (radius of 10 μm).

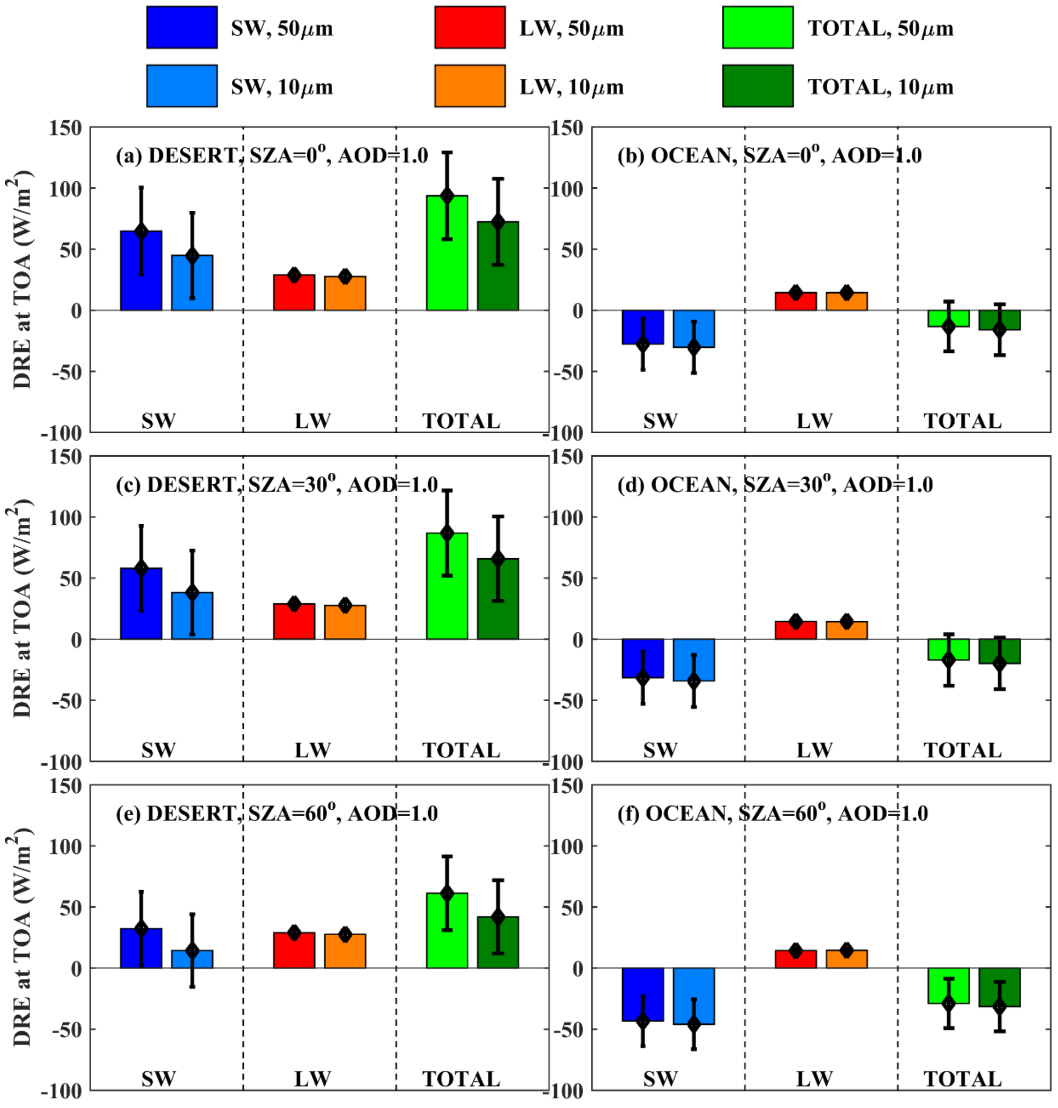
Max dust size considered in this study (radius of 50 μm).

Tsekeri et al., in preparation



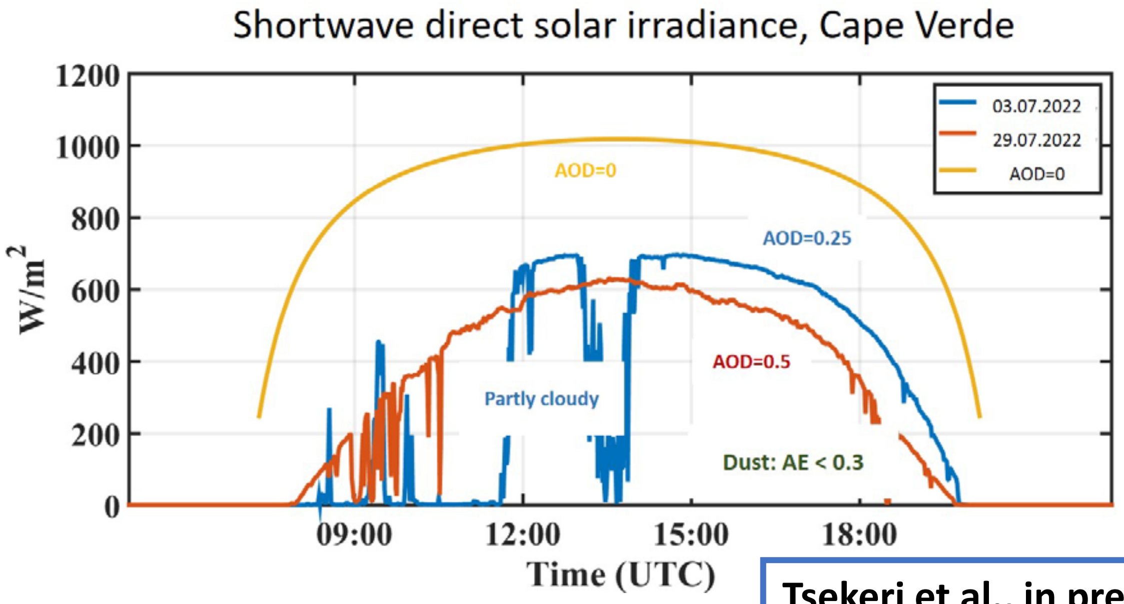
Refractive indices that cover most of the range provided in the literature.

Physical Processes



Direct radiative effect at TOA:

- The underestimation of super-coarse in TOA radiation modeling exhibits a warming effect above deserts
- The impact is only minor during the transport above ocean, due to the small number of super-coarse particles simulated.



Tsekeri et al., in preparation

Use of ASKOS-like measurements for:

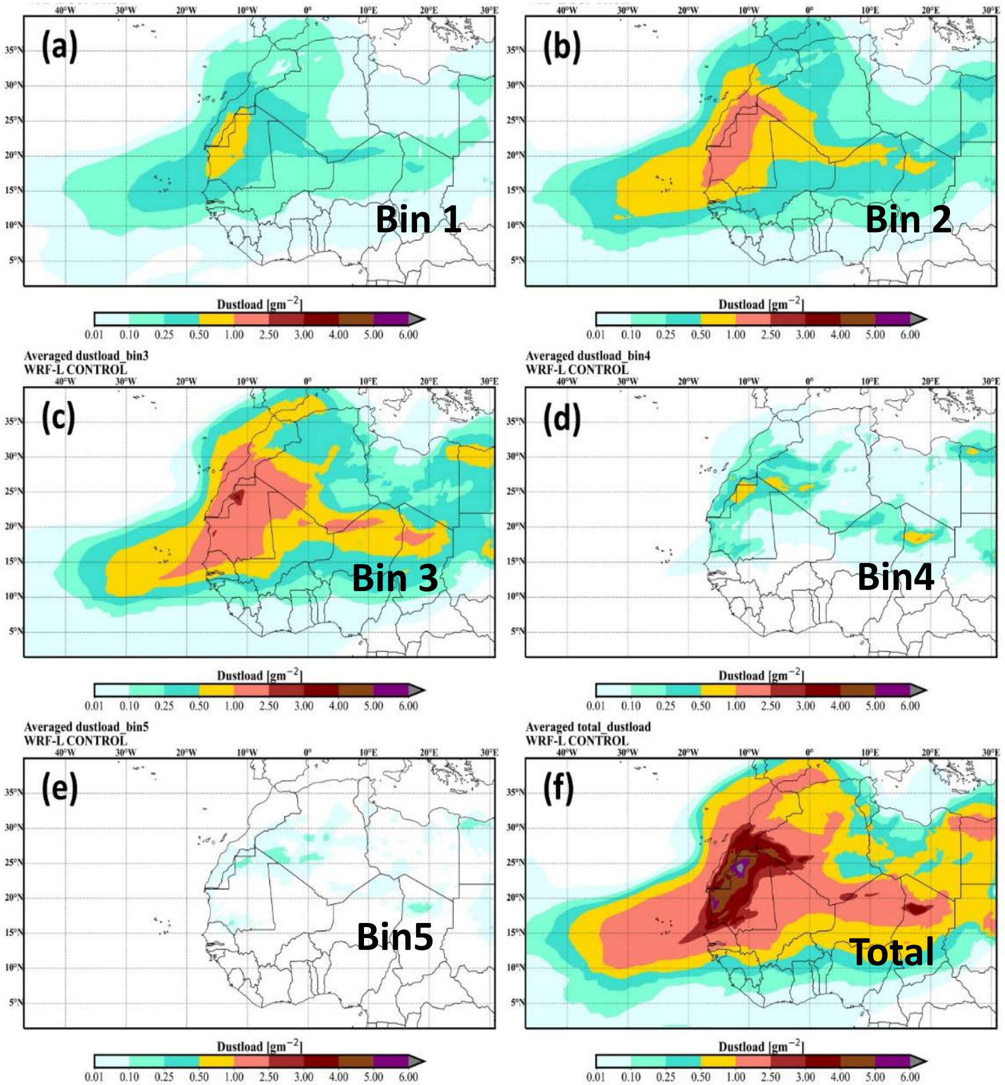
Decoding atmospheric dust processes

Physical Processes

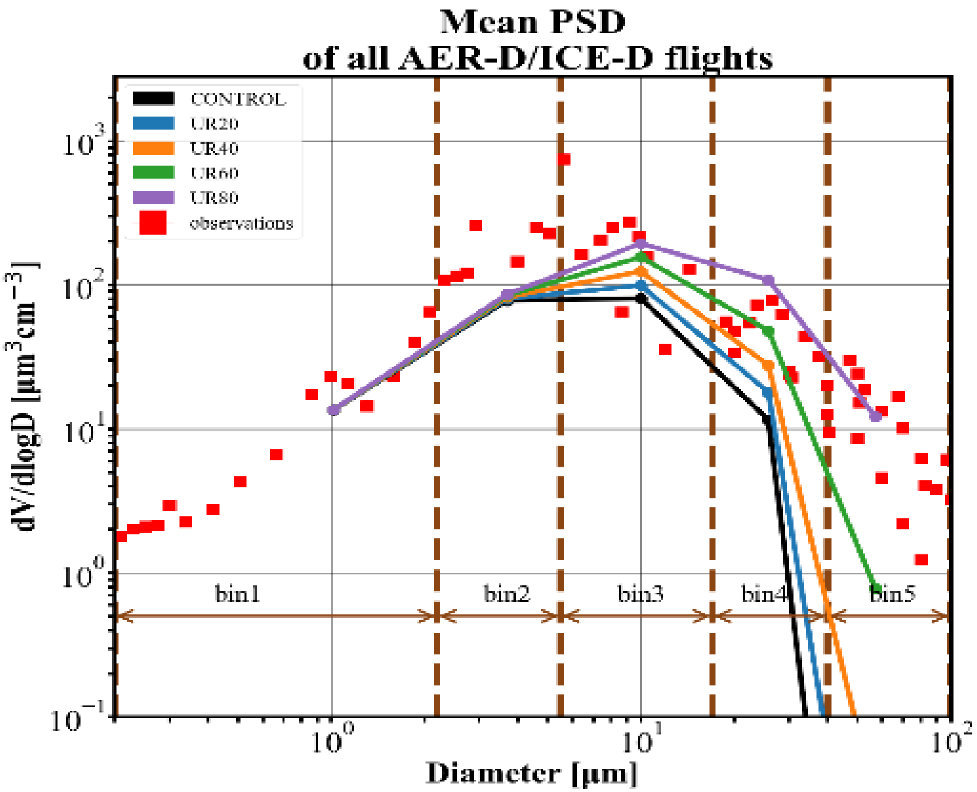
$d_{veq\_eff\_k}$ (μm)
1.46
2.8
4.8
9.0
16.0

