Assessment of AERONET dust coarse-mode size retrieval: A radiative closure study from visible to thermal infrared

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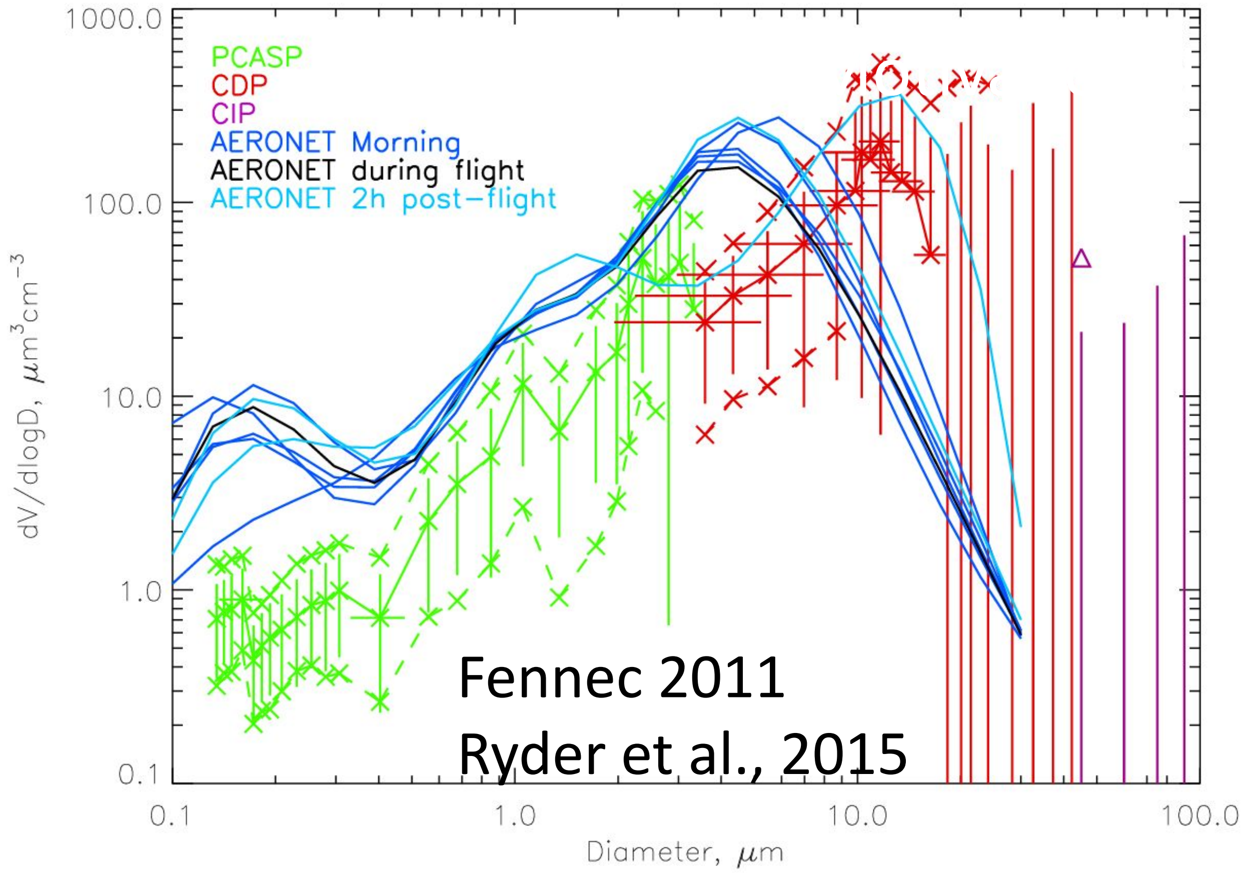
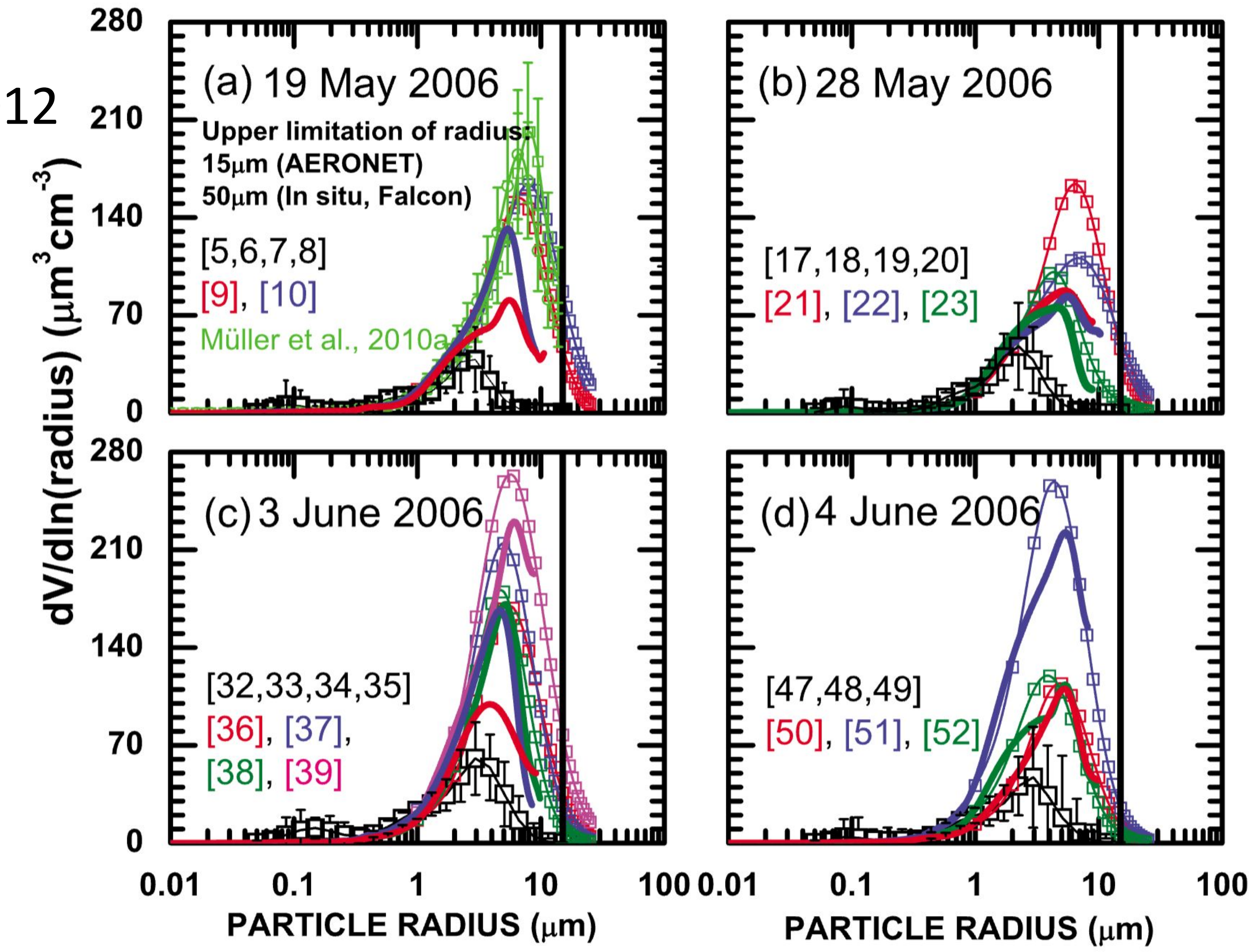
Motivation: In-situ & AERONET Comparison



