Assessing lidar ratio impact on CALIPSO retrievals utilized for estimating aerosol shortwave direct radiative effects over the NAMEE domain

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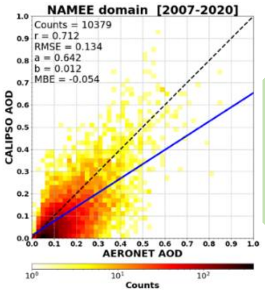
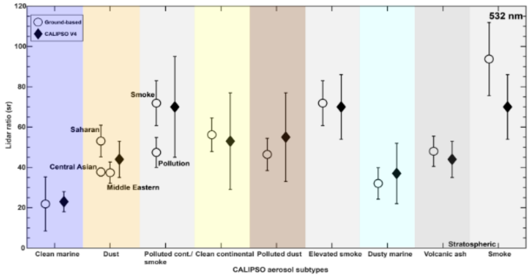
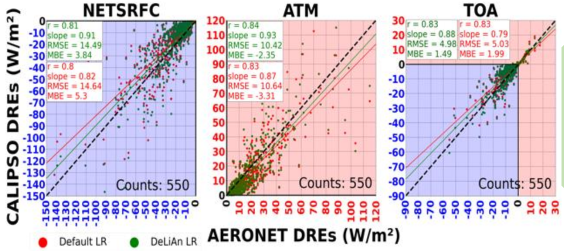
Research objectives



Identify deficiencies on CALIOP retrievals affecting the assessment of aerosol-radiation interactions



Advancing CALIPSO retrievals (emphasizing on the lidar ratio) towards a better representation of speciated AOD



Assessment of aerosol-induced SW direct radiative effects (DREs) under clear-sky conditions

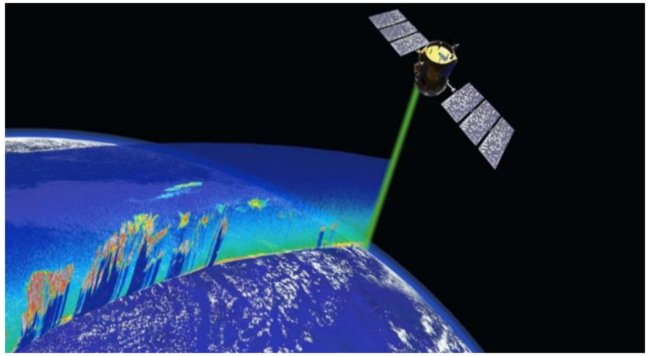
CALIOP-CALIPSO spaceborne retrievals

Dataset

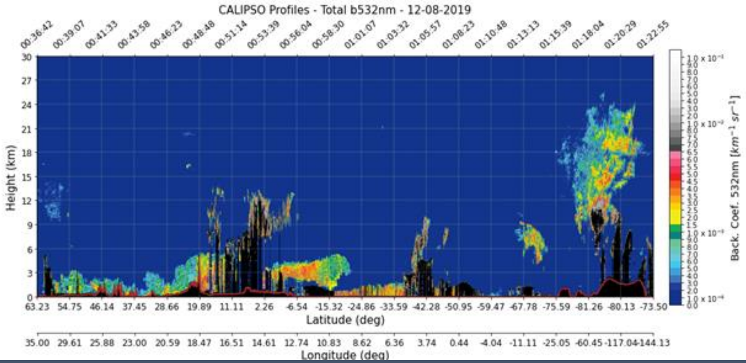
- ➢ QA CALIPSO Level 2 (L2) Version 4.2 (V4.2) vertically resolved retrievals
- ▪ Backscatter coefficient & Linear particle depolarization (532 nm)

Extracted from the LIVAS database (Amiridis et al., 2015)

- ➢ Time period: 2007-2020 [14 years]



Raw retrievals



Averaging methods and quality filtering procedures
Aerosol extinction for "clear-air" assigned ≡ 0 km^{-1}
Clear-air below aerosol layers with bases < 250 m (a.g.l.) ignored
Isolated 80 km horizontal resolution aerosol layers rejected
CAD score outside [−100, −20] range rejected
Aerosol in contact with ice clouds (top temperature < 0 °C), above 4 km (a.m.s.l.) rejected
Extinction QC flag ≠ 0, 1, 16, 18 rejected
Extinction uncertainty = 99.9 km^{-1} rejected, and all extinction below
All samples ≤ 60 m (a.g.l.) excluded

Proestakis et al. (2018)
Marinou et al. (2017)
Tackett et al. (2018)

Advantages

- ➢ Vertical profiles of aerosol-speciated optical and macrophysical properties
- ➢ Depolarization measurements (identification of non-spherical particles)

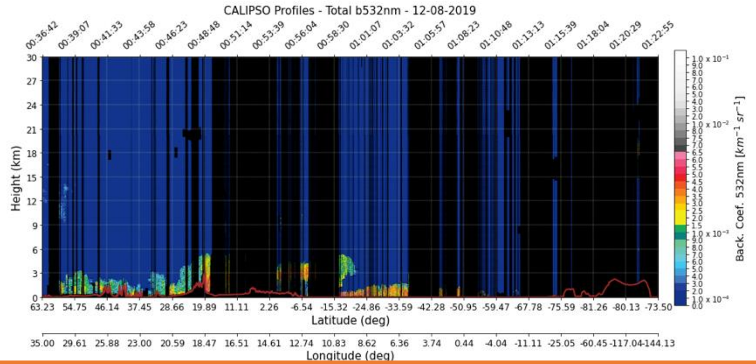
Drawbacks

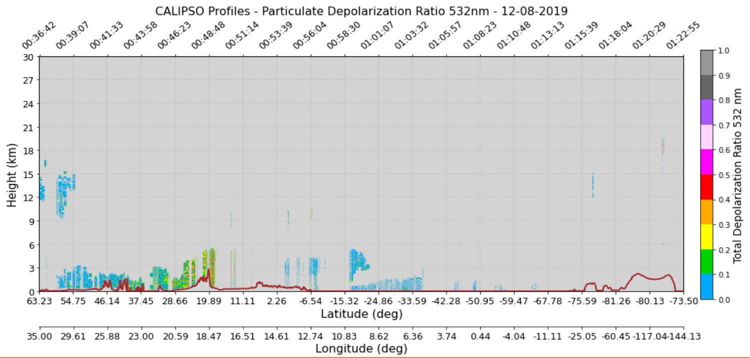
- ➢ Misclassification of aerosol subtypes
- ➢ Accurate definition of lidar ratio (LR)

Elastic lidar !!