$d_{veq\_eff\_k}$ (μm)
1.02
3.7
10.0
25.8
57.2

Drakaki et al., 2022



Physical Processes



Observations

40% Reduction

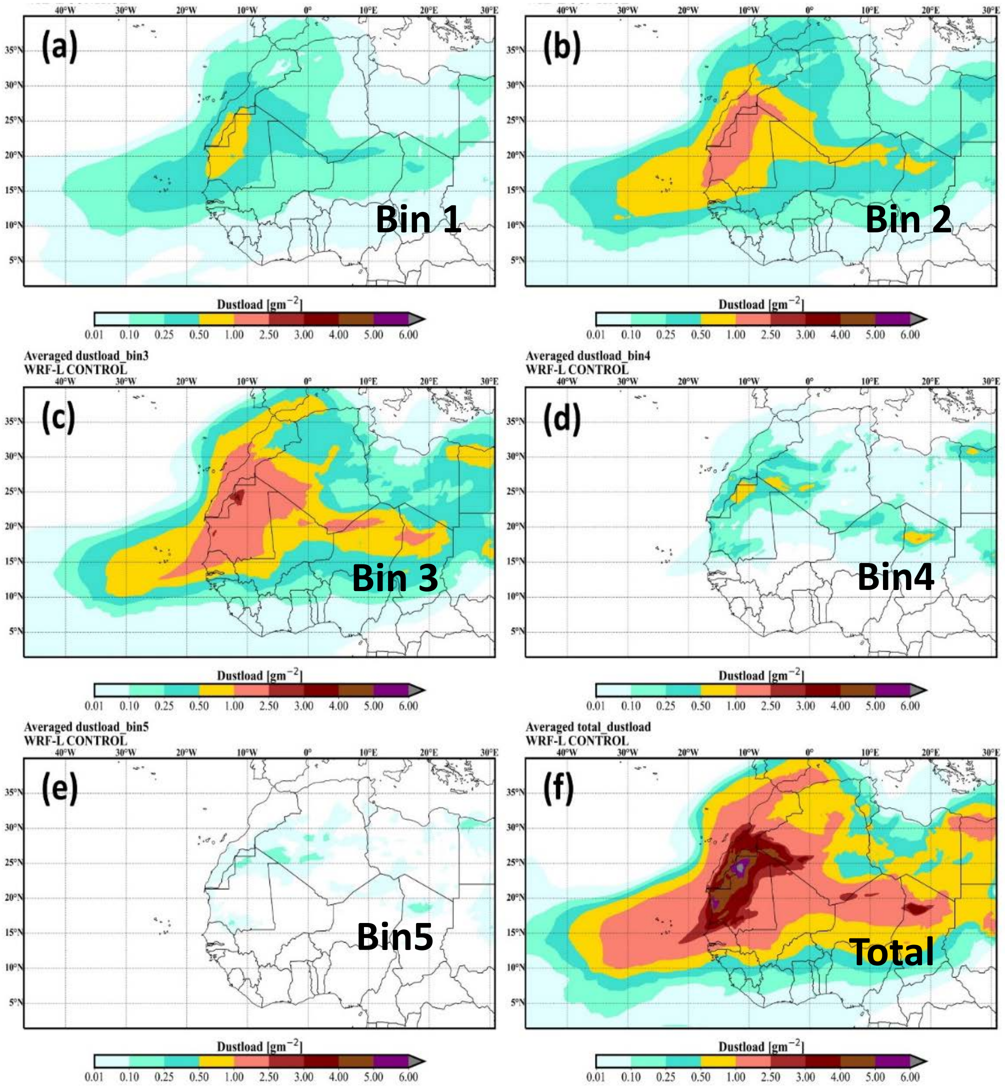
CONTROL – no Reduction

60% Reduction

20% Reduction

80% Reduction

Drakaki et al., 2022

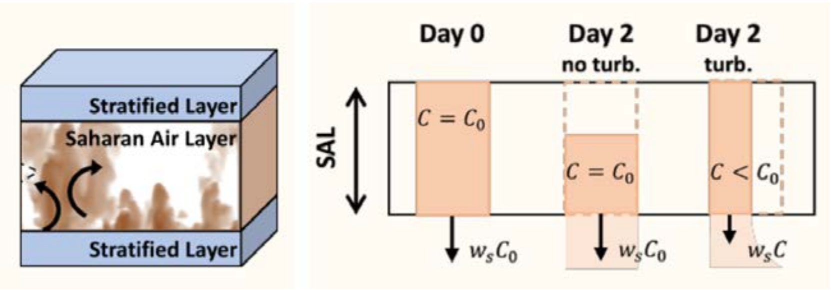


Physical Processes

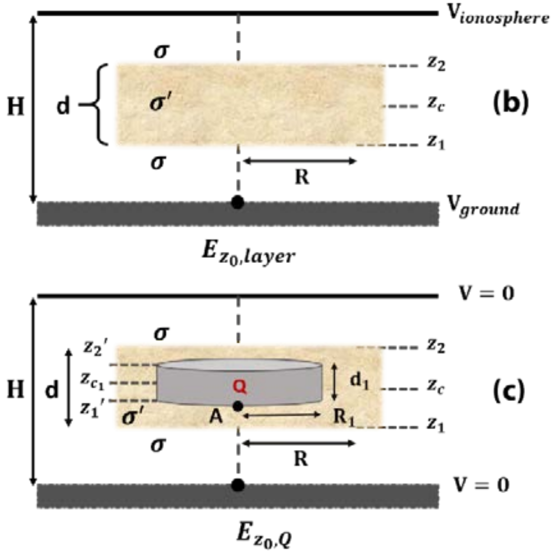
Super-coarse mode

Processes suggested:

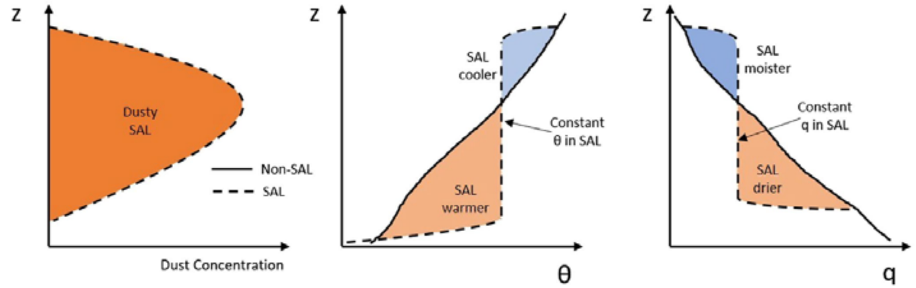
- Dynamics related to numerical diffusion and turbulence
- Dust asphericity, shape
- Electrostatic forces & particle orientation
- Water vapor impact on convection