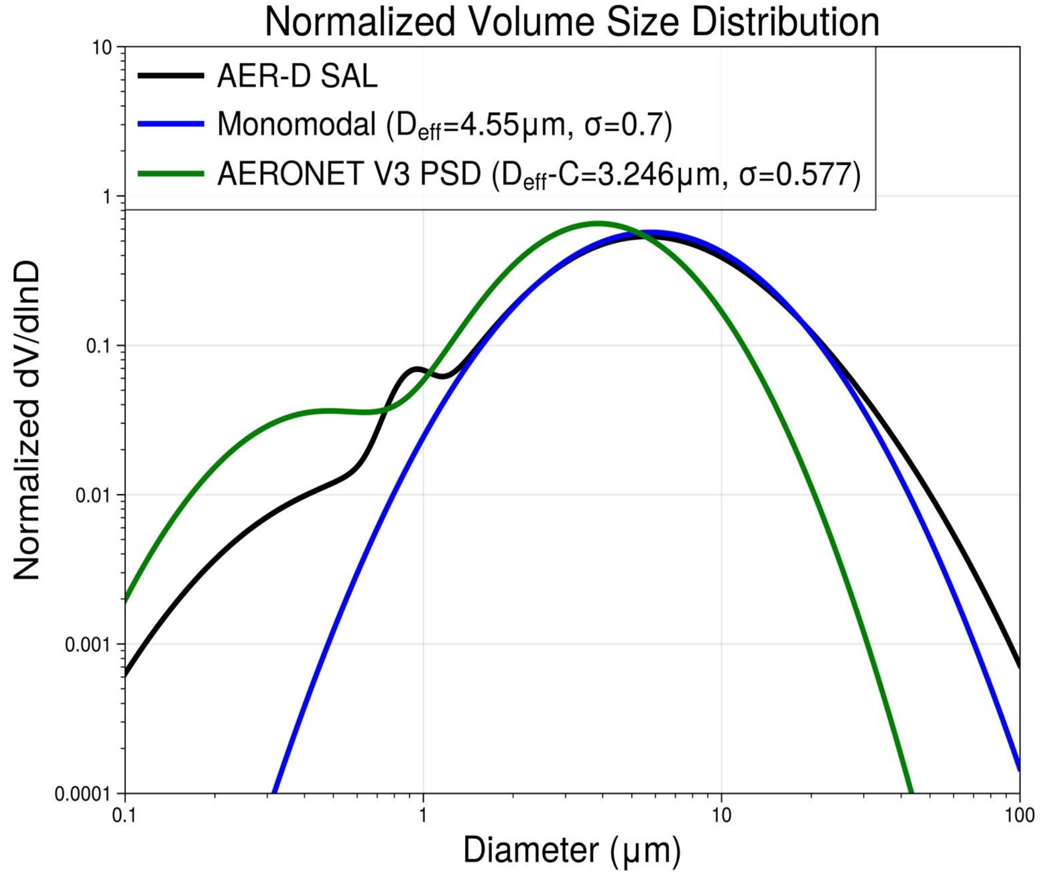
SAMUM 2006
Müller et al., 2012



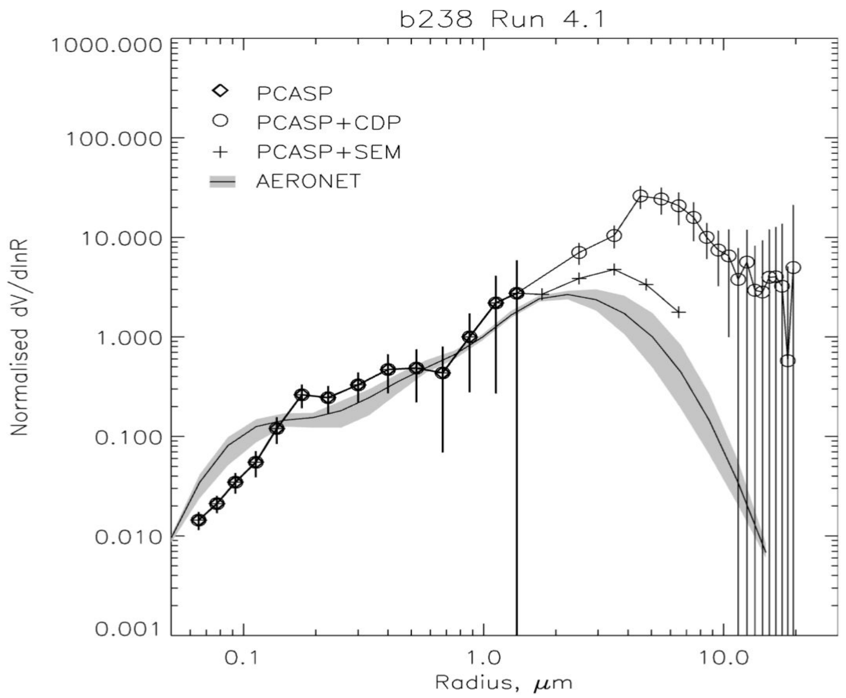
They suggested AERONET undersize dust in coarse-mode

Yet with not well-explained reasons

Apple-to-pear comparison

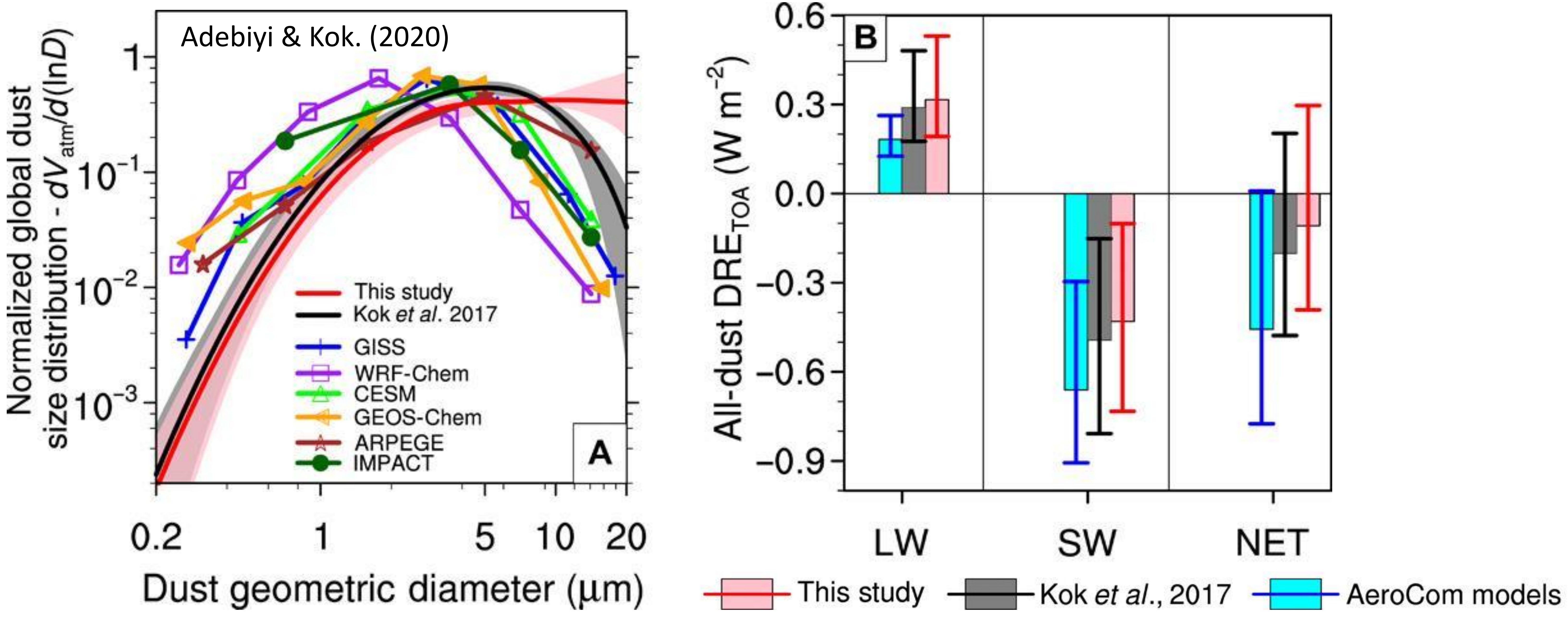


AER-D 2015 & TIR retrieval
Zheng et al 2023



DODO 2006
McConnell et al., 2008

Motivation: Super-coarse dust impact on DRE



Global mean dust DRE at TOA is significantly impacted by **whether or not** and **how much** should we include dust particles with D > 10 μm.

How to evaluate AERONET dust size retrieval?