Convert backscatter to extinction ➔ AOD [vertical integration of extinction]

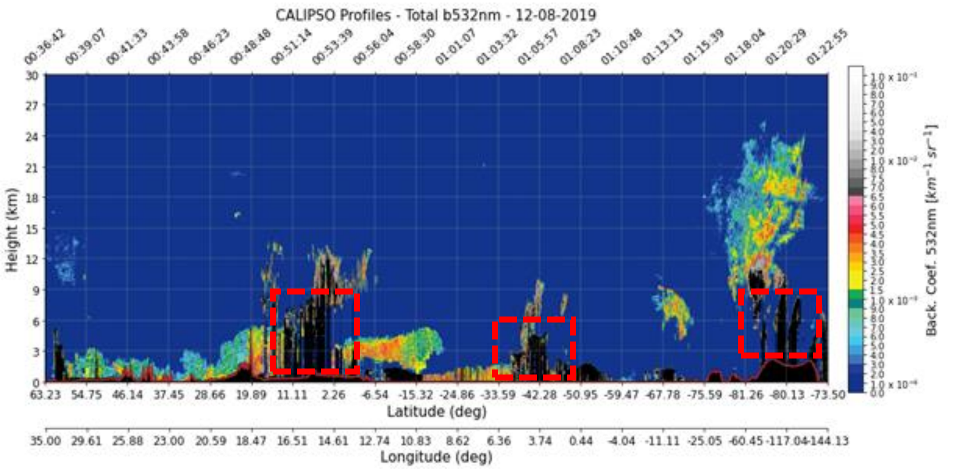
QA retrievals



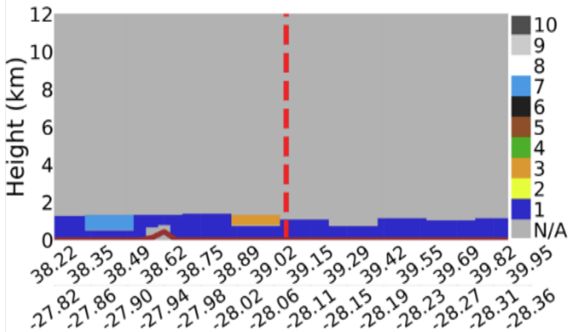


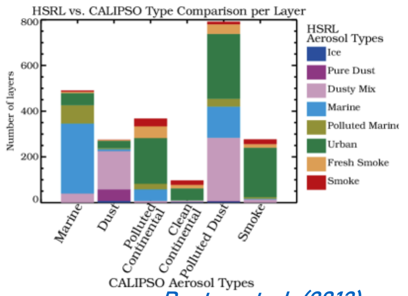
CALIPSO deficiencies

Total attenuation



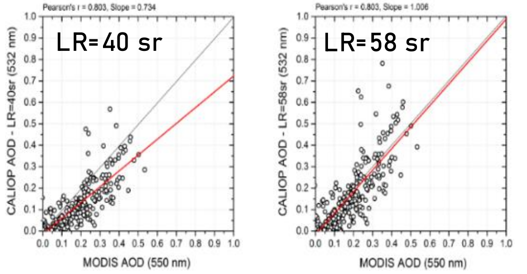
Misclassification of aerosol types





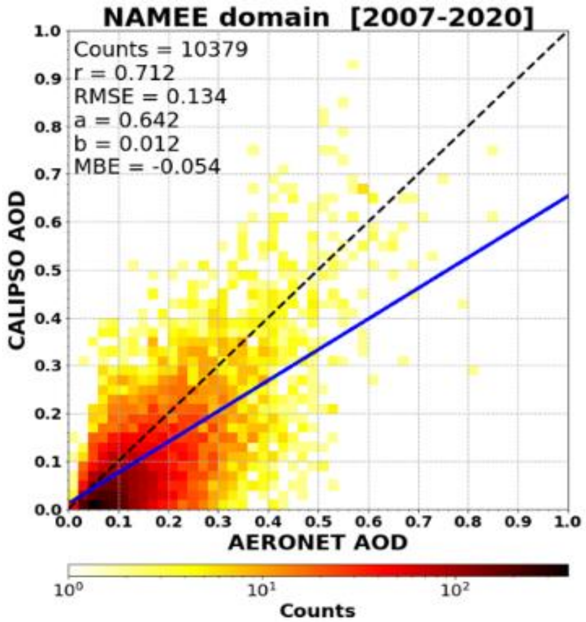
Burton et al. (2013)

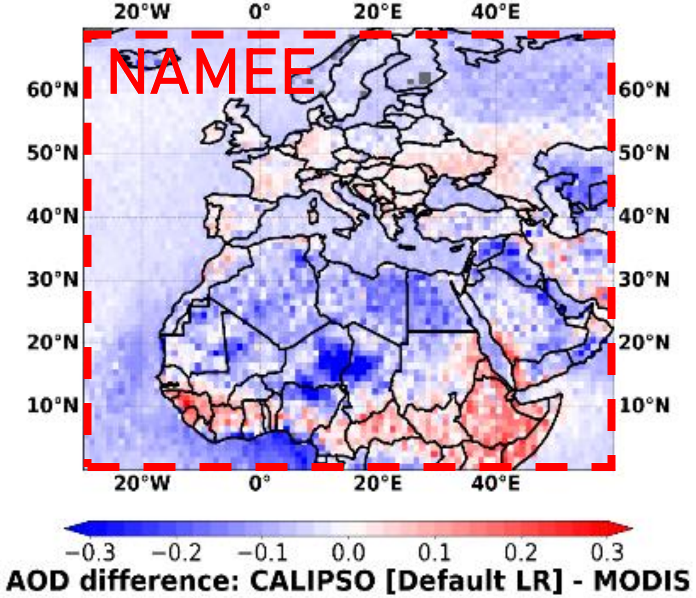
Misrepresentative LR



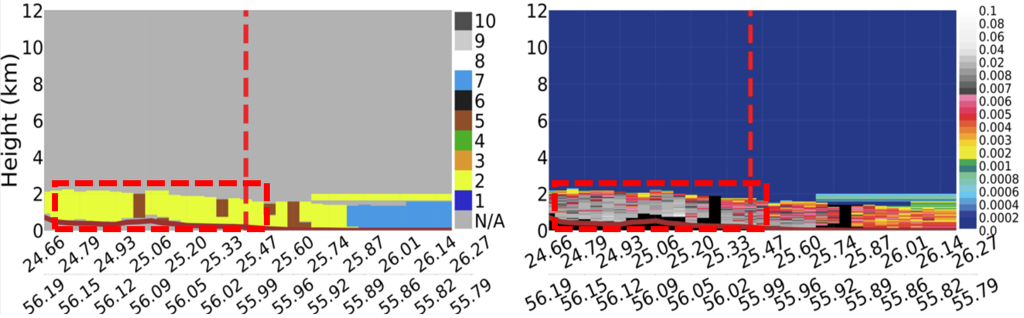
Amiridis et al. (2013)