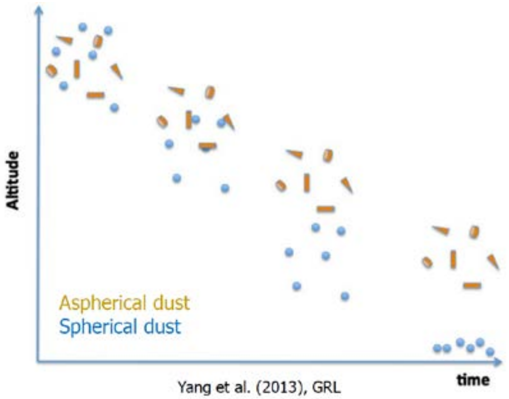
Gasteiger et al., ACP, 2017



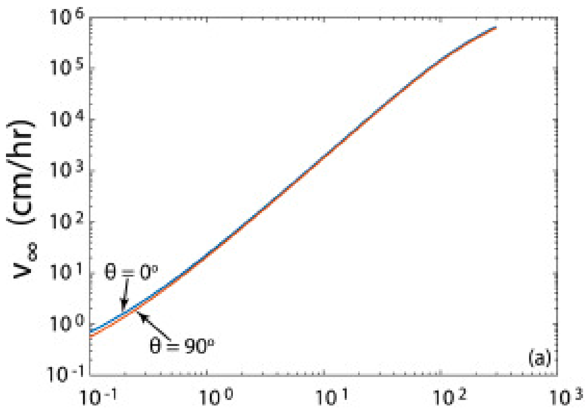
Daskalopoulou et al., 2021



Gutleben, 2019; Ryder, 2021

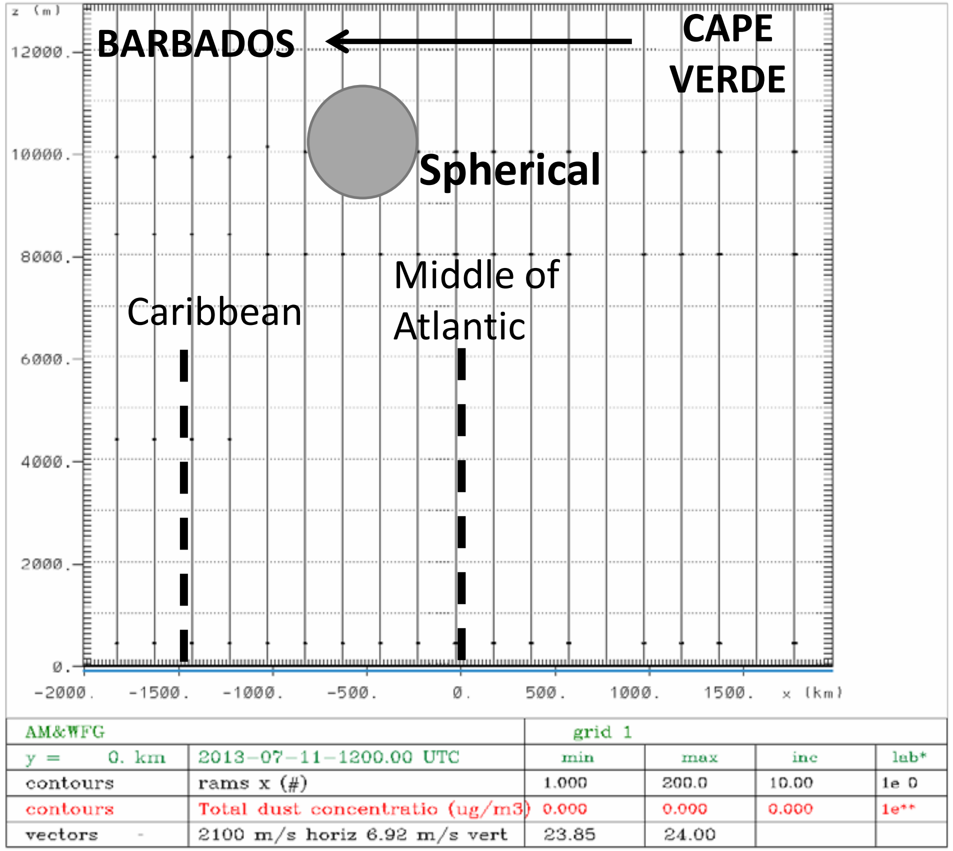


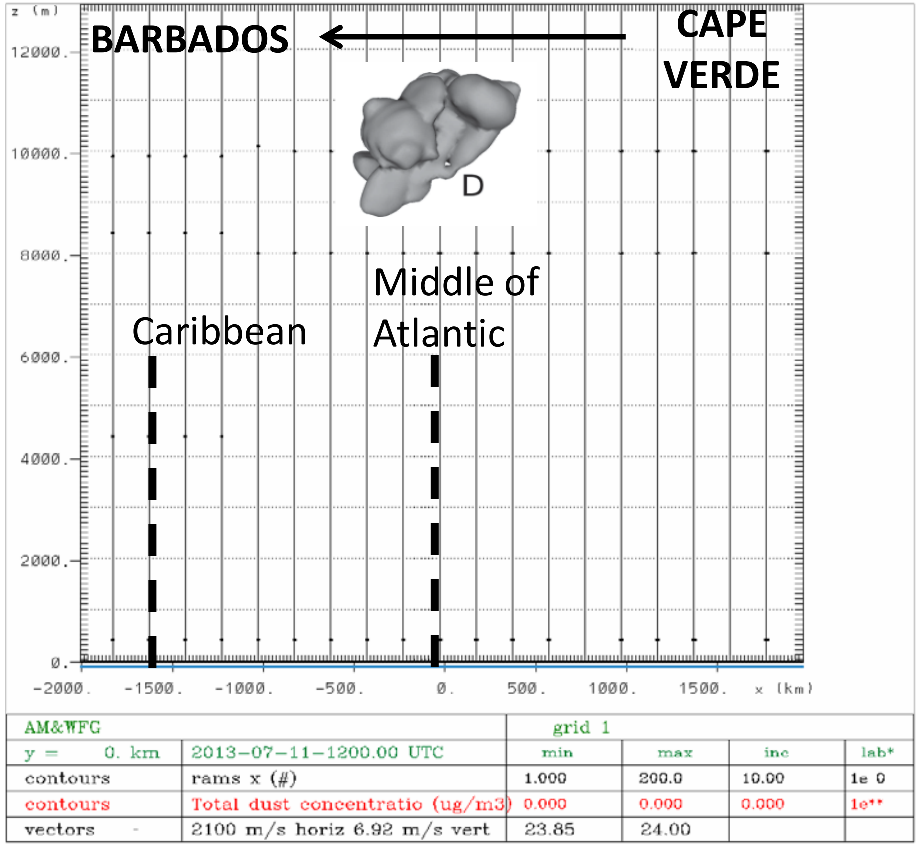
Yang et al., GRL, 2013



Mallios et al., 2013

Super-coarse mode: asphericity



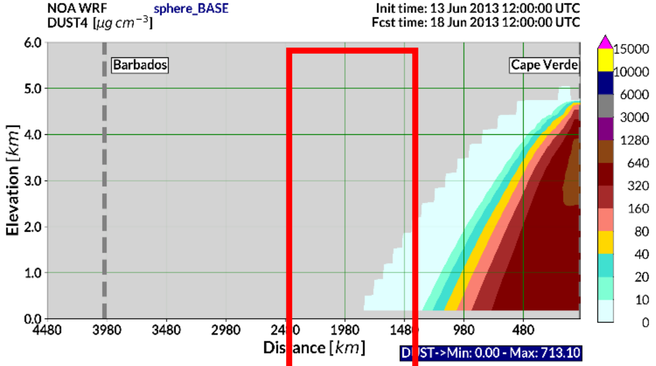


Physical Processes

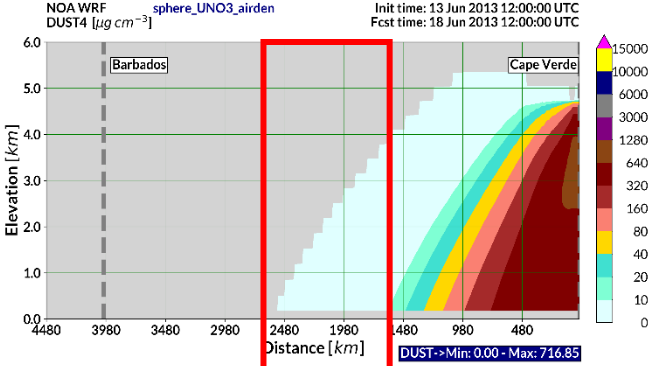
Super-coarse mode: numerical diffusion and asphericity