We test whether AERONET size distribution retrieval can achieve radiative closure in thermal infrared (TIR)

Reasons:

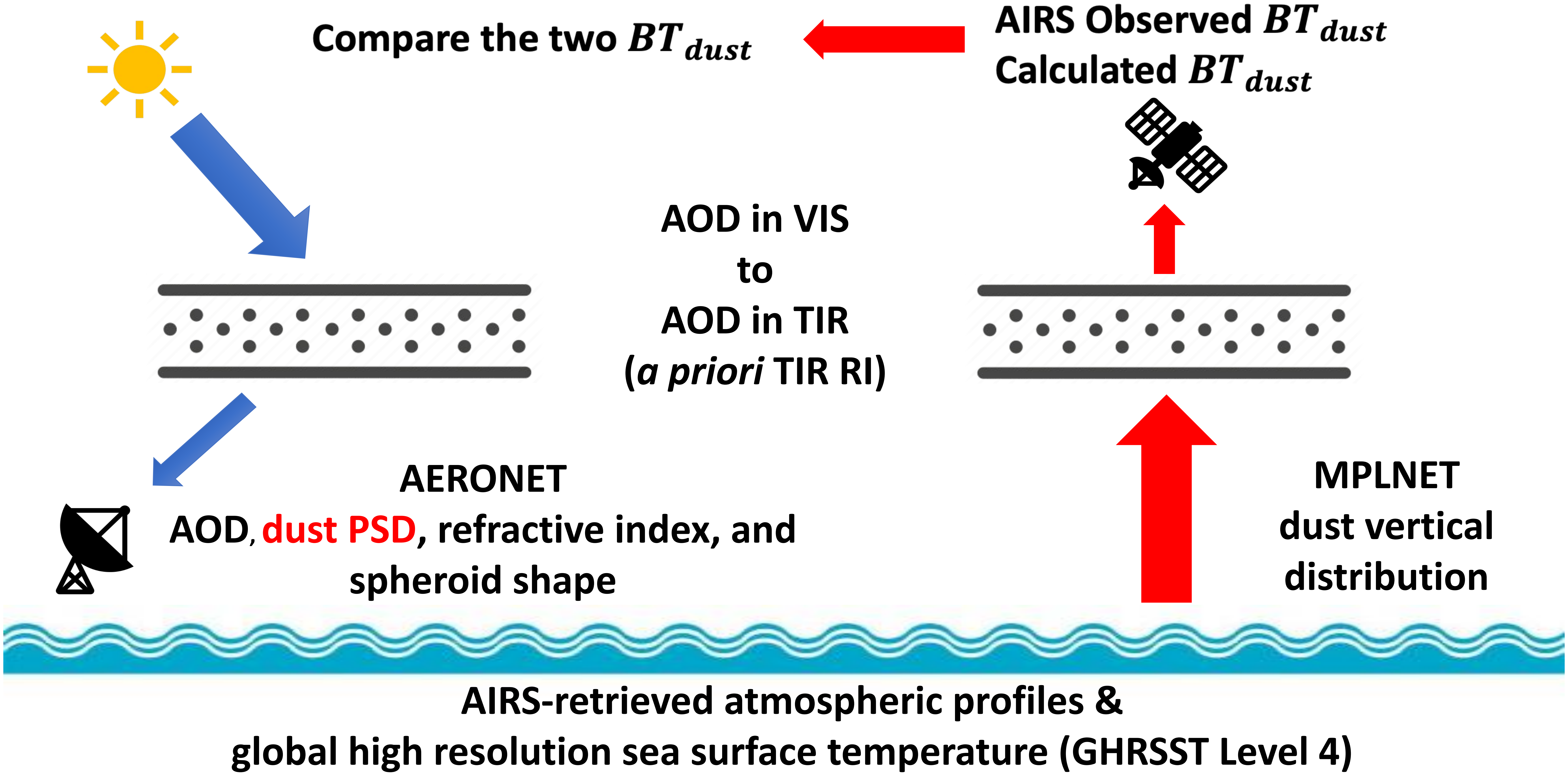
1. The coarse-mode dust (e.g., D > 10 μm) is more sensitive in TIR than VIS.

2. The radiative closure avoids apple-to-pear comparison with in-situ measurements

If yes The AERONET size distribution is appropriate.

If no What are the reasons? Is it possible that the size is not coarse enough?