AOD underestimation

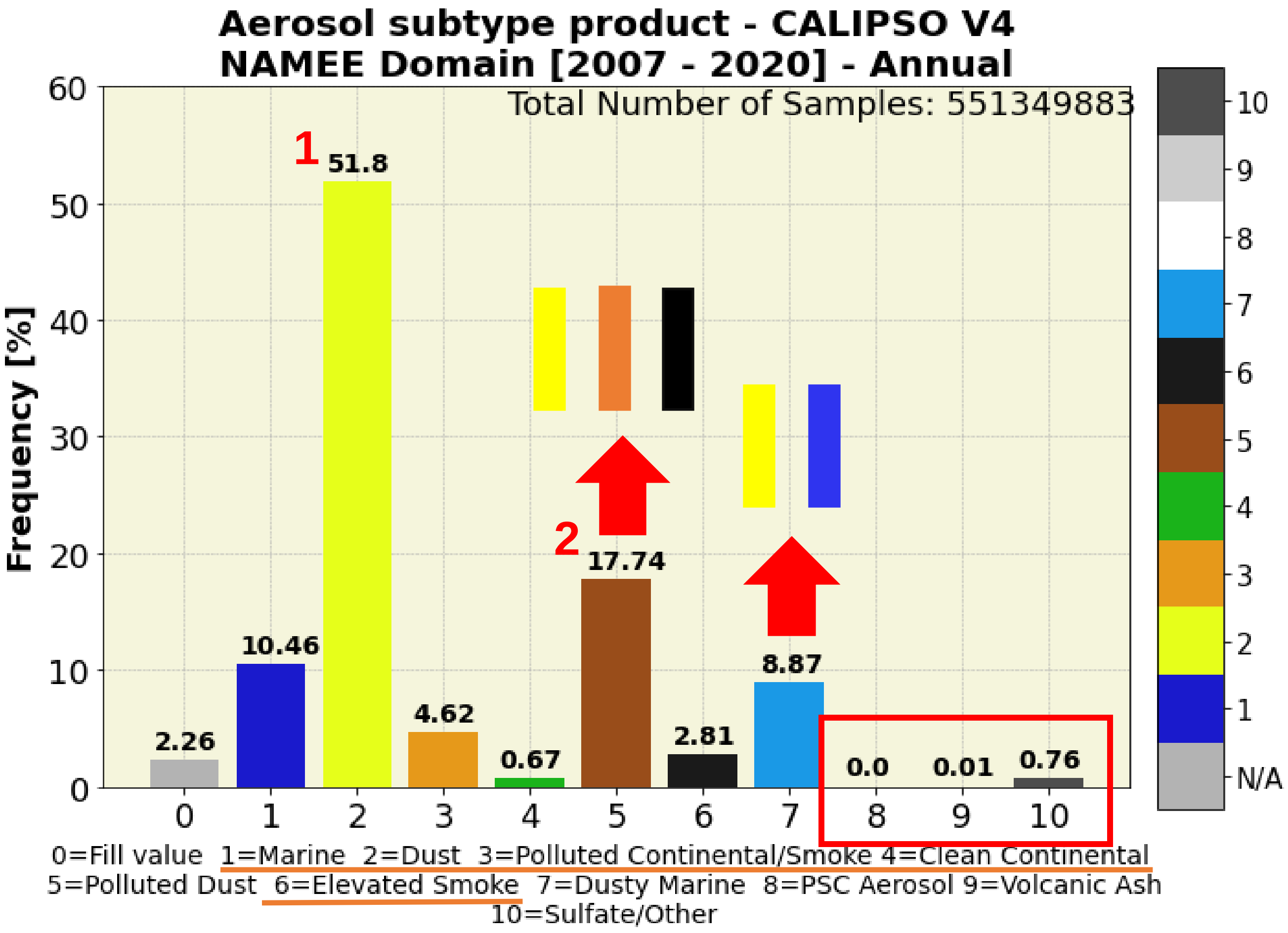




Misclassified Clouds



CALIPSO aerosol types within NAMEE



- Dust is the most predominant type [FoO ~ 52%]
- Stratospheric aerosols are recorded rarely [FoO ~ 0.8%]
- Dust mixtures [Polluted dust and Dusty marine] are also major contributors to the total aerosol load [FoO ~ 27%]

Dust discrimination in aerosol mixtures

Polluted dust
Dusty marine

$$\beta_{\lambda,\mathrm{d}} = \beta_{\lambda,\mathrm{p}} \frac{(\delta_{\lambda,\mathrm{p}} - \delta_{\lambda,\mathrm{nd}})(1+\delta_{\lambda,\mathrm{d}})}{(\delta_{\lambda,\mathrm{d}} - \delta_{\lambda,\mathrm{nd}})(1+\delta_{\lambda,\mathrm{p}})}.$$

Tesche et al. (2009)

- Dust $\delta_{\lambda,d}$= 0.28
- $\delta_{\lambda,nd}$ varying depending on the non dust component according to the DeLiAn database (Floutsi et al., 2023)