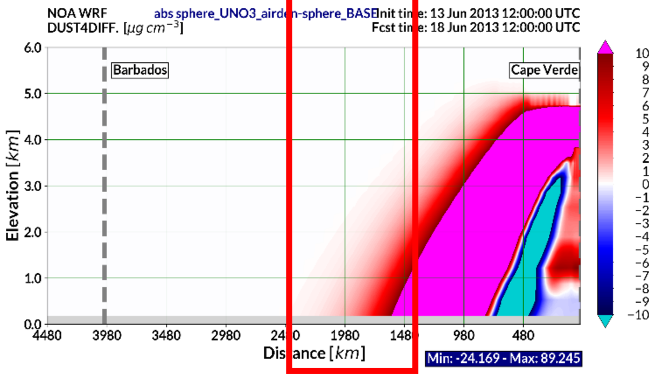
BIN 4 (D=26 µm) after 5 days

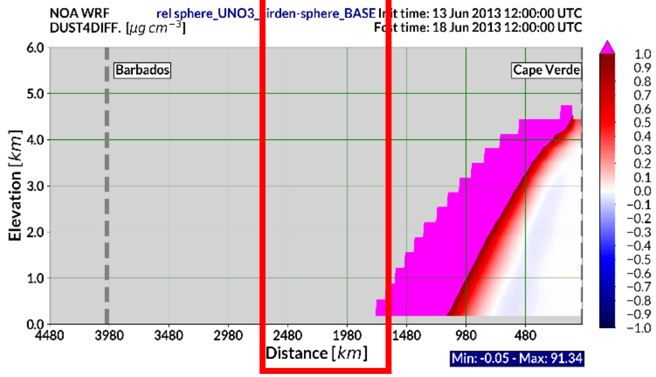
BASE RUN

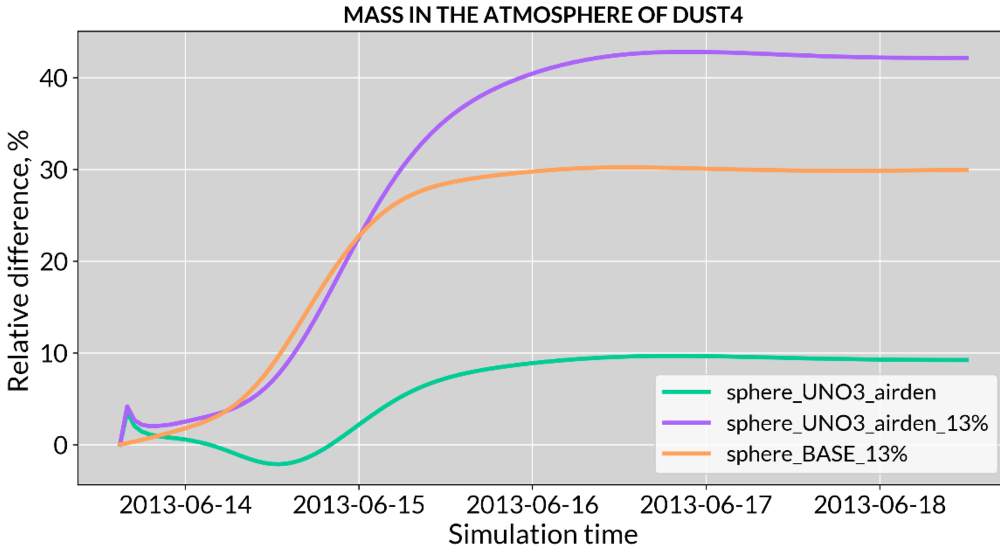


UNO3 RUN







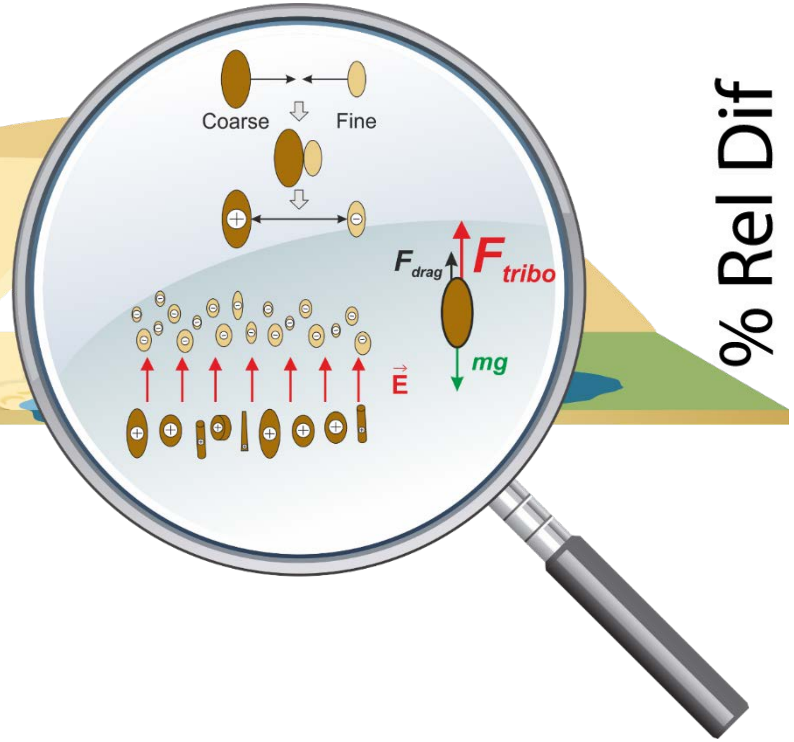


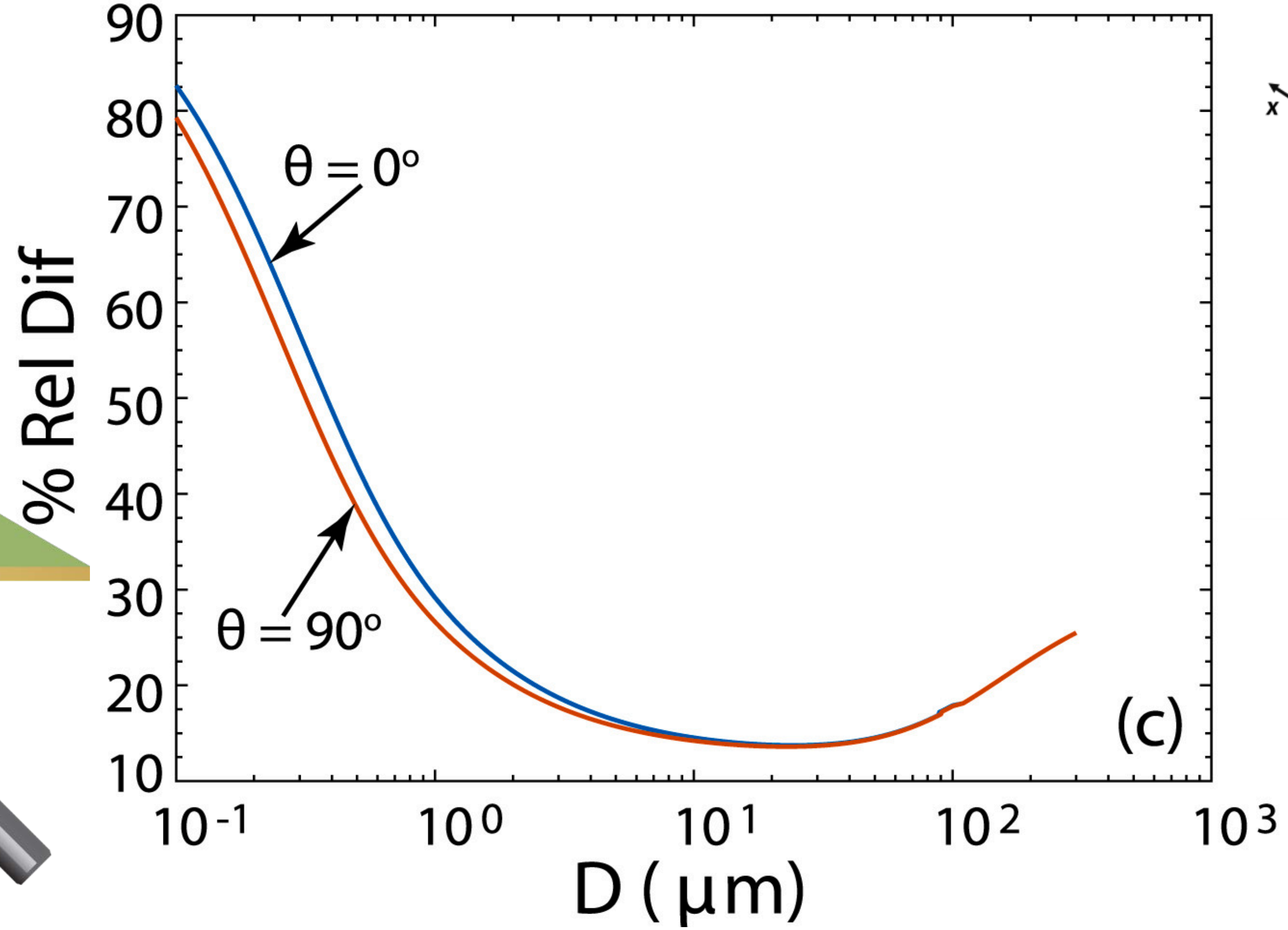
Asphericity is 3 times more efficient in sustaining mass under UNO3.

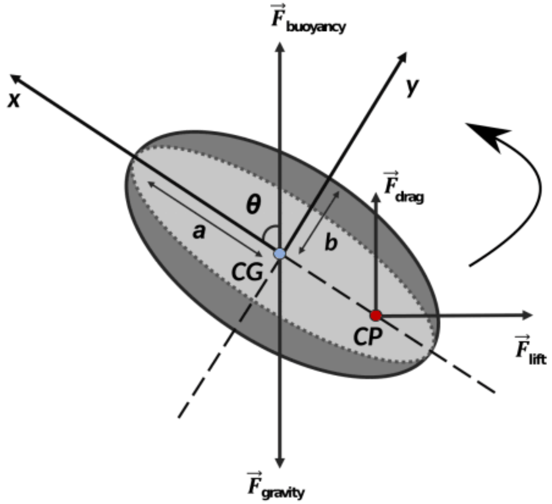
UNO3 propagates particles 500 km further away from their sources