Forward simulation: VIS-to-TIR BT closure



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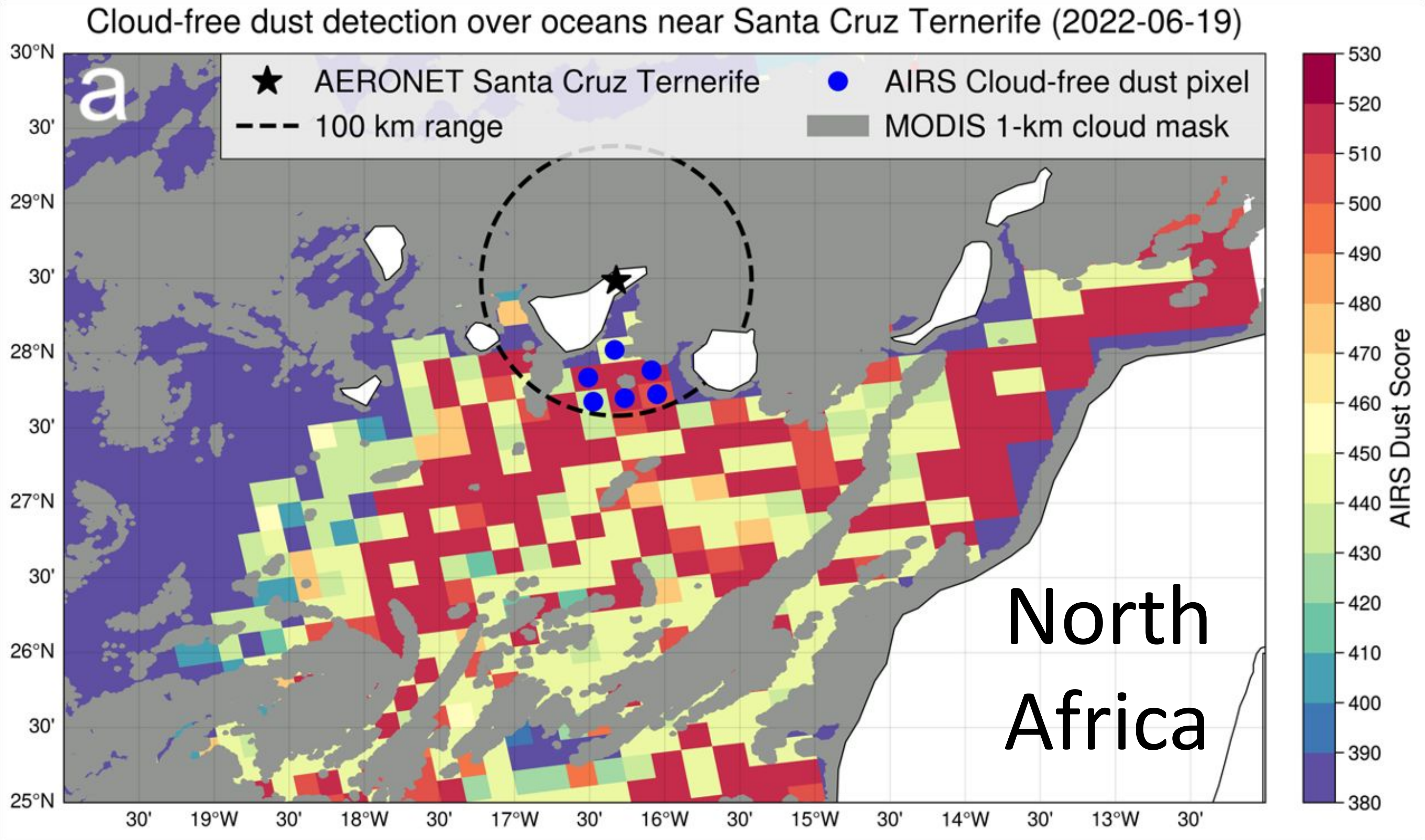
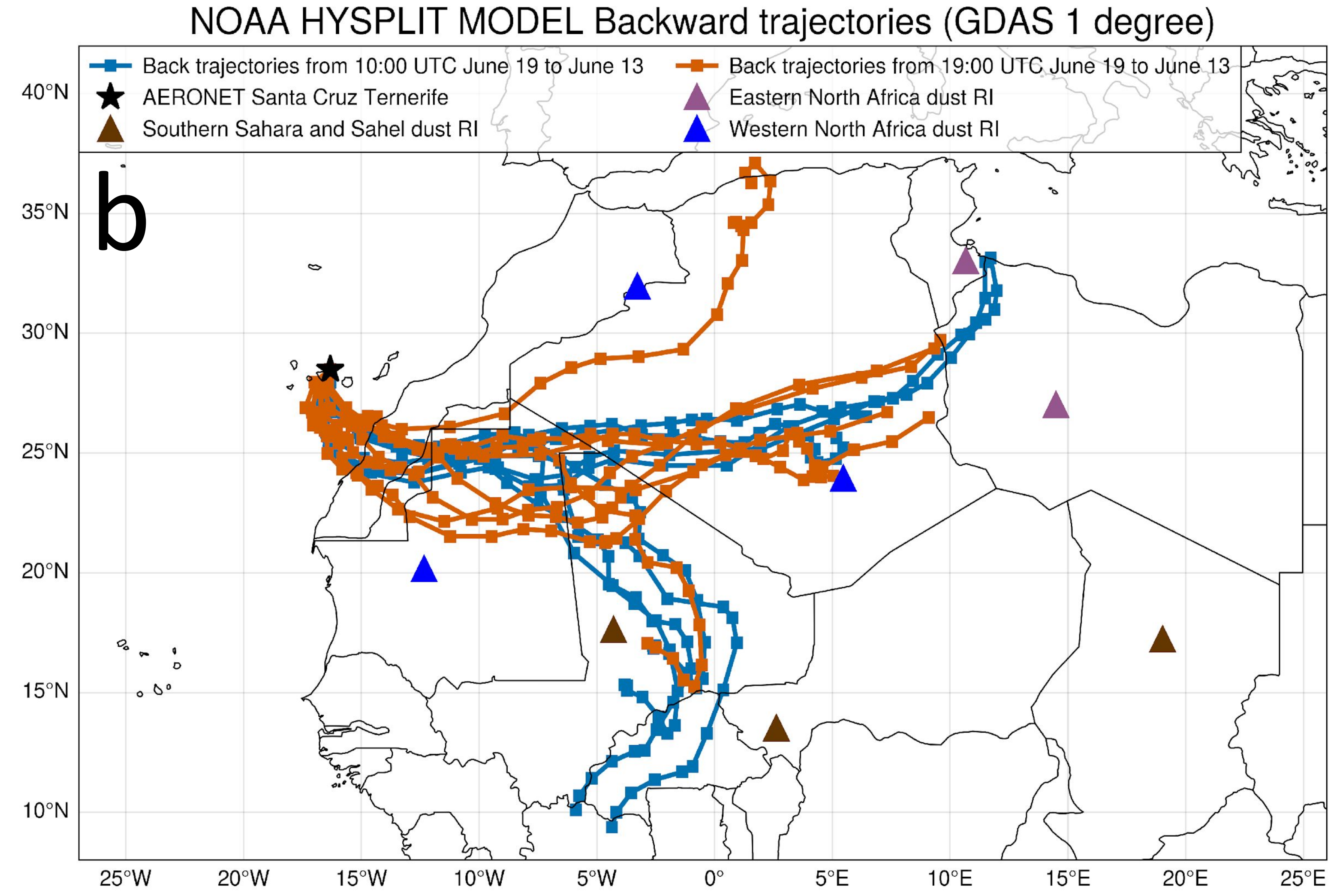
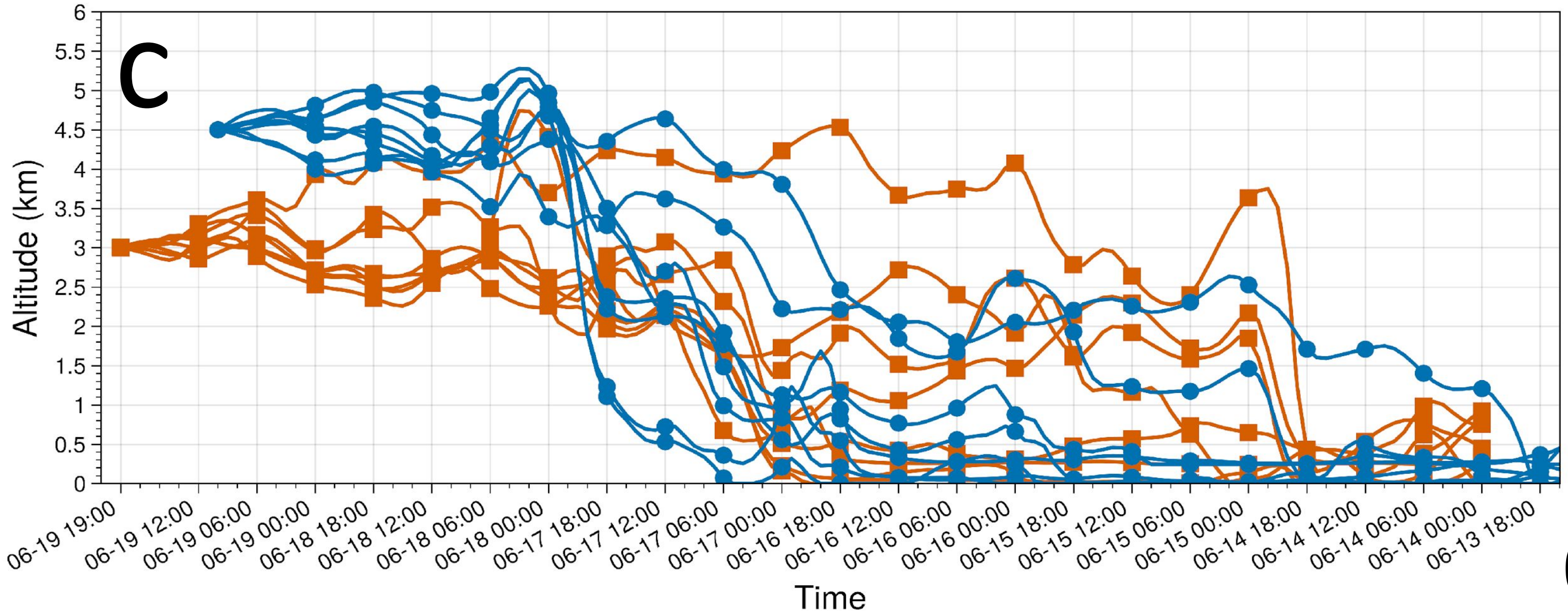
Case study at Santa Cruz Tenerife (2022-06-19)







Case setups:

6 cloud-free AIRS pixels

8 TIR RIs over North Africa (Di Biagio et al 2017)

based on the HYSPLIT ensemble back-trajectories

Case study at Santa Cruz Tenerife (2022-06-19)

Case setups:

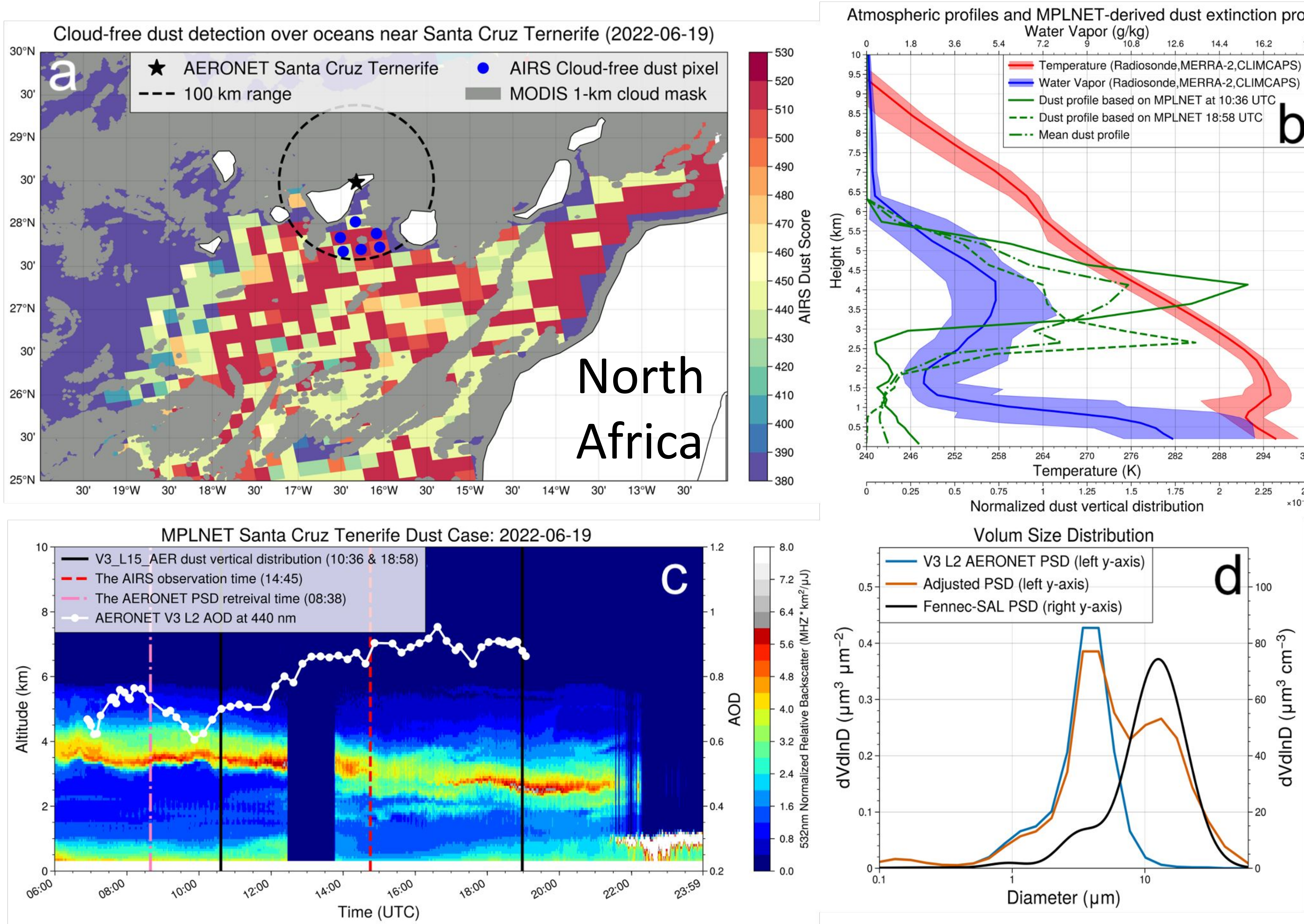
1. Two MPLNET L3 dust vertical profile

2. Radiosonde, AIRS-retrieved, MERRA-2 3-hourly profiles

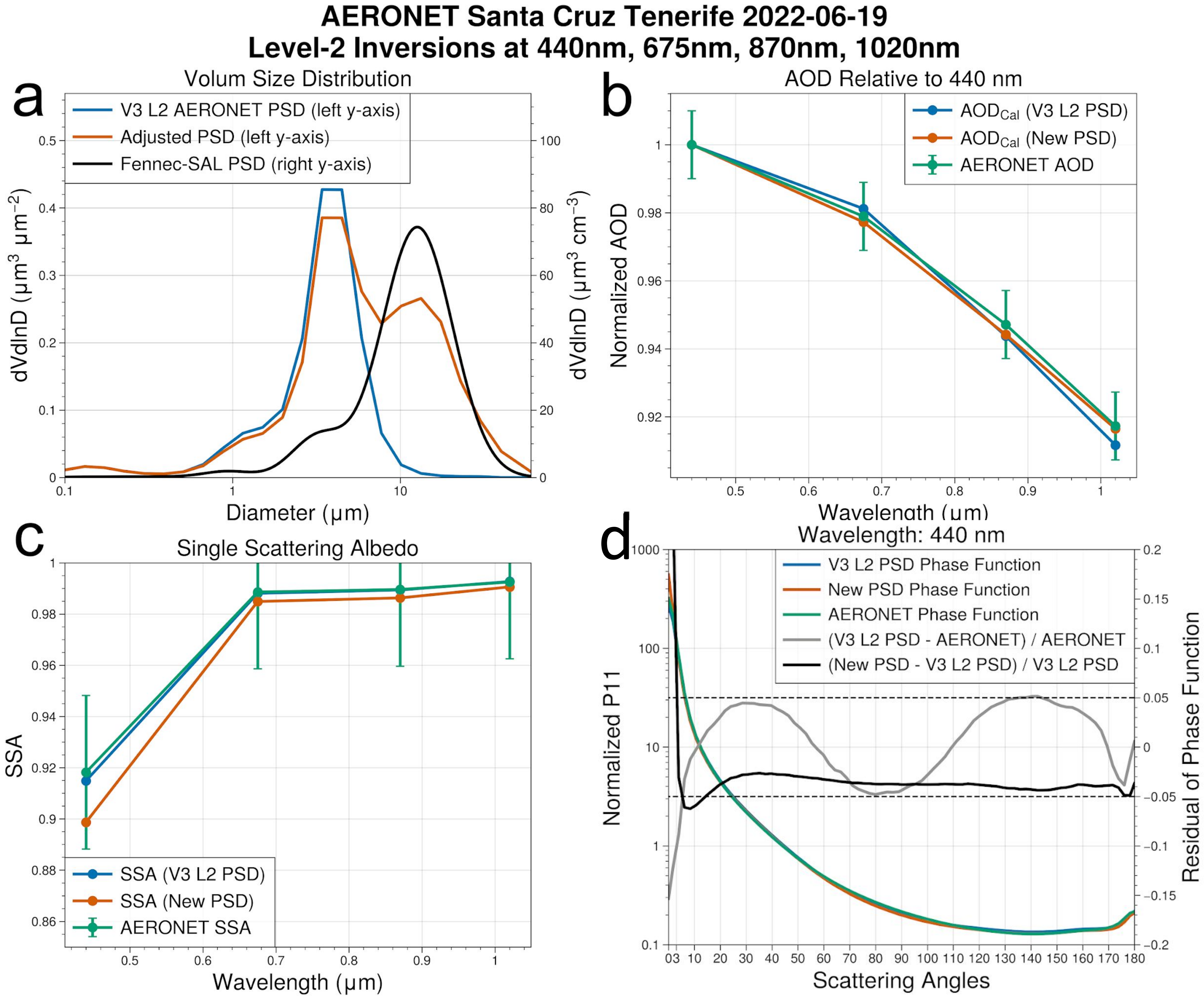
3. Sea surface temperature (GHRSST, ERA5, MERRA-2) with $\pm 1.0\ K$ error

5760 forward calculations of TIR BTs for each of the six AIRS pixels.

34560 BT_obs – BT_cal



Sensitivity in VIS-NIR



Using the IITM (from Dr. Ping Yang) to calculate bulk properties of spheroid dust

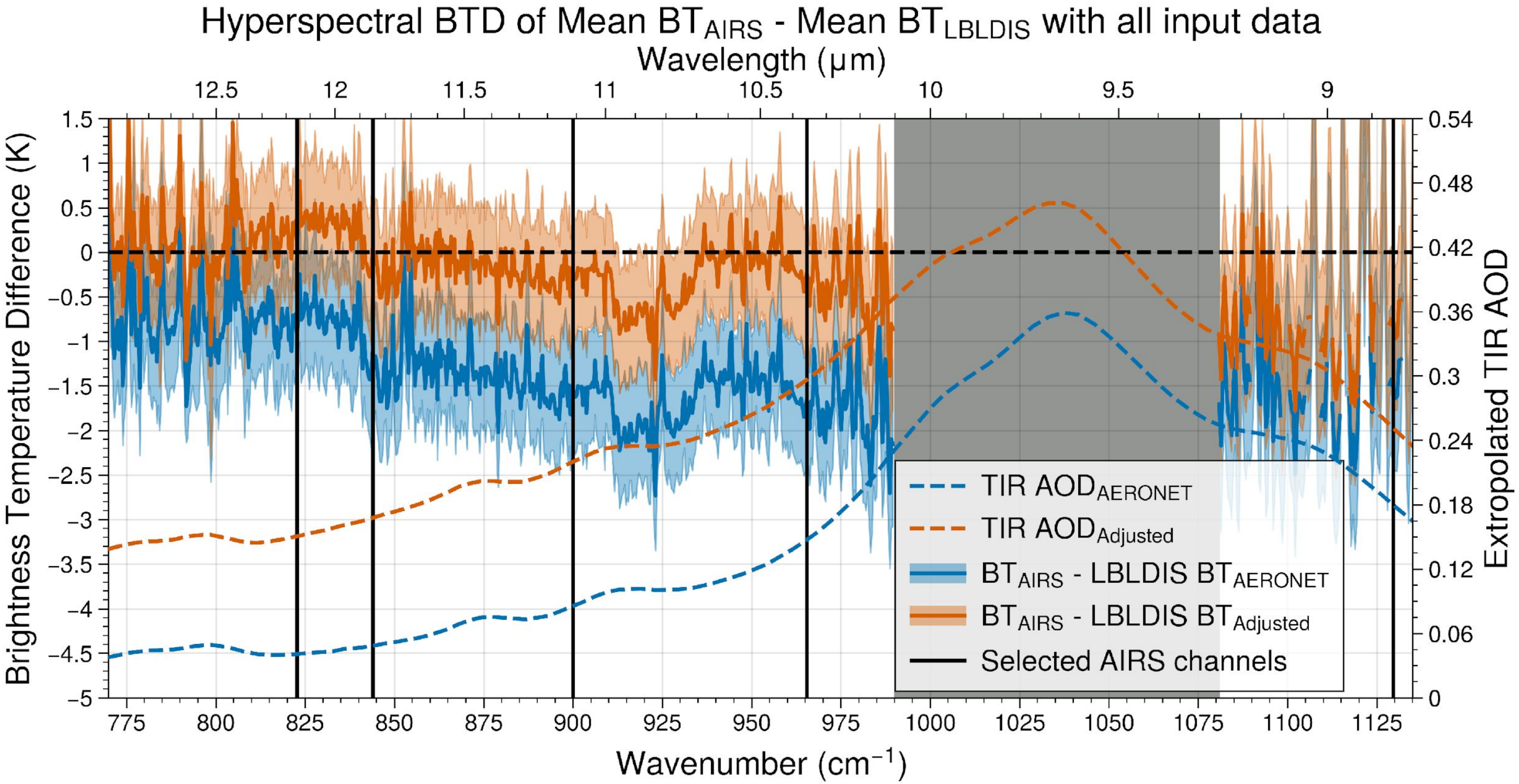
1. IITM-calculated properties agree with AERONET