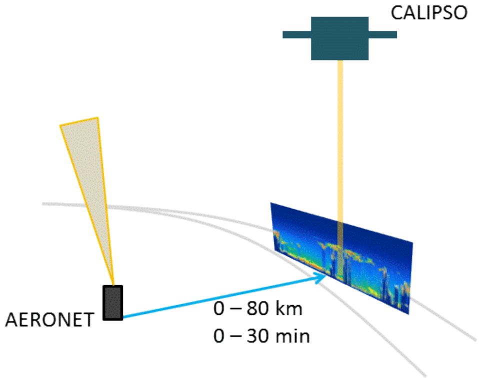
5 aerosol types

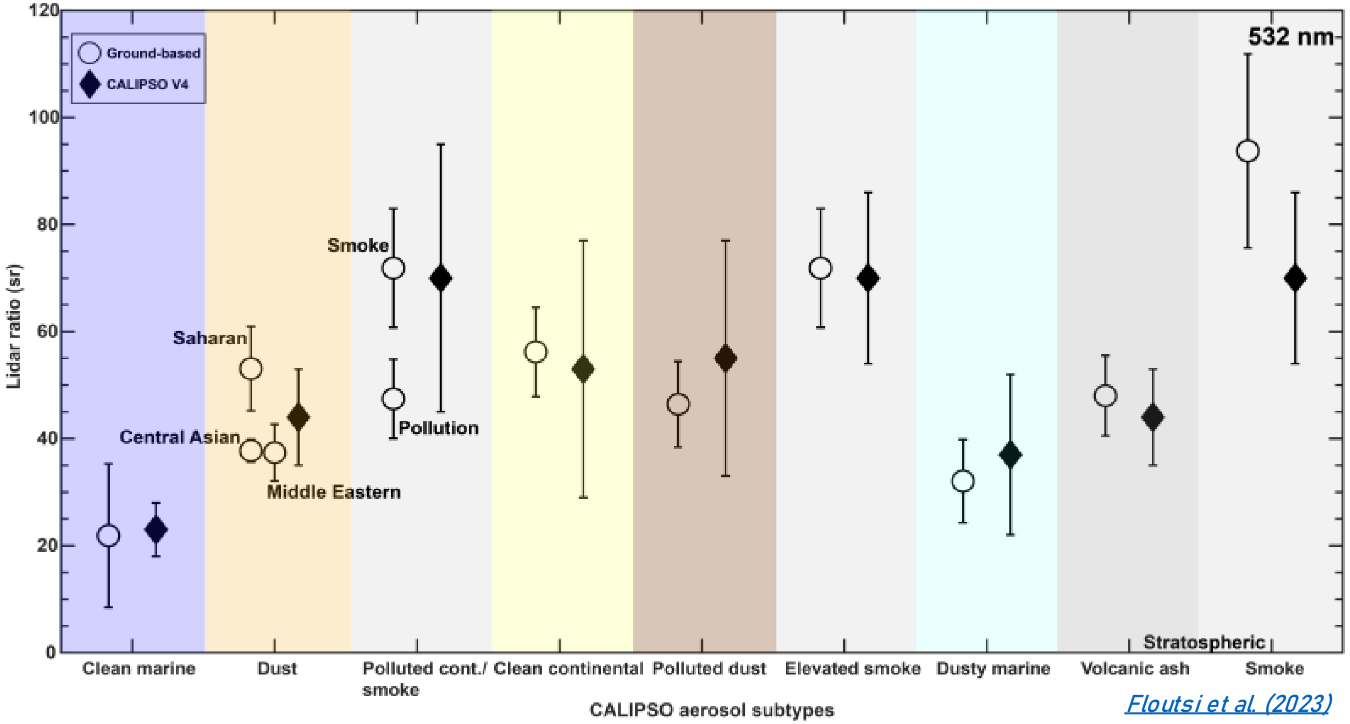
Radiative transfer simulations

Observational datasets

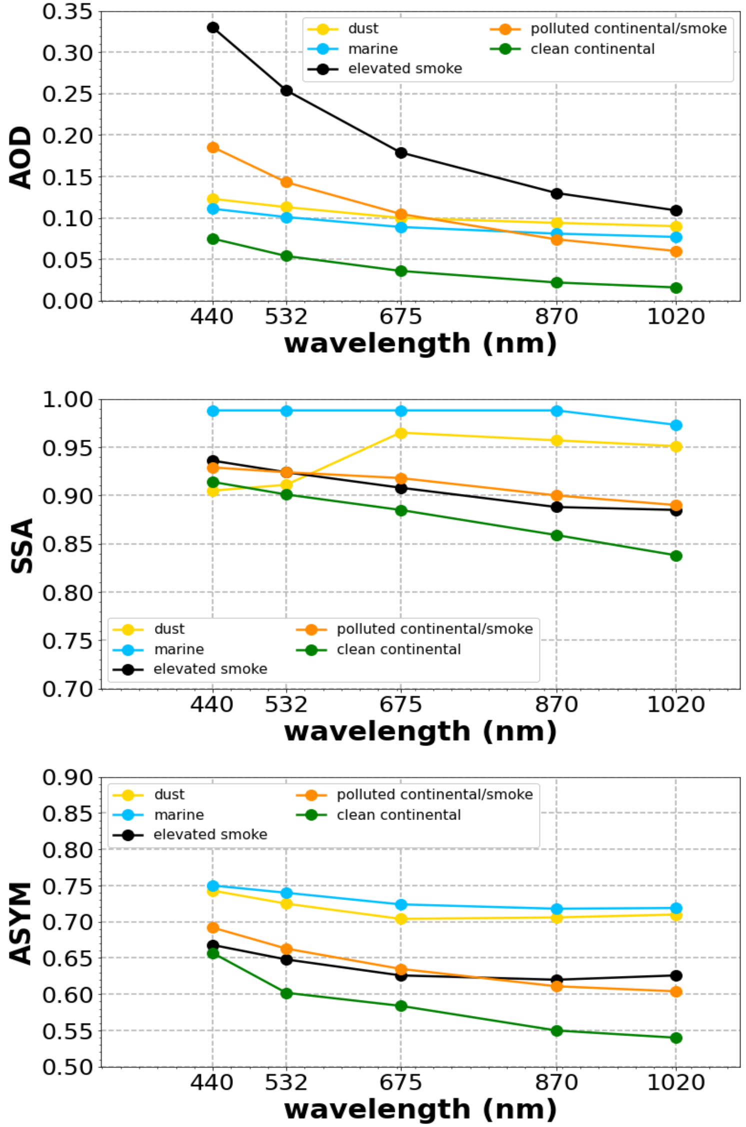
Aerosol Properties

- ➢DeLiAn database ([Floutsi et al., 2023]) Revised LRs
- ➢AERONET sun-direct & retrievals AOD,SSA,ASYM





Floutsi et al. (2023)



Moustaka et al. (under review; Remote Sens.)