Drakaki et al., in preparation

Super-coarse mode: particle orientation and electric charge



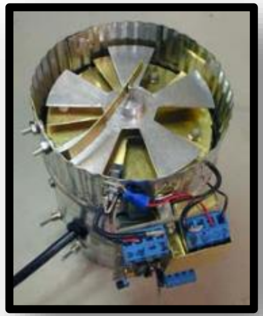


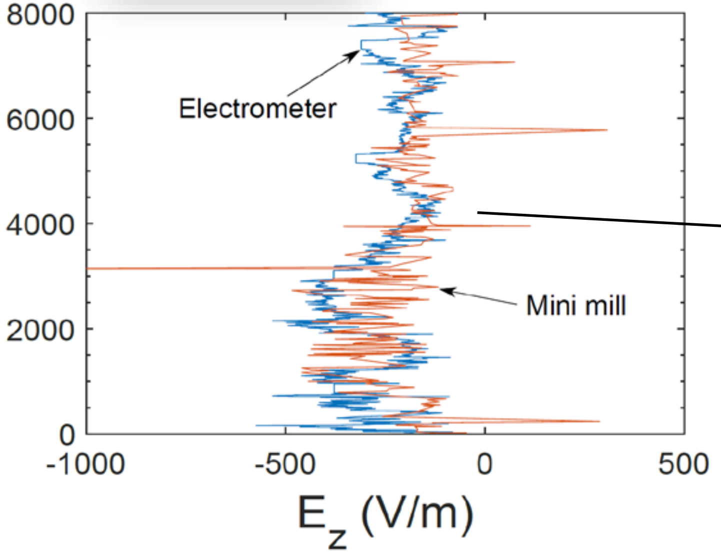


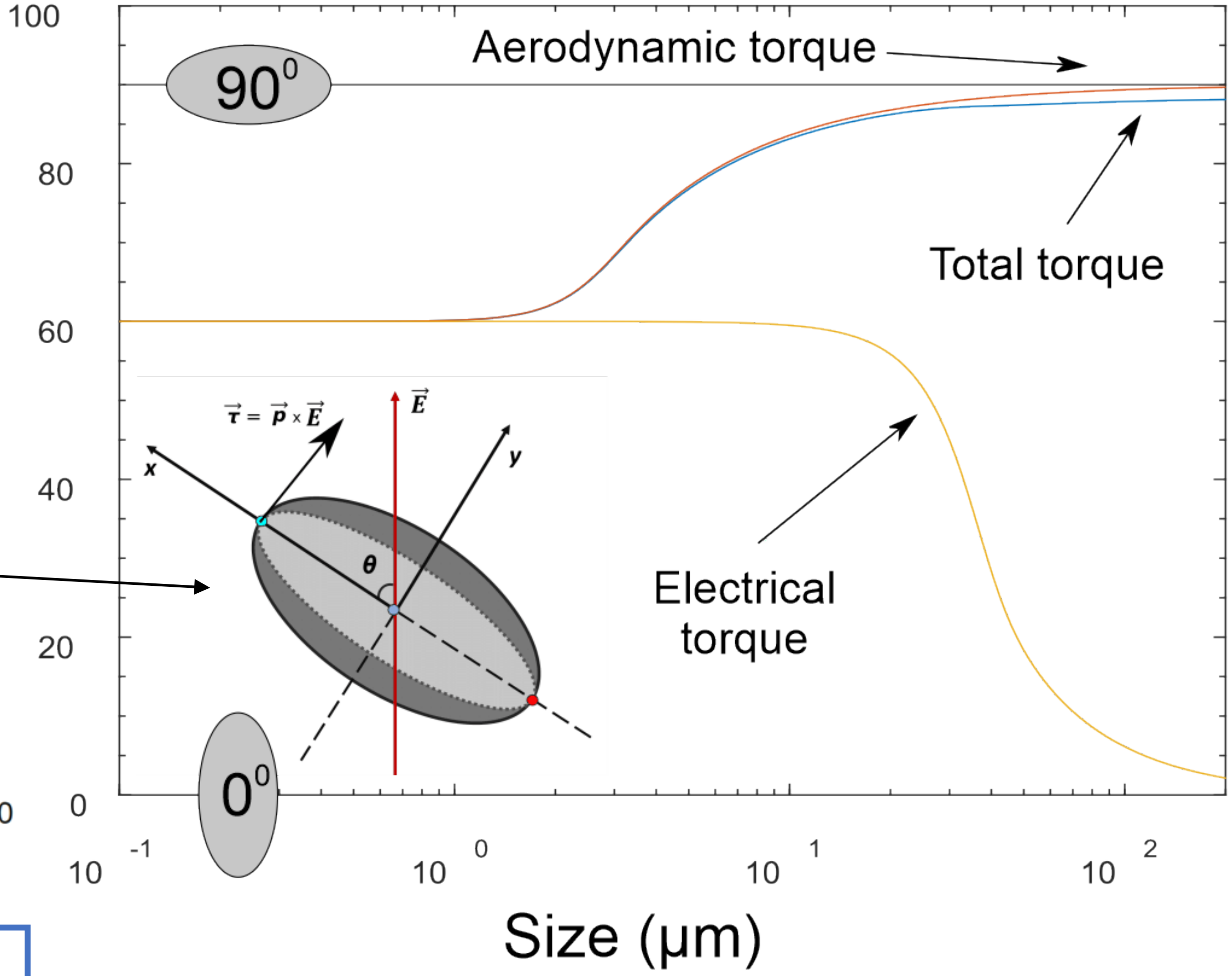
Mallios et al., 2020

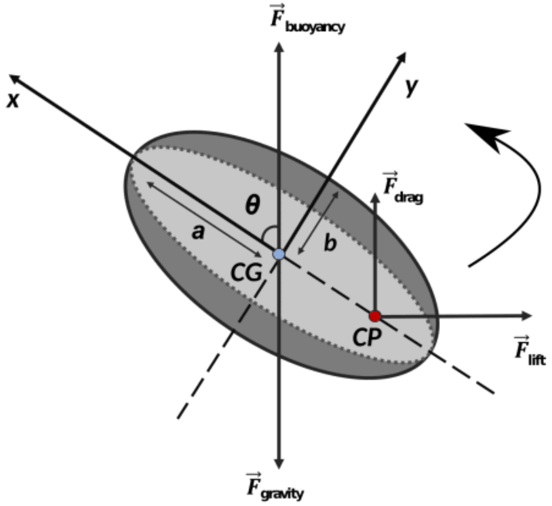
Physical Processes

Super-coarse mode: particle orientation and electric charge





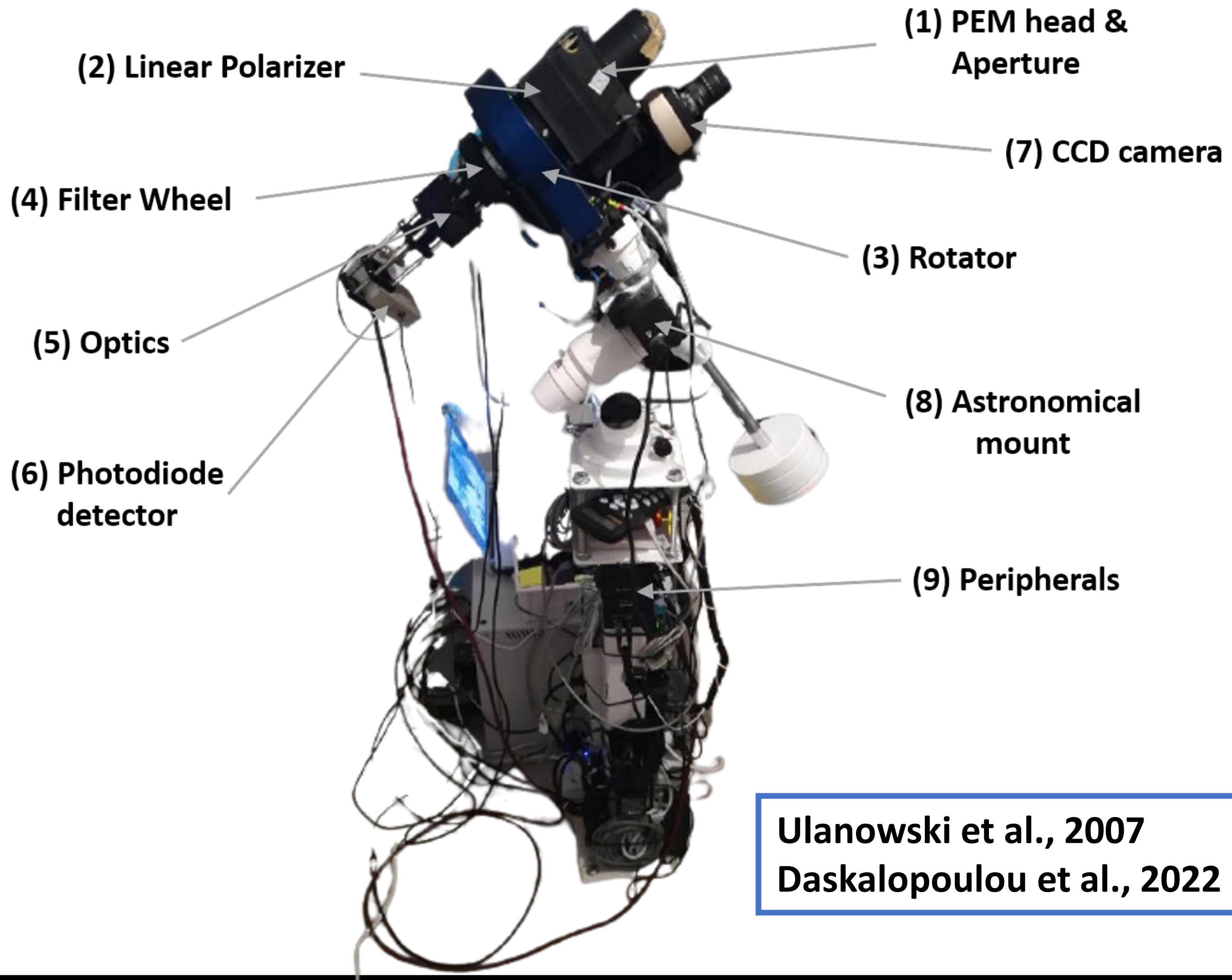




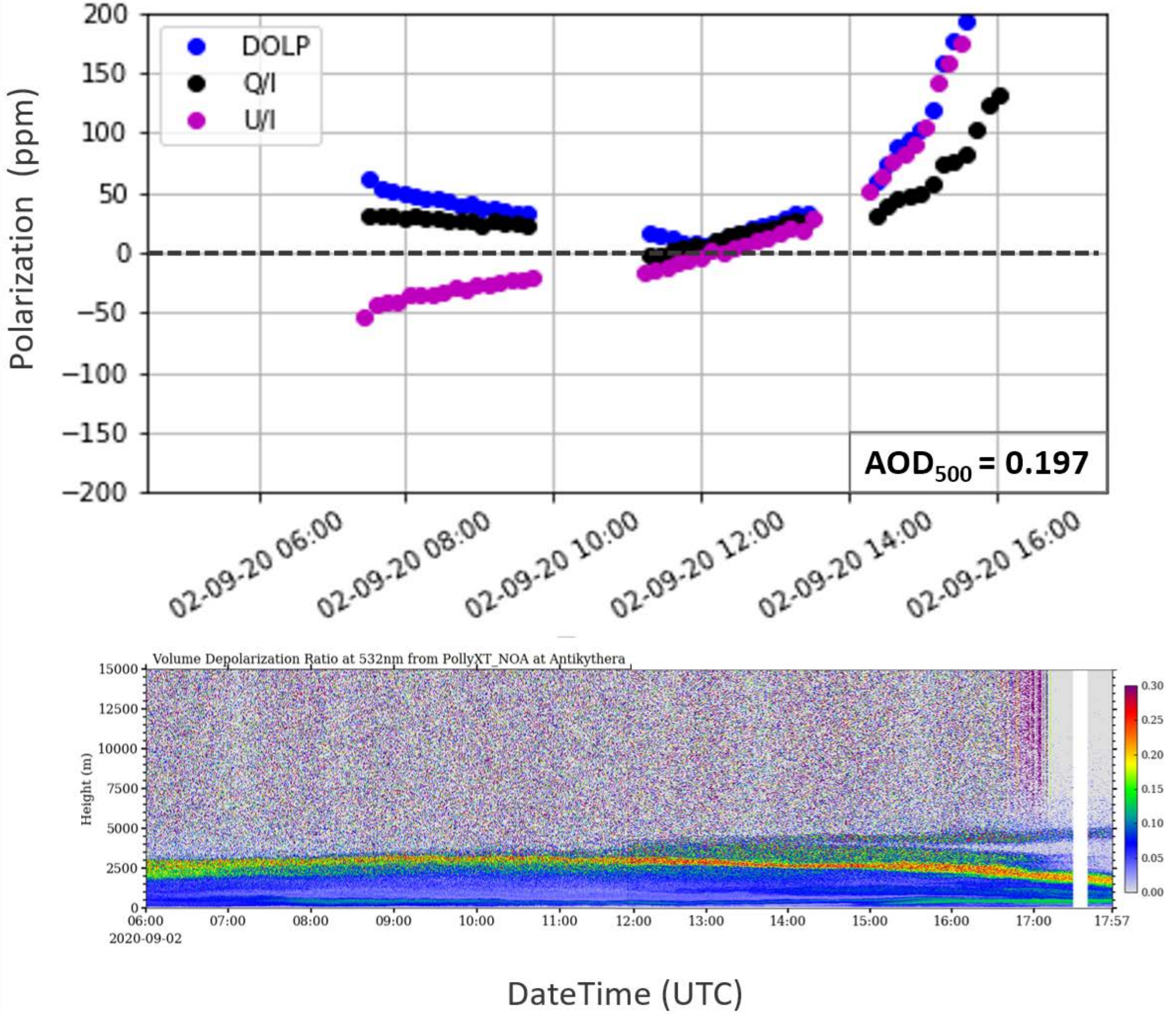
Mallios et al., 2021