2. Add super-coarse mode dust PSD to AERONET PSD

3. The adjusted PSD still agree with AERONET within their uncertainty

(Limited sensitivity at AERONET channels in VIS-NIR)

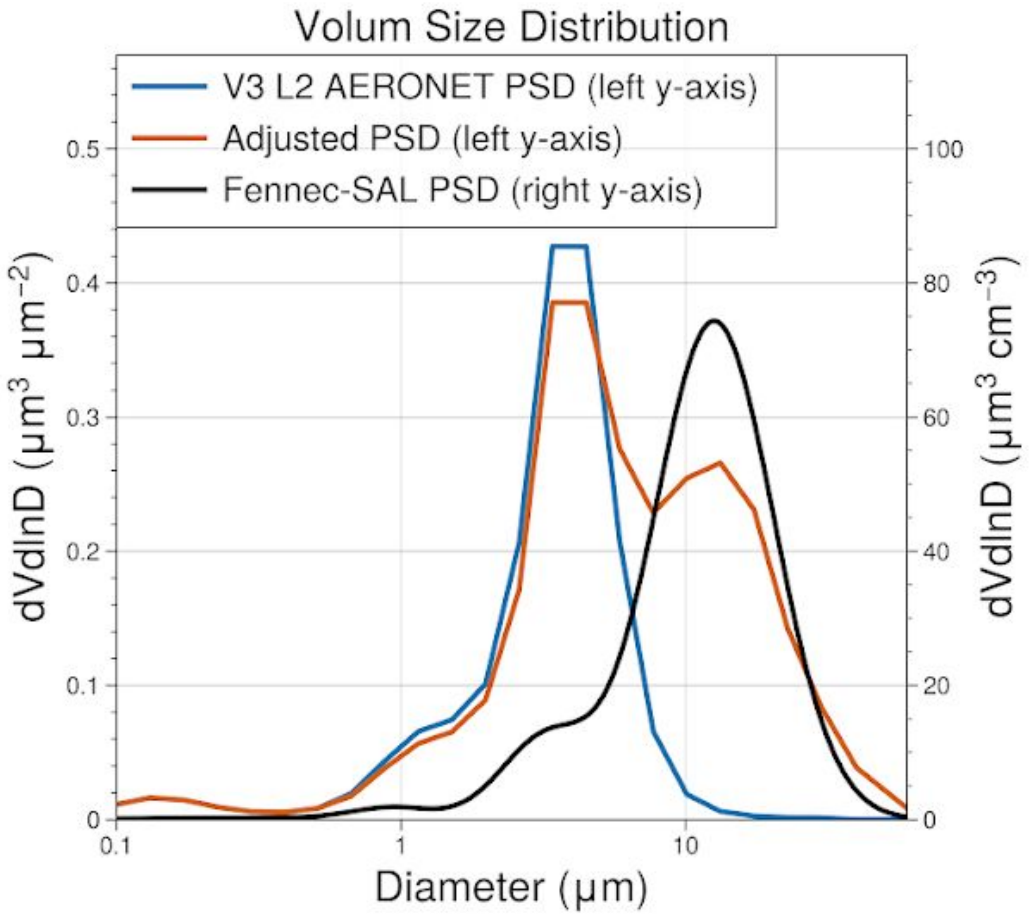
Adjusted coarse mode size



BTD (BT_obs –BT_cal)

The mean BTDs based on AERONET PSD (blue) and Adjusted PSD (red)

Standard deviation of BTDs (shadow areas)