LibRadtran setup

Aerosol data

AOD @ 532 nm
LIVAS-CALIPSO aerosol-speciated AOD profiles
using different LRs
- CALIPSO and DeLiAn LR +AERONET-based

lookup-tables providing spectral AOD, SSA & ASYM per aerosol type based on AERONET

TOA incoming solar irradiance

Gueymard solar spectrum [250-5000 nm]

- adjustment of spectral AOD in order to agree with CALIOP @ 532 nm

Surface data

MODIS (MCD12C1 v061)
- Land Cover Type (IGBP)

MODIS (MCD43c1 v061)
- percent snow

surface type: ocean, snow / ice → Built-in IGBP albedo library

surface type: Snow-free land →
- Ross–Li BRDF model parameters (volumetric, isotropic, geometric) snow-free MODIS BRDF/albedo (MCD43c2 v061)

Atmospheric data

(MERRA-2 reanalysis M2T1NXSLV)
- O3 & Water vapor

Other gases: from standard atmospheres

UVSPEC Radiative Transfer Model

DISORT solver
(4-streams)

Model Output

Downwelling & Upwelling solar fluxes
- Surface
- Atmosphere (profile | 121 layers)
- TOA

$$DRE_i = F_{NET,i}^{AER} - F_{NET,i}^{NOAER} \quad (1)$$

$$i = TOA, ATM, NETSRFC$$

$$DRE_{TOA} = DRE_{ATM} + DRE_{NETSRFC} \quad (2)$$

Selection criteria for the cases of interest

- Identification of CALIPSO orbits nearby AERONET sites
  - CALIPSO orbits residing within a circle of 100 km radius centered at an AERONET station
  - AERONET observations within a ±30 min time window centered at the CALIPSO overpass time

- Clear sky conditions based on the CALIPSO classification scheme

- Laser beam penetrates throughout the atmosphere reaching at the ground level (representative sampling without totally attenuated signal – opaque aerosol layers)

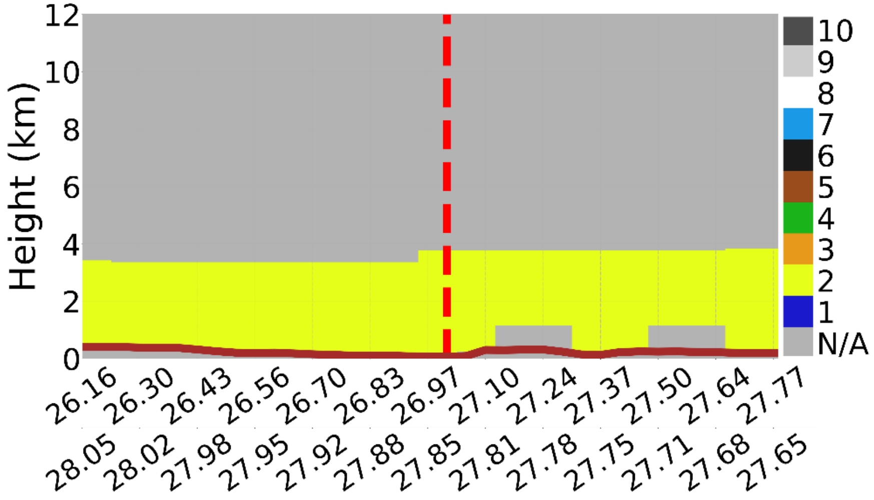
- Exclusion of unrealistic retrievals (outliers) after the QA control

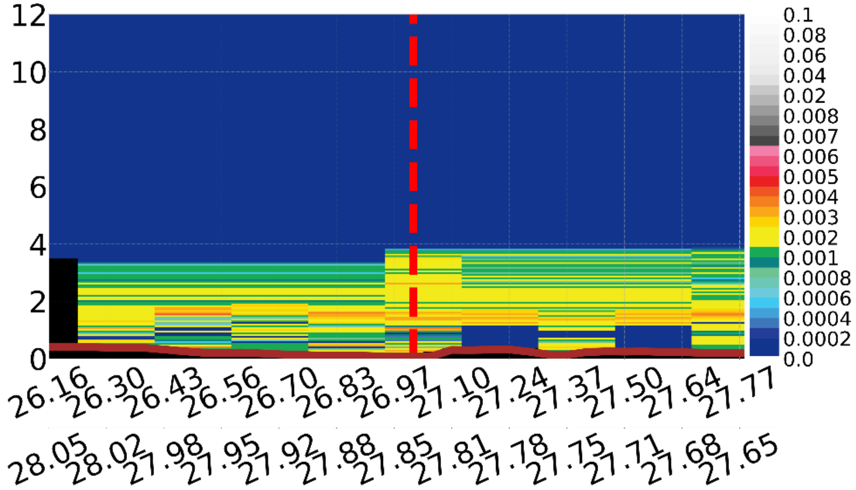
550 study cases →

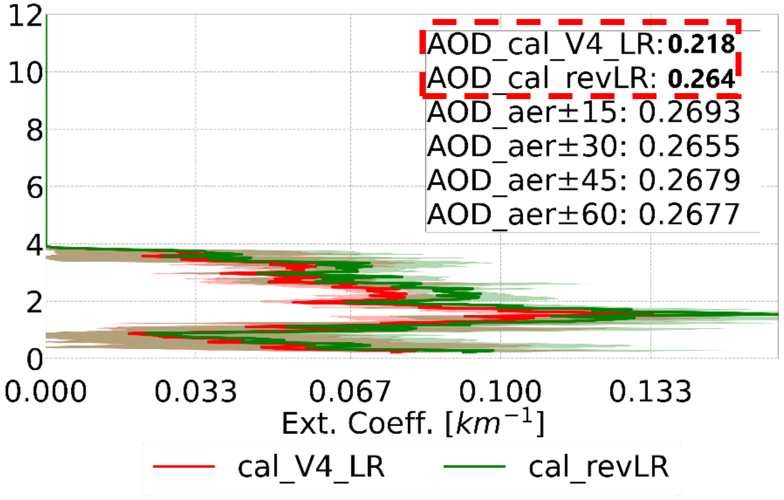
1. D
2. D+M
3. D + P/S
4. M
5. P/S
6. Other

Dust over El Farafra [26-09-2014]