Daskalopoulou et al., in preparation

Particle orientation as a RS tracer for super-coarse particles

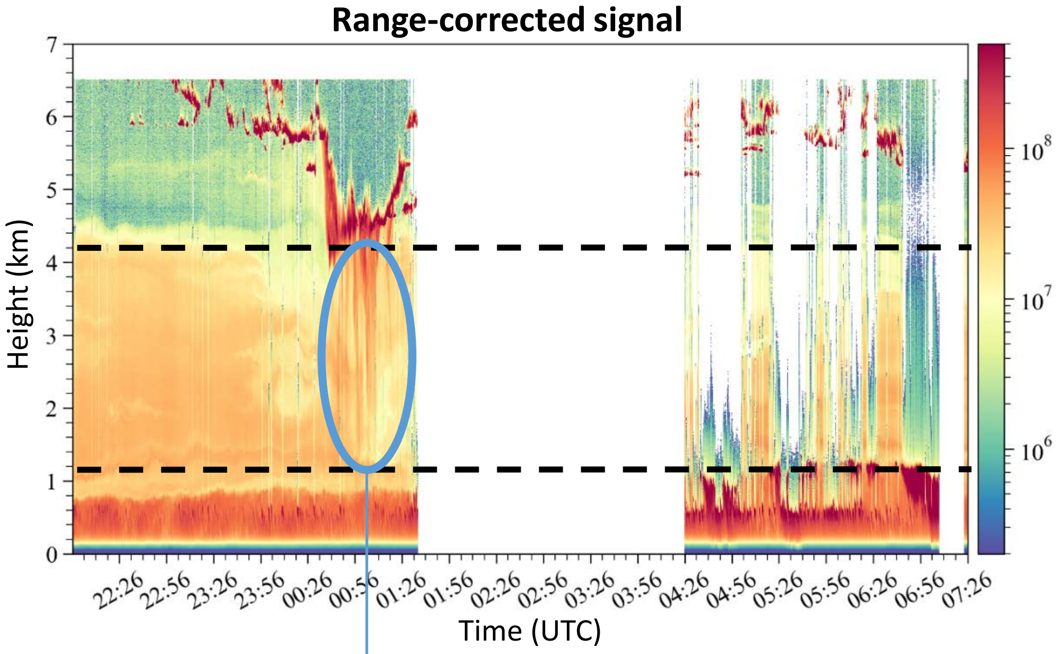


Ulanowski et al., 2007
Daskalopoulou et al., 2022

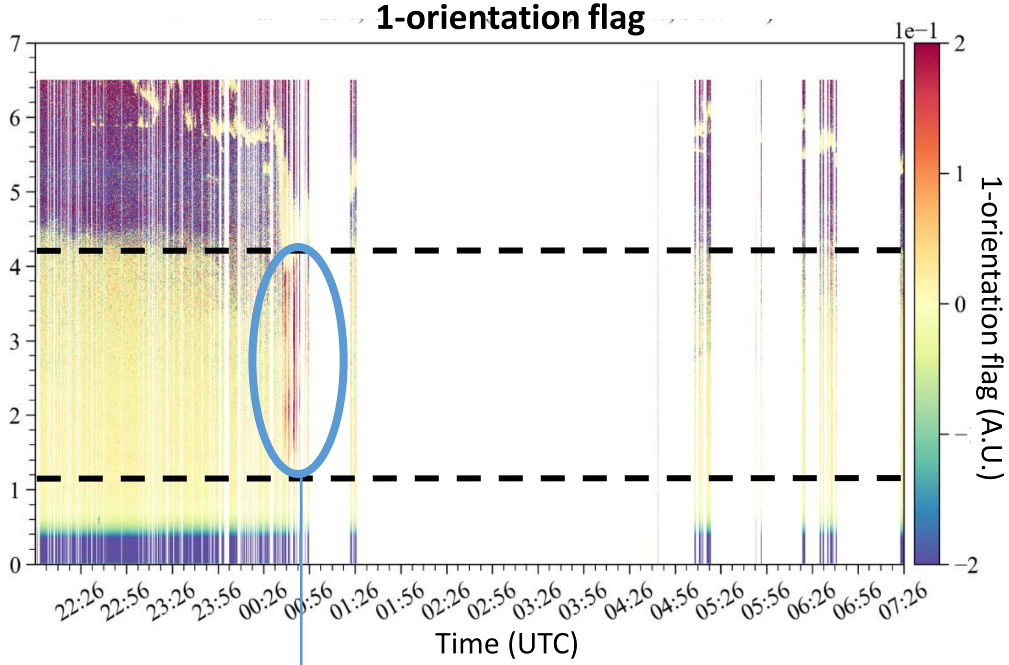


Physical Processes

Particle orientation as a RS tracer for super-coarse particles

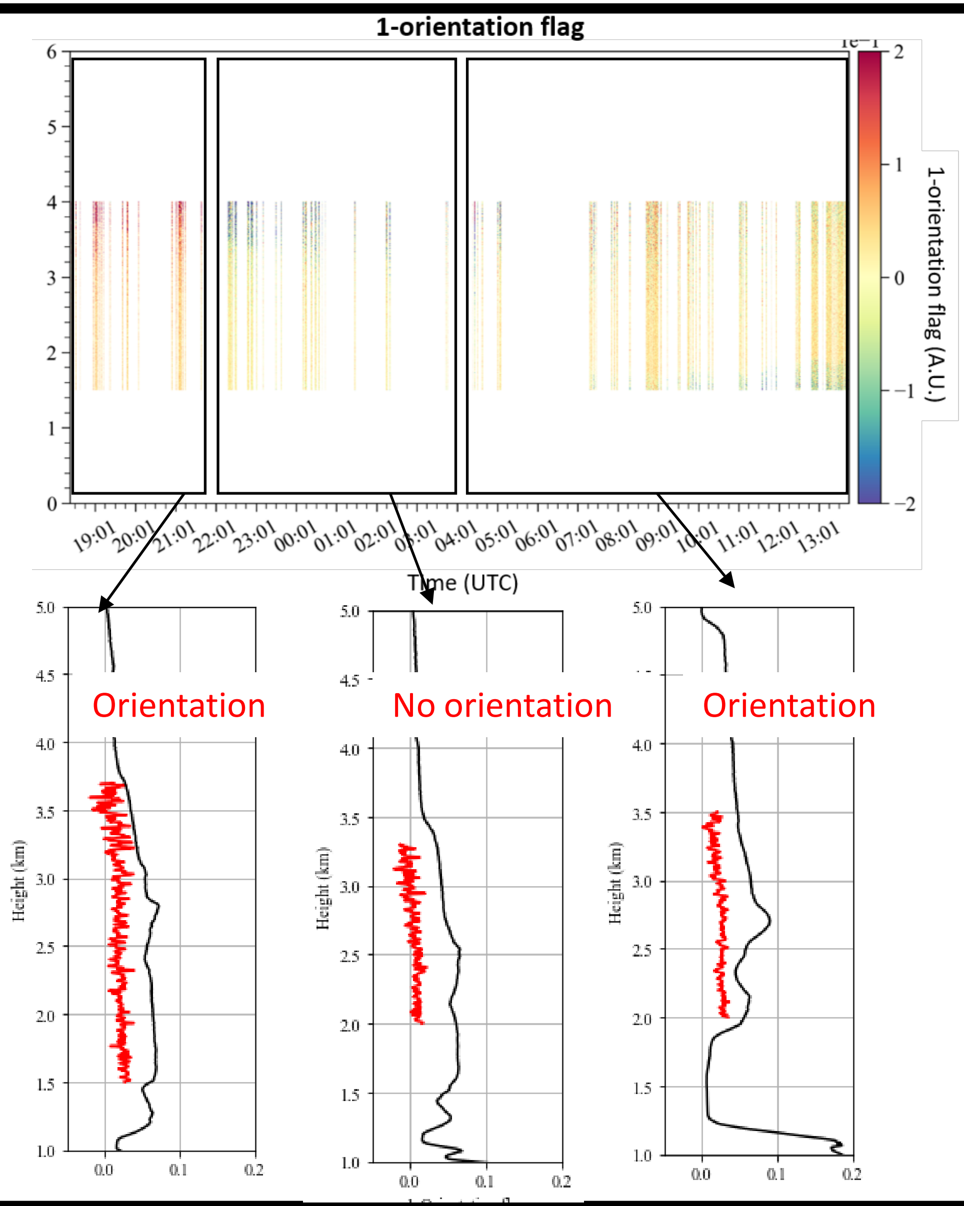


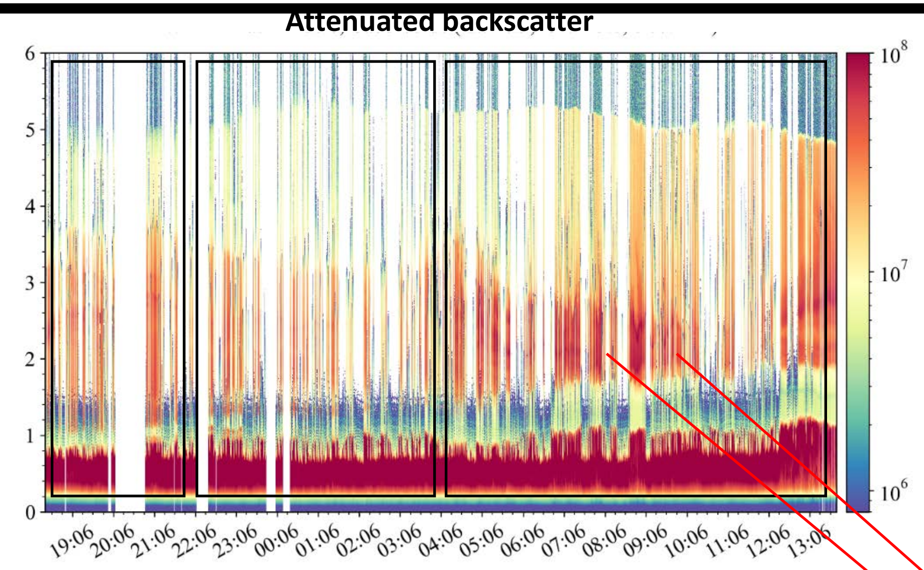
Rain droplets



Orientation flag

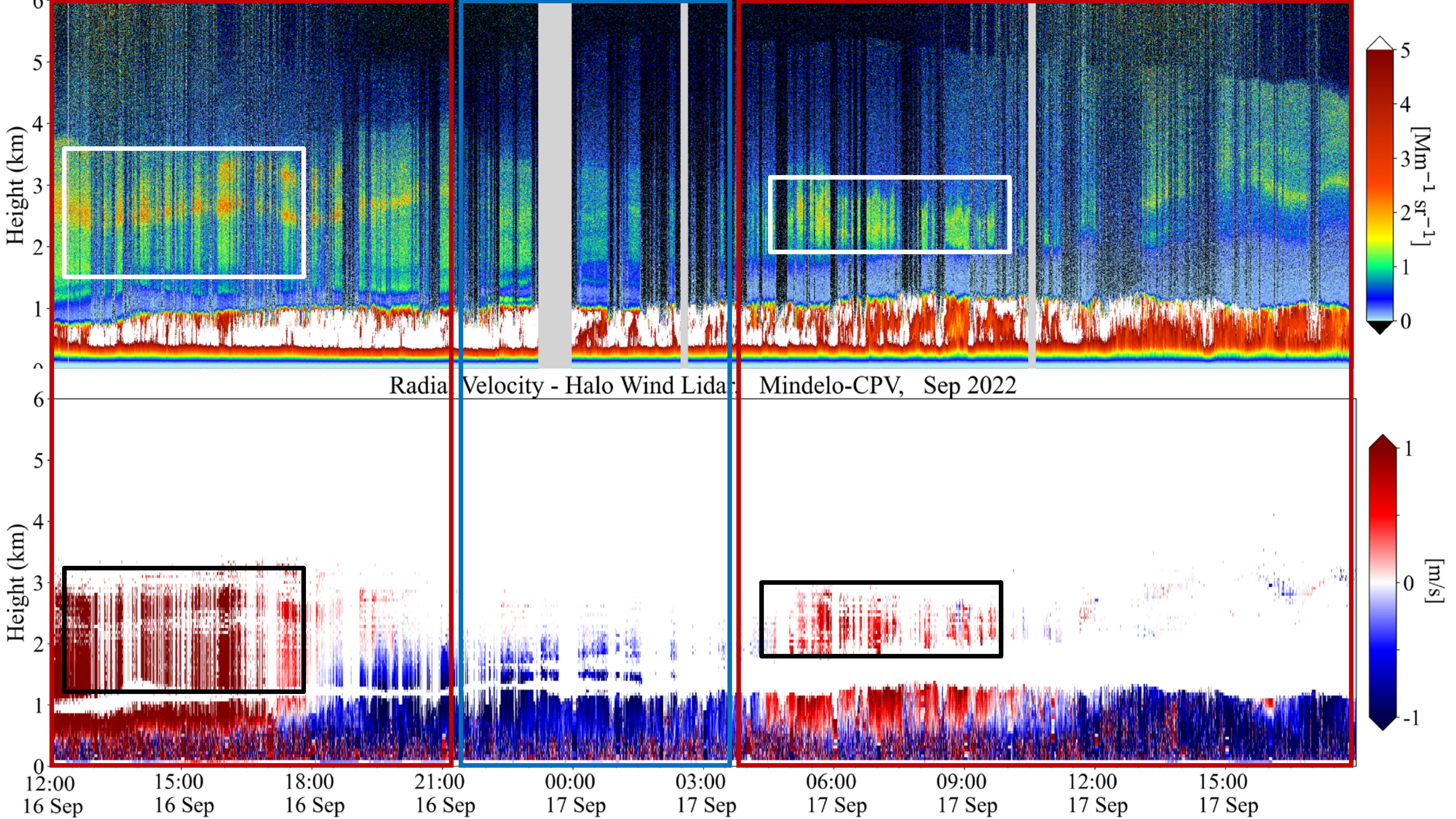
Physical Processes