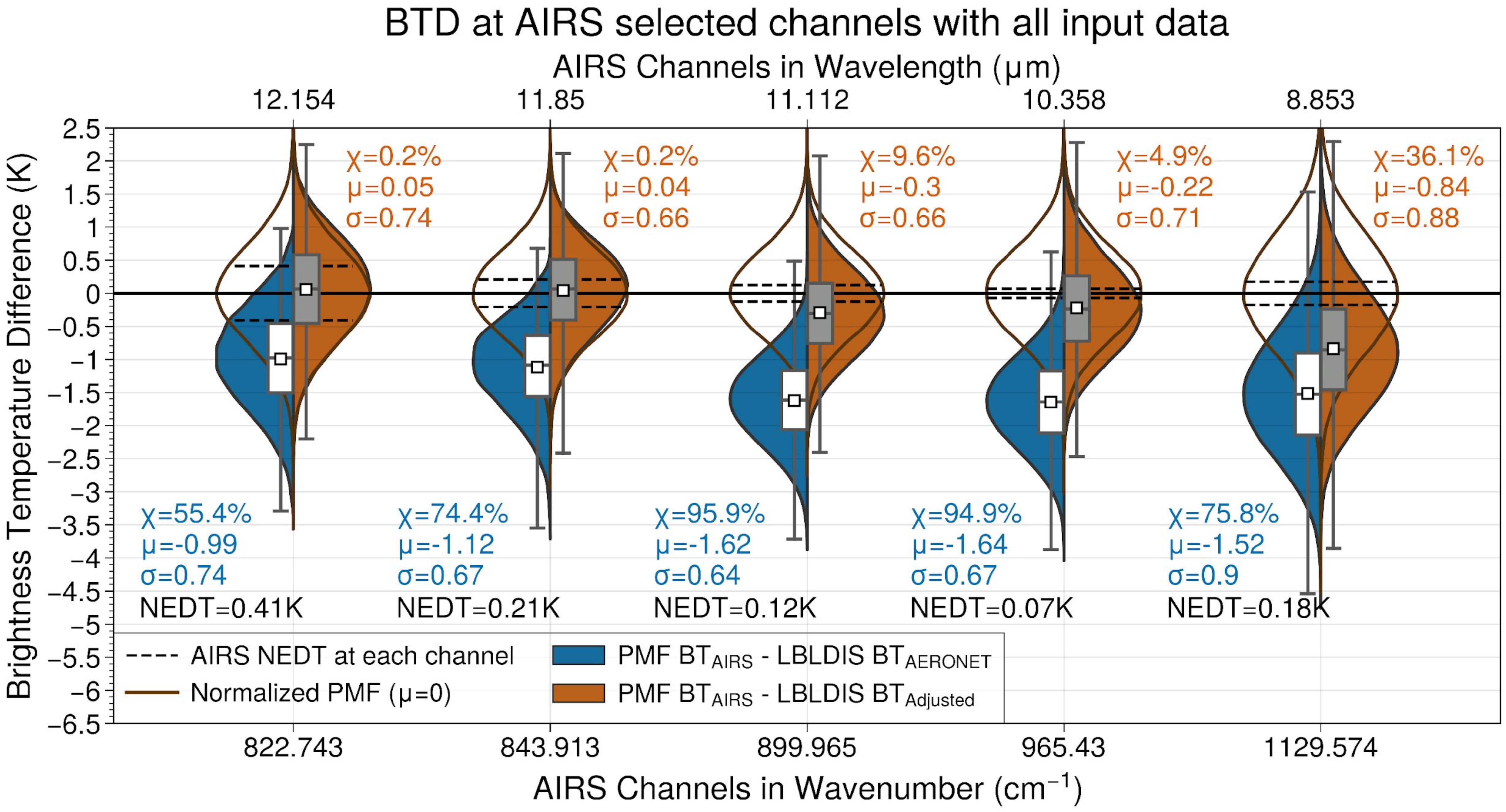


Negative bias of AERONET PSD BTDs -> LBLDIS BTs bias warm

Reason: Too less dust extinction produced by the AERONET's inputs

Increased dust extinction using Adjusted PSD -> Reduced bias of BTDs

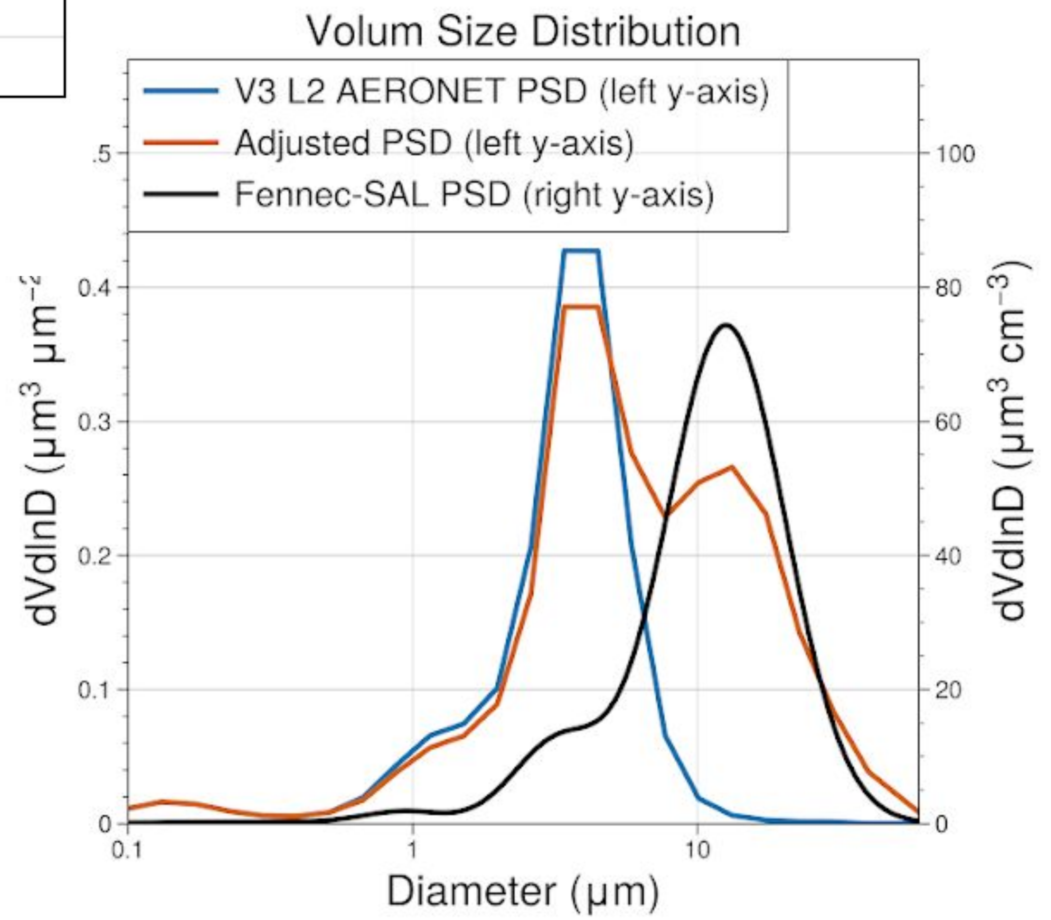
Adjusted coarse mode size



BTD (AIRS BT – LBLDIS BT)

Probability mass function (PMF) and defined Bias (χ) of BTD samples

At five dust-sensitive AIRS channels



Using the adjusted PSD:
Bias at 11.1-μm channel is reduced from 96% to 9.6%
Bias at 11.8-μm channel is reduced from 74% to 0.2%

The closure is much more possible to make compared to using AERONET PSD
-> **We need combined VIS-NIS-TIR observation for dust PSD retrieval**

Take home messages

1. AERONET size distribution retrieval for dense Sahara dust plumes highly possibly underestimated based on the radiative closure study from VIS to TIR.

2. Increasing volume distribution in coarse mode (D > 10 μm) has limited sensitivity in VIS-NIR AERONET channels while having a 30%-80% improvement in TIR radiative closure.

3. Bringing TIR radiometers/interferometers (ARM AERI) with sun-photometers can improve the size distribution retrieval in the full practical range (0.01-100 μm).

Reference: Zheng, J. et al, 2024. Assessment of Dust Size Retrievals Based on AERONET: A Case Study of Radiative Closure From Visible-Near-Infrared to Thermal Infrared. Geophys. Res. Lett. 51. https://doi.org/10.1029/2023gl106808

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Back up Slides

Uncertainty sources

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1. MPLNET estimated dust vertical distribution
   Two qualified cloud-free dust vertical profiles

2. Atmospheric profiles
   Radiosonde measurements
   Collocated AIRS-retrieved profiles (CALIMCAPS) $\pm$ retrieval errors
   MERRA-2 3-hourly profiles

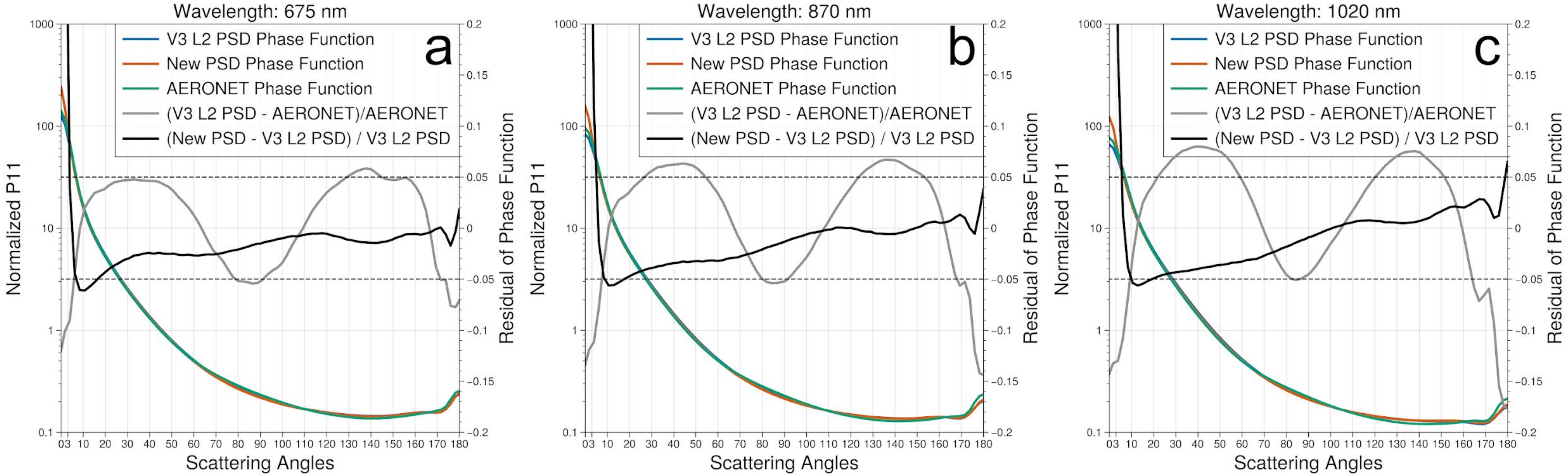
3. Surface properties
   Averaged SST from multiple datasets (GHRSST, ERA5, MERRA-2) with $\pm 1.0\ K$ error
   Spectral sea surface emissivity with ± 0.004