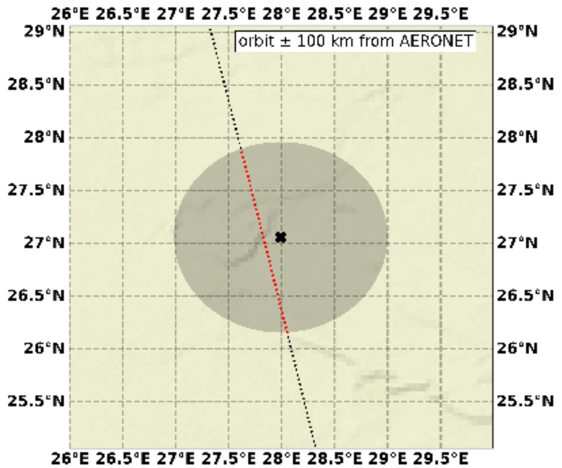
LIVAS_CALIPSO_L2_Orbit_2014-09-26T11-03-31ZD
AERONET station: El_Farafra Lat: 27.06 Lon: 27.99 Elevation: 0.092 km Min_dist: 16.1 km
Orbit time: 2014-09-26 11:36:23 Number of Profiles: 39 Number of AERONET obs.: 4



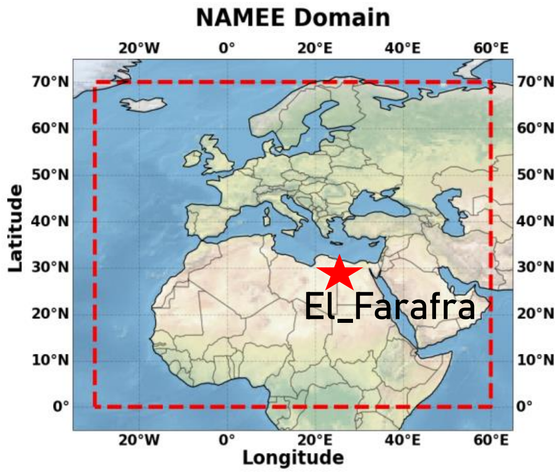




Moustaka et al. (under review; Remote Sens.)



Station	AOD CALIPSO LR=44sr	AOD DeLiAn LR=53sr	AOD AERONET ±30min
El_Farafra	0.22	0.26	0.27



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Lidar ratio assessment within the ROI

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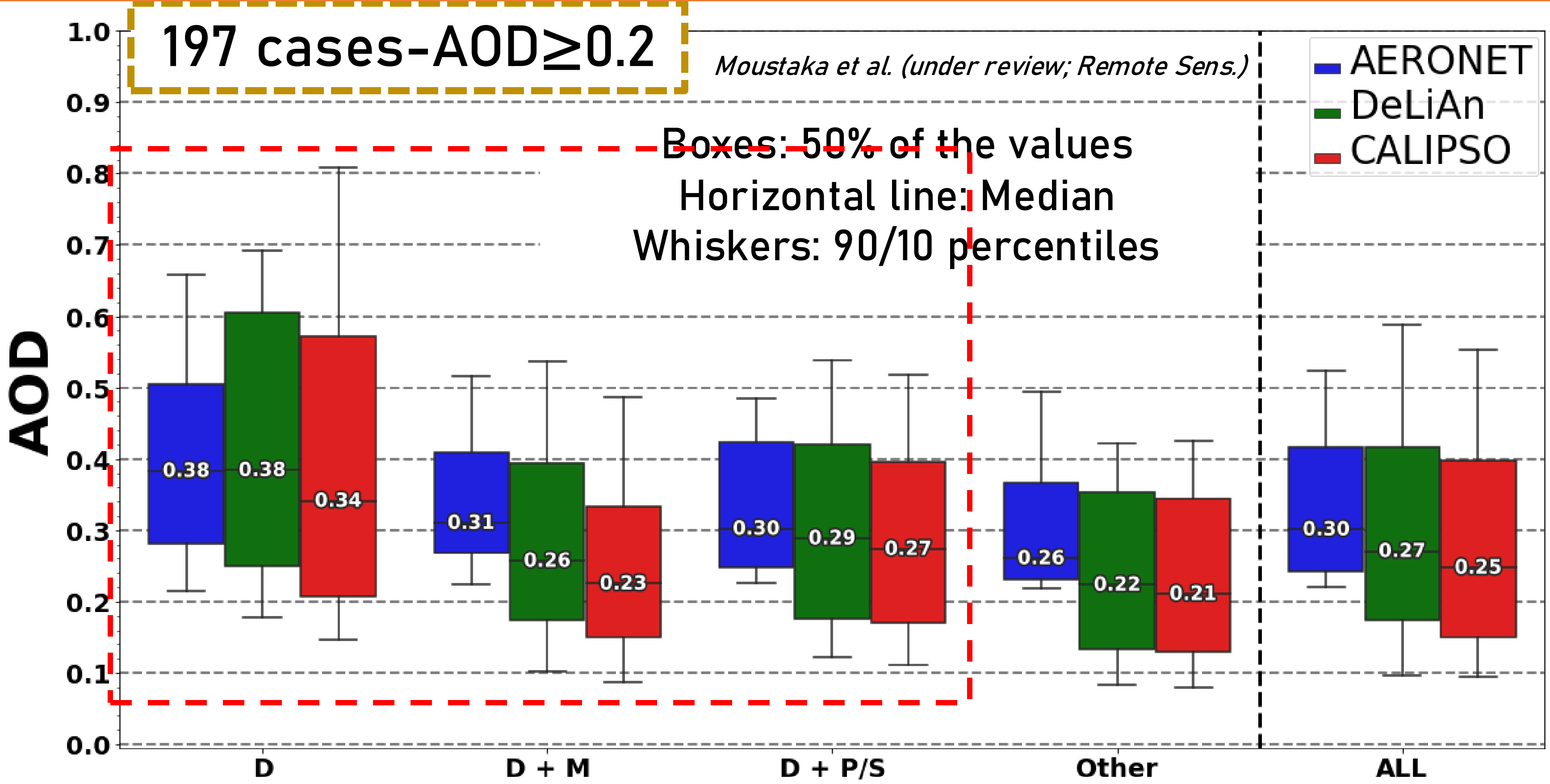
Impact on aerosol-speciated AODs