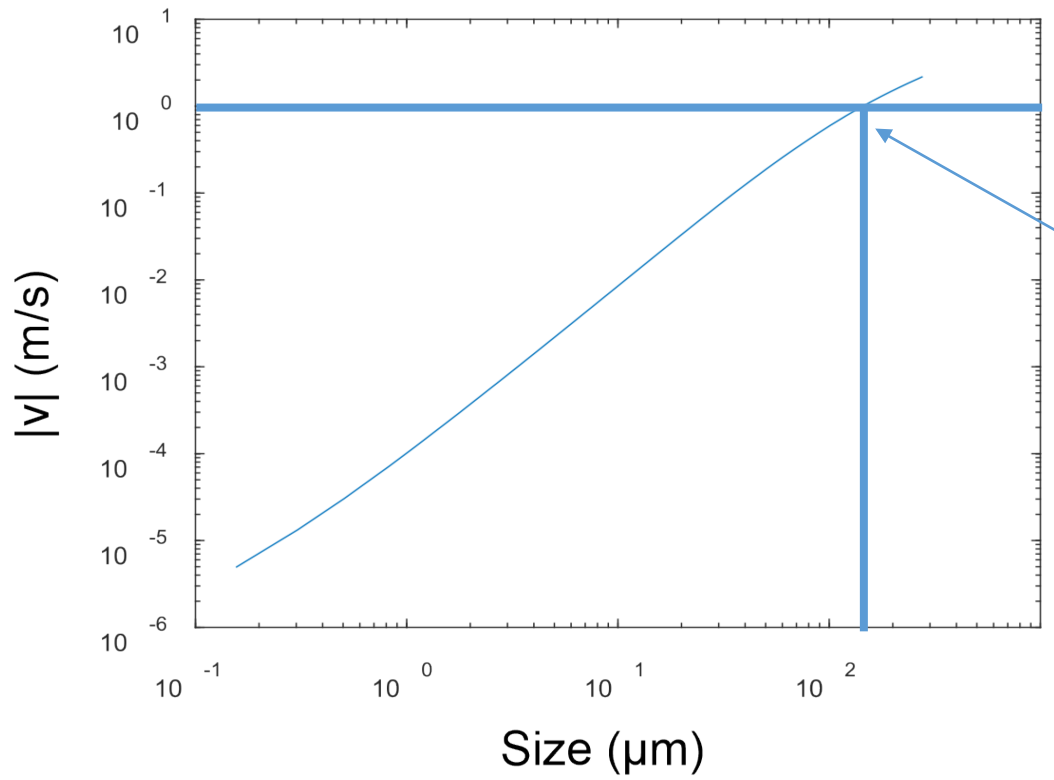
Orientation flag depends on:

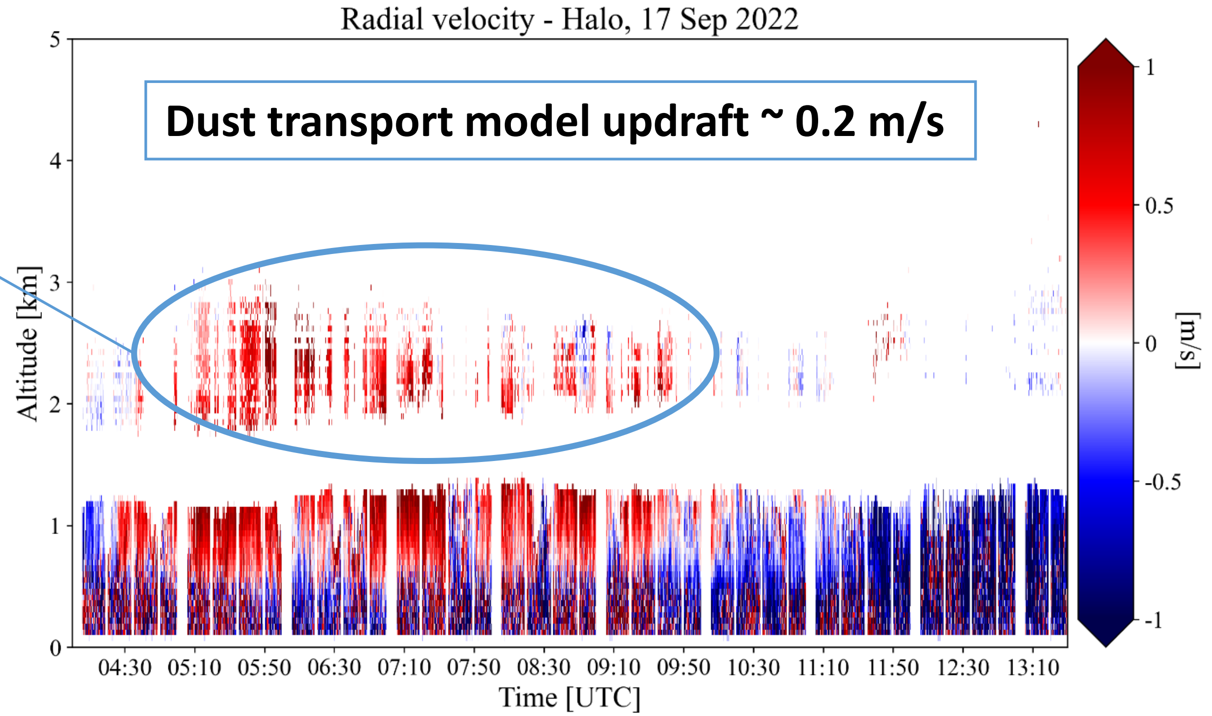
- Particle size parameter
- Particle refractive index
- Particle shape
- Particle orientation angle
- Percentage of oriented particles in the volume



Radial Velocity - Halo Wind Lidar Mindelo-CPV, Sep 2022
Height (km)
[Mm^{-1} sr^{-1}]
[m/s]
12:00 16 Sep
15:00 16 Sep
18:00 16 Sep
21:00 16 Sep
00:00 17 Sep
03:00 17 Sep
06:00 17 Sep
09:00 17 Sep
12:00 17 Sep
15:00 17 Sep