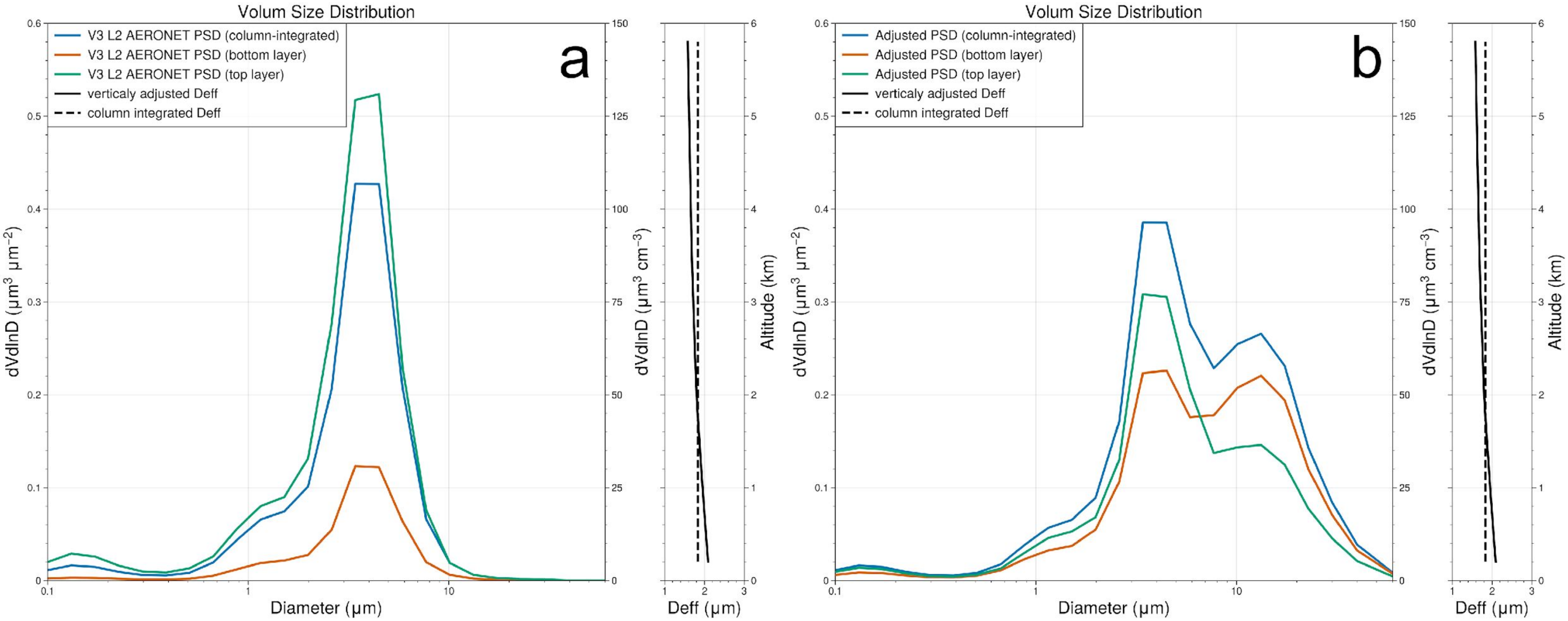
4. AIRS pixels
   We selected six cloud-free dust pixels near AERONET (within 100 km)

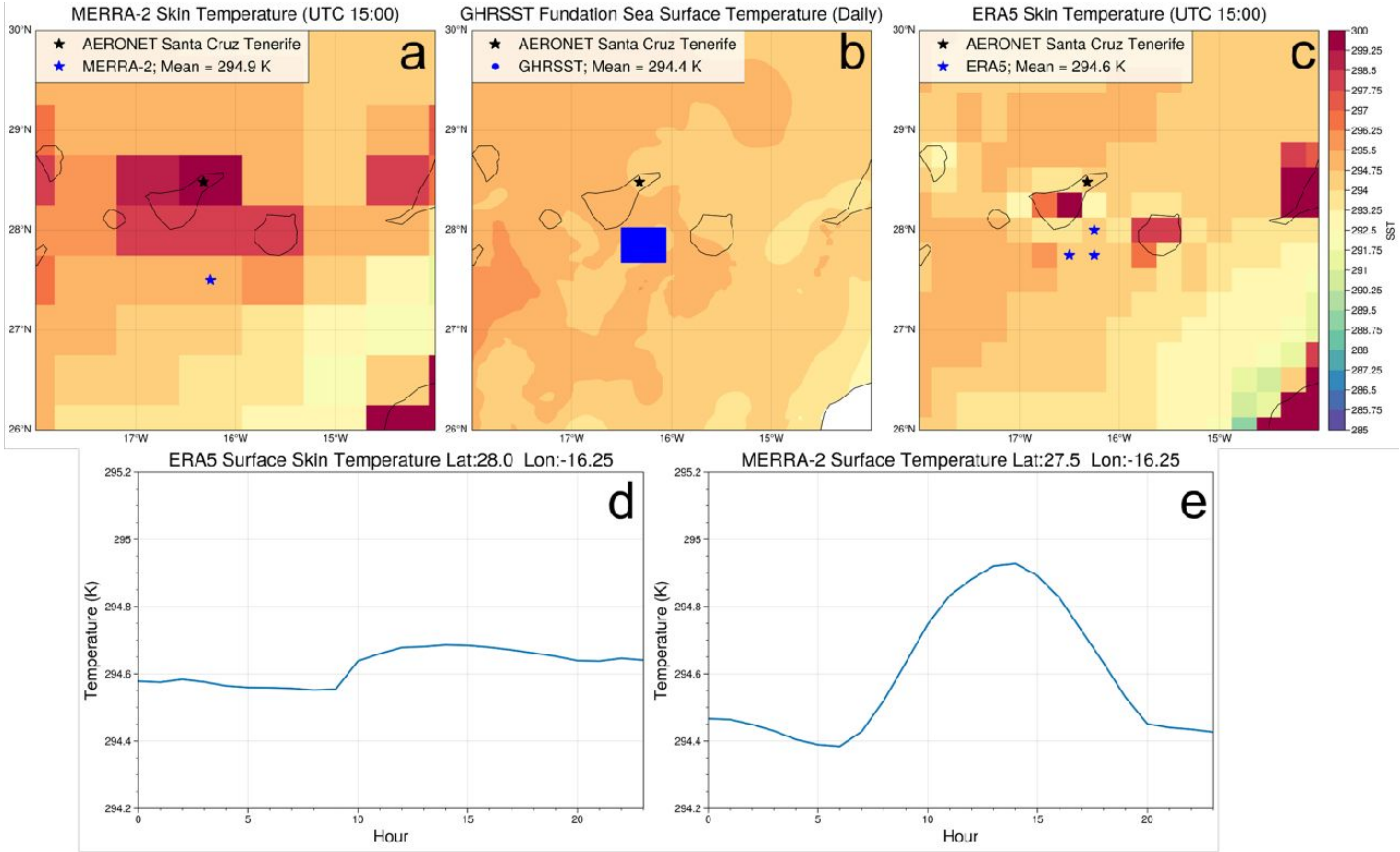
5. Dust TIR refractive indices
   We selected eight possible dust TIR refractive indices based on HYSPLIT back trajectories

TIR simulation using LBLRTM+DISORT (LBLDIS) with inputs from the above data
5760 simulations of TIR BTs and 34560 BTDs combined with the six AIRS pixels.

AERONET Santa Cruz Tenerife 2022-06-19 Level-2 Inversions at 675nm, 870nm, 1020nm




Volum Size Distribution
V3 L2 AERONET PSD (column-integrated)
V3 L2 AERONET PSD (bottom layer)
V3 L2 AERONET PSD (top layer)
verticaly adjusted Deff
column integrated Deff
a
dVdlnD (μm³ μm⁻²)
dVdlnD (μm³ cm⁻³)
Altitude (km)
Diameter (μm)
Deff (μm)
Volum Size Distribution
Adjusted PSD (column-integrated)
Adjusted PSD (bottom layer)
Adjusted PSD (top layer)
verticaly adjusted Deff
column integrated Deff
b
dVdlnD (μm³ μm⁻²)
dVdlnD (μm³ cm⁻³)
Altitude (km)
Diameter (μm)
Deff (μm)


MERRA-2 Skin Temperature (UTC 15:00)
AERONET Santa Cruz Tenerife
MERRA-2; Mean = 294.9 K
a
GHRSST Fundation Sea Surface Temperature (Daily)
AERONET Santa Cruz Tenerife
GHRSST; Mean = 294.4 K
b
ERA5 Skin Temperature (UTC 15:00)
AERONET Santa Cruz Tenerife
ERA5; Mean = 294.6 K
c
30°N
29°N
28°N
27°N
26°N
17°W
16°W
15°W
SST
300
285
ERA5 Surface Skin Temperature Lat:28.0 Lon:-16.25
d
MERRA-2 Surface Temperature Lat:27.5 Lon:-16.25
e
Temperature (K)
Hour
295.2
295
294.8
294.6
294.4
294.2
0
5
10
15
20

Reference

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