AERONET
CALIPSO LR
DeLiAn LR

AOD is one of the main drivers of the aerosol-induced DREs

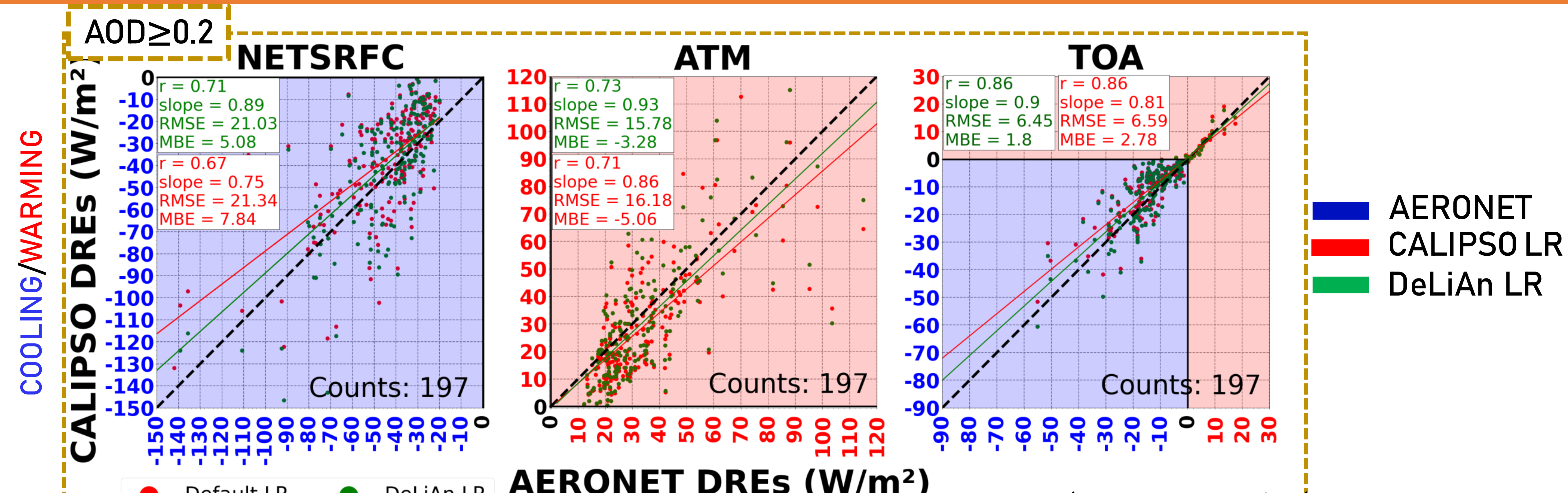
DREs underestimation

Dust or Dust dominated scenes

- DeLiAn LR ↓ CALIOP AOD underestimation (up to 11%)

- CALIPSO underestimates AOD with respect to AERONET
  - undetected tenuous layers, aerosol misclassification, contamination by low-level clouds over ocean

Impact on DREs



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$DRE_{NETSRFC}$ (negative values – cooling effect)

- ↓ Underestimation of cooling (~ 3 W/m²)

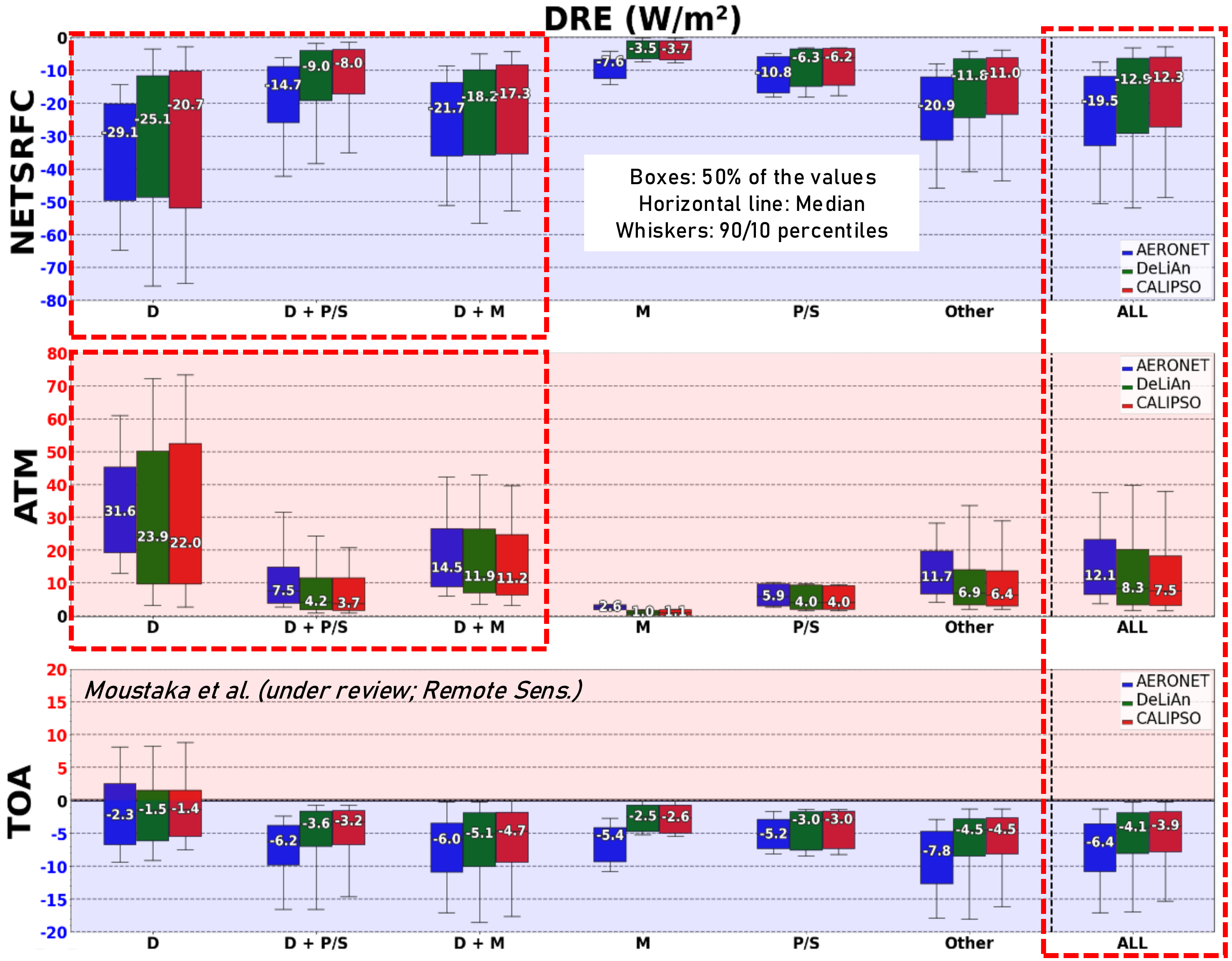
DRE_{ATM} (positive values – warming effect)