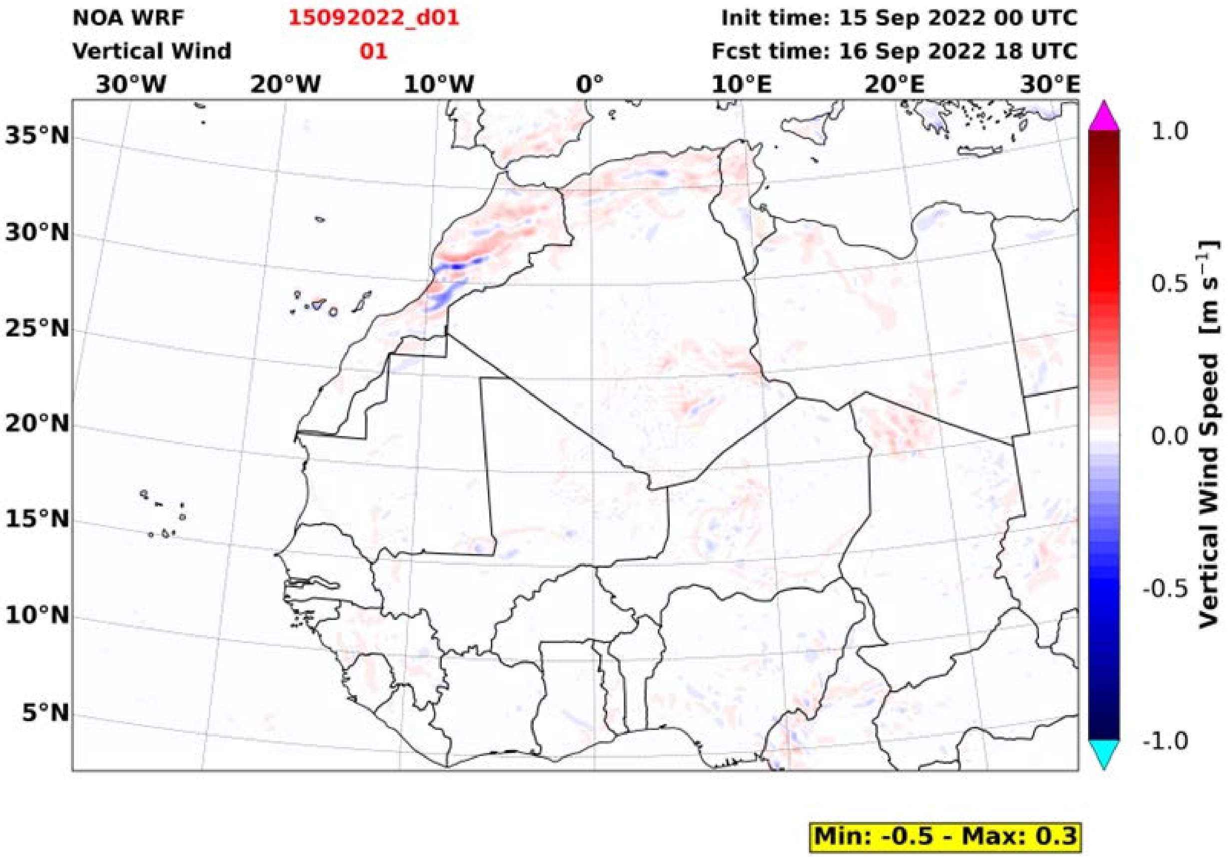
Super-coarse mode and updrafts



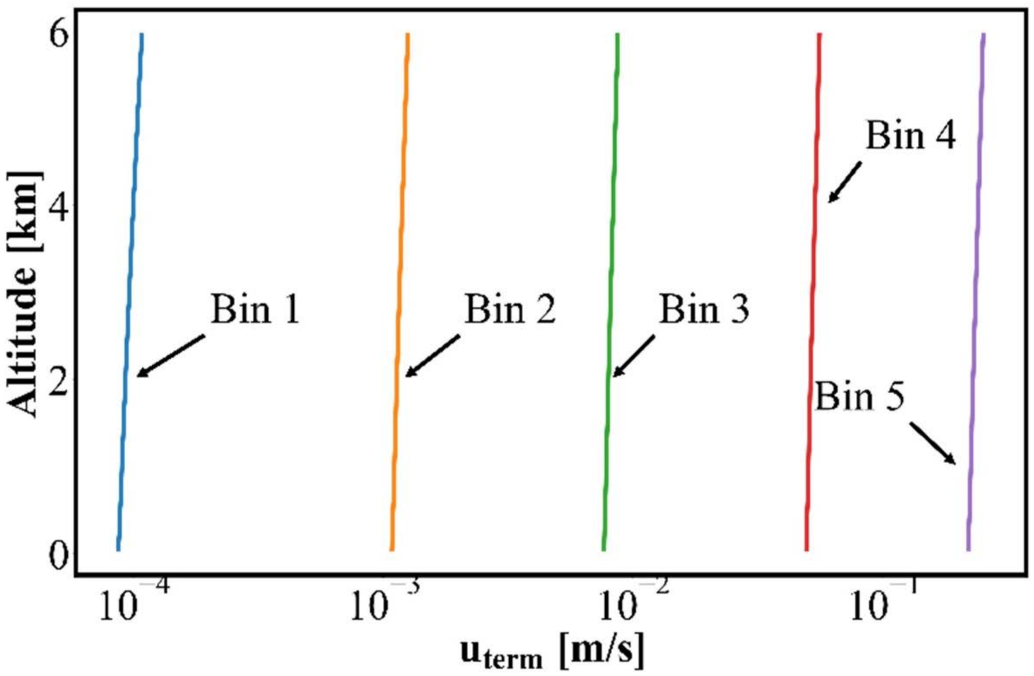


Physical Processes

Super-coarse mode and updrafts



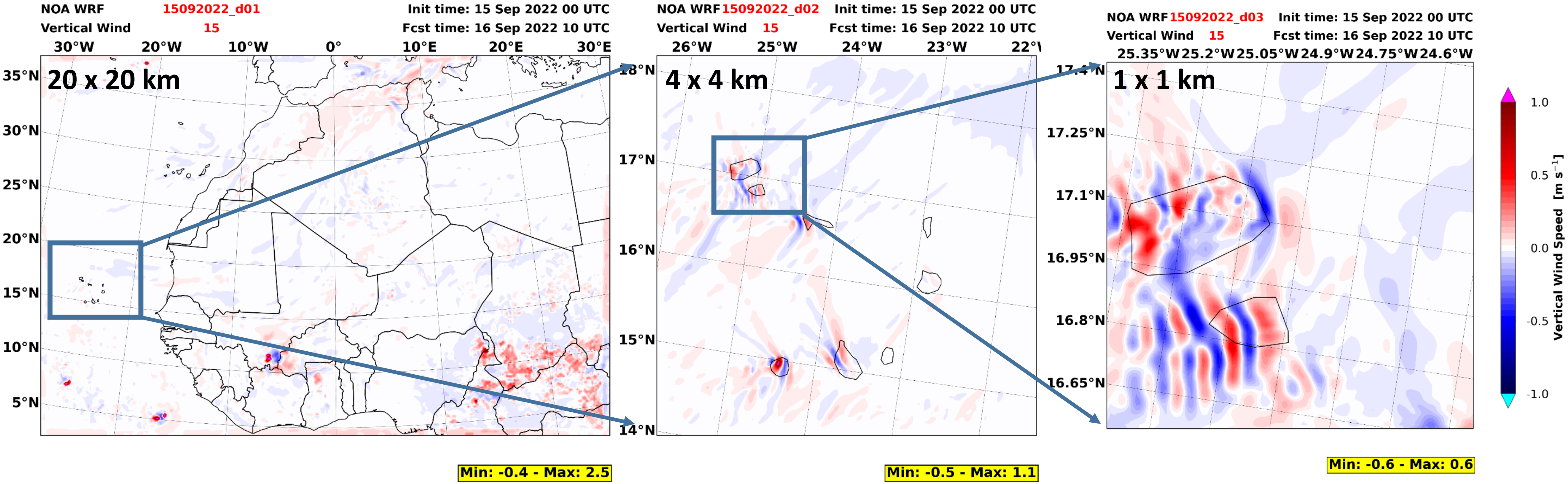
Particle settling velocities



Super-coarse particles' settling velocities are well above simulated updrafts

Physical Processes

Super-coarse mode and updrafts

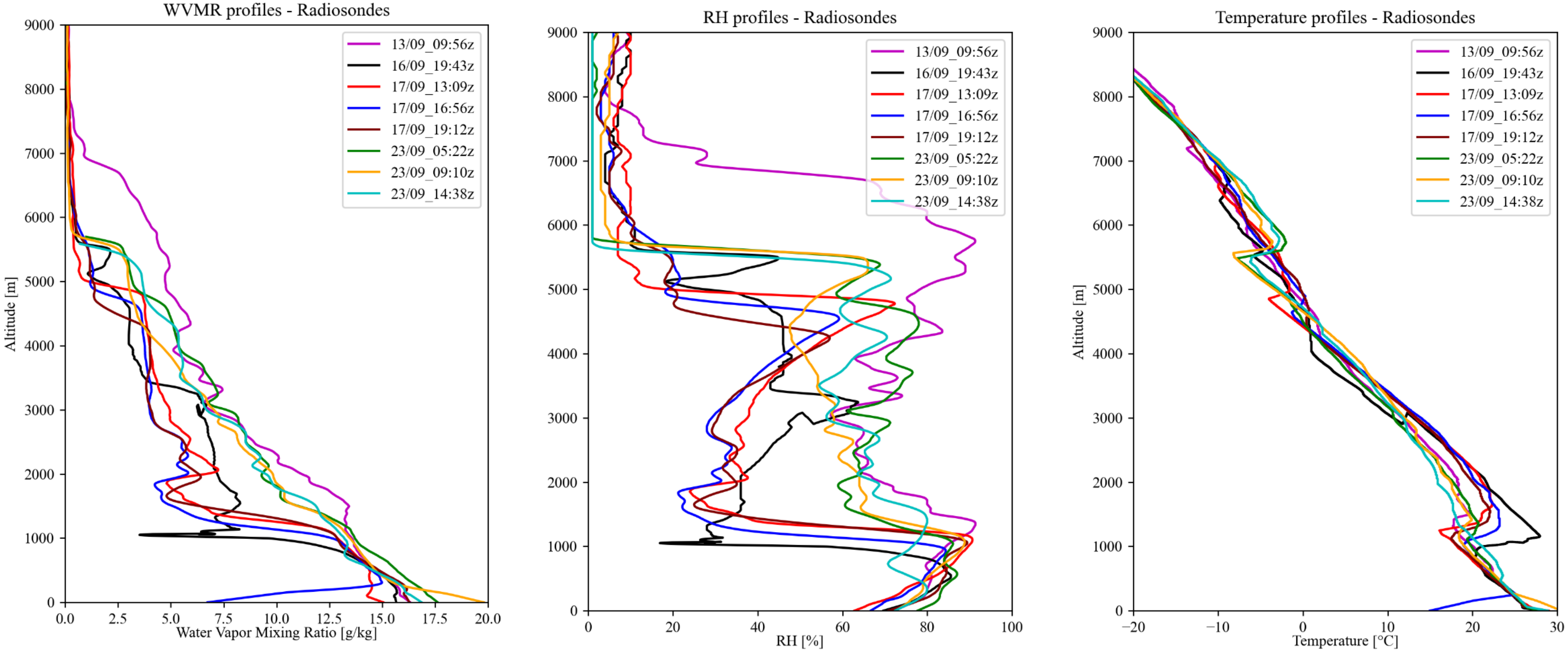


Impact of model resolution

Simulated updrafts on the 10th model level (~ 4km height)

Physical Processes

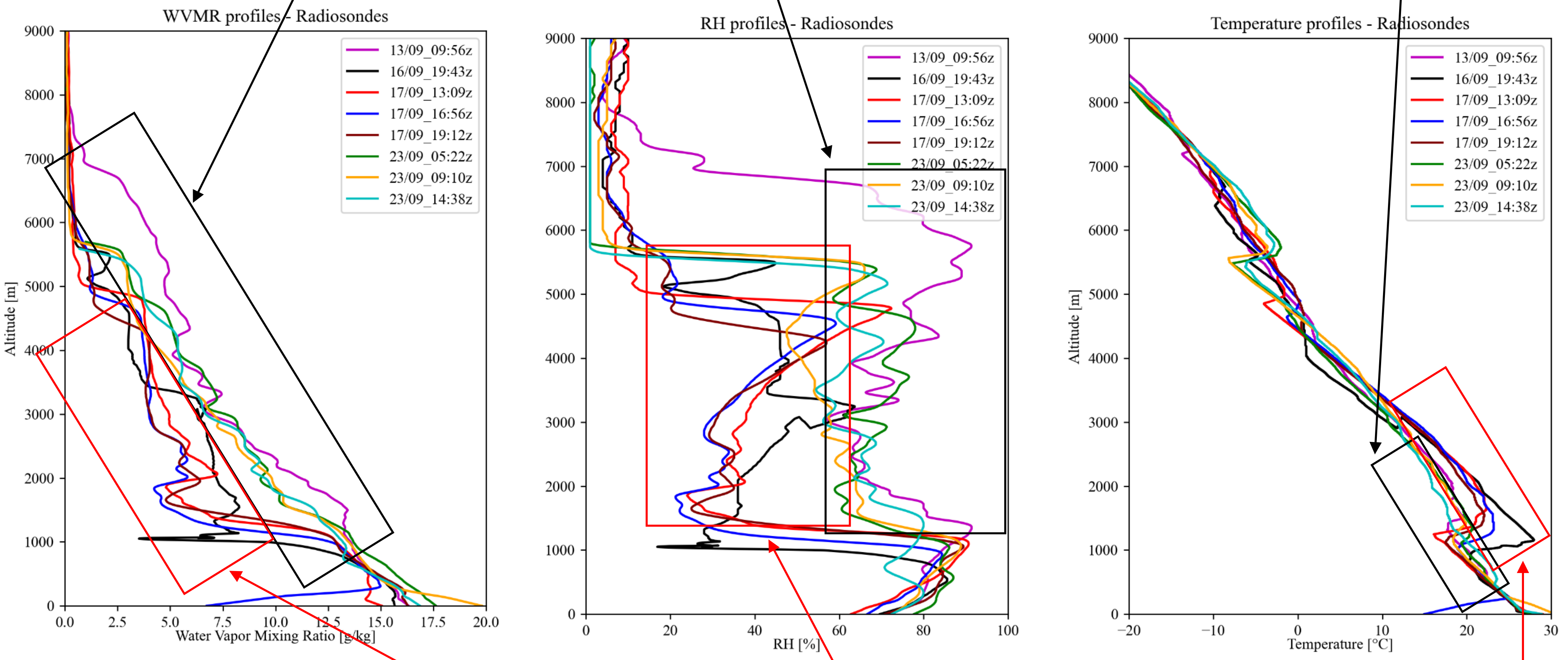
No orientation: SAL is more humid. The WV profile is almost constant throughout the SAL. No strong inversions between MBL and SAL. AOD at 0.45-0.6 at 440nm.



Yes orientation: SAL is drier, with low RH at the bottom of SAL and high RH at the top of SAL. Stronger inversion between MBL and SAL. AOD at 0.3 at 440nm.

Physical Processes

No orientation: SAL is more humid. The RH profile is almost constant throughout the SAL. No strong inversions between MBL and SAL. AOD at 0.45-0.6 at 440nm.



Yes orientation: SAL is drier, with low RH at the bottom of SAL and high RH at the top of SAL. Stronger inversion between MBL and SAL. AOD at 0.3 at 440nm.

Take-home message

- We haven't solved the coarse mode paradox yet, but we will continue working on it!
- ASKOS/JATAC provide an unprecedented dataset for desert dust research
- Similar experiments would be very important in support of the future flagship missions EarthCARE and AOS
- Studies from the dust community over ASKOS/JATAC datasets are more than welcome, the datasets are open, and we will support their use