- ↓ Underestimation of atmospheric warming (~ 2 W/m²)

DRE_{TOA} (from cooling (down to -60.6 W/m²) to warming (up to 17.8 W/m²)

In the 93% of the case studies ↓ Underestimation of planetary cooling effects (~ 1 W/m²)

Impact on aerosol-speciated DREs



<u>DUST</u>

Median DREs are underestimated by~ 29% (CALIOP-based) and 14% (DeLiAn-based) vs AERONET-based → **15% reduction**

<u>DUST + POLLUTION/SMOKE</u>

7% reduction

<u>DUST + MARINE</u>

4% reduction

<u>DUST</u>

Median DREs are underestimated by~ 30% (CALIOP-based) and 24% (DeLiAn-based) vs AERONET-based → **6% reduction**

<u>DUST + POLLUTION/SMOKE</u>

7% reduction

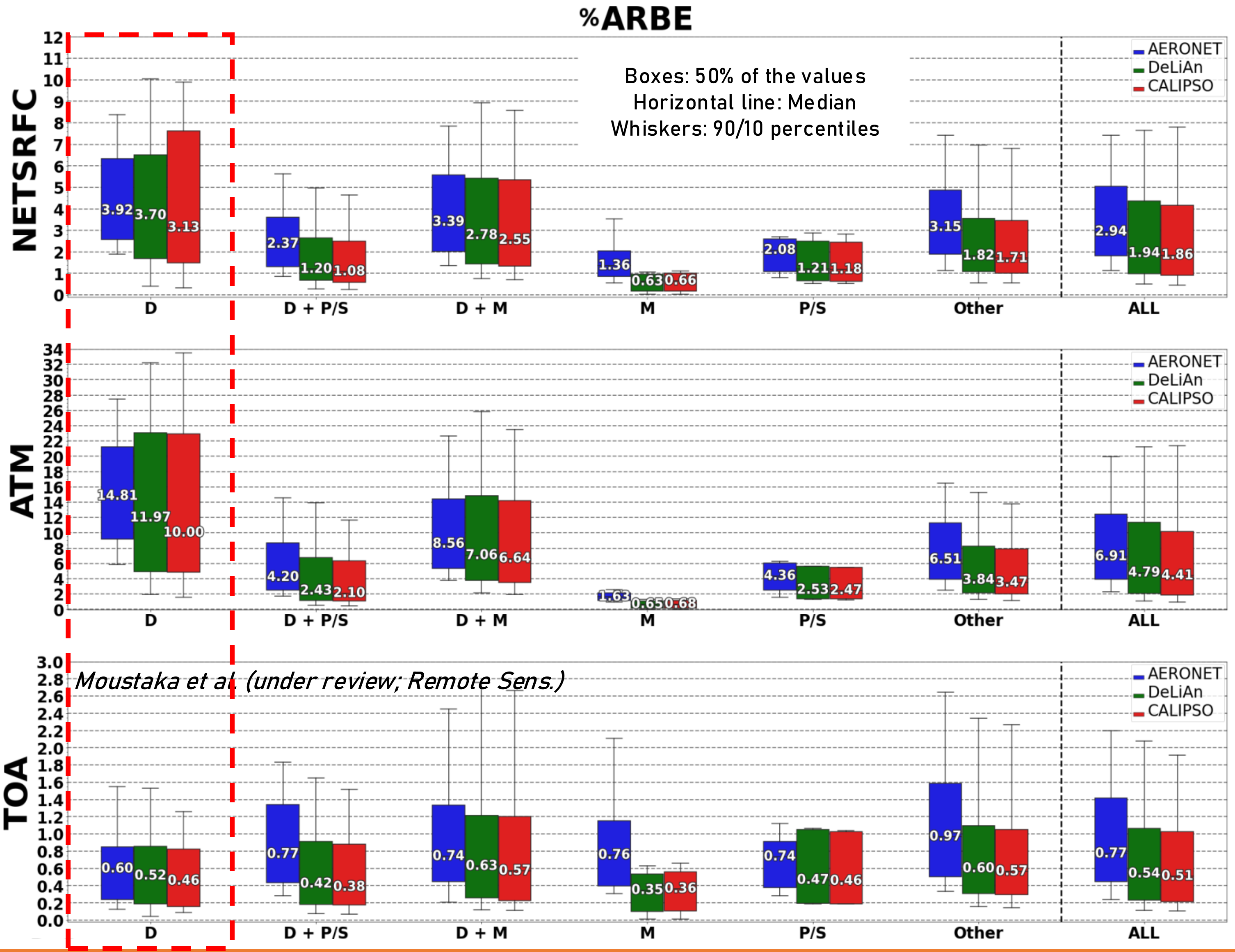
<u>DUST + MARINE</u>

6% reduction

OVERALL → 3% (NETSRFC) | 7% (ATM) | 3% (TOA)

The impact of the updated LR on DREs becomes evident in pure dust and dust-dominated scenes

Impact on aerosol-speciated ARBEs



$$ARBE_i = \% |DRE_i| / F_{i,noaer},$$
$$i = NETSRFC, ATM, TOA$$

A way to isolate the aerosol from solar elevation effects → Pure aerosol effect

The impact of the updated LR on ARBEs becomes evident in pure dust scenes

AT THE SURFACE (NETSRFC)

Median %ARBEs are underestimated by~ 20% (CALIOP-based) and 6% (DeLiAn-based) vs AERONET-based

WITHIN THE ATMOSPHERE (ATM)

Median %ARBEs are underestimated by~ 33% (CALIOP-based) and 19% (DeLiAn-based) vs AERONET-based

14%

Summary

- **Aerosol-induced SW DREs within NAMEE under clear-skies**
- Synergy of spaceborne retrievals (**CALIPSO**), RTM simulations (**LibRadtran**) and ancillary datasets (**DeLiAn, AERONET, MODIS, MERRA-2**)
- Assessment of the **CALIPSO deficiencies** (**emphasizing on LR**) affecting DREs estimation
- **Refined lidar ratios improve CALIOP AODs thus leading to a better quantification of DREs, particularly under dust or dust-dominated conditions**

Future steps

Synergy of **CALIOP-CALIPSO** and **POLDER-3/GRASP** aerosol retrievals towards:

- Defining **dust lidar ratio** over the deserts of the planet
- Assessing the dust-induced perturbations of the Earth-Atmosphere system radiation budget, from regional to global scales, throughout the CALIPSO era

Thank you for your attention!!!

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