ATARRI

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GRASP and satellite-based data for Lidar ratio retrievals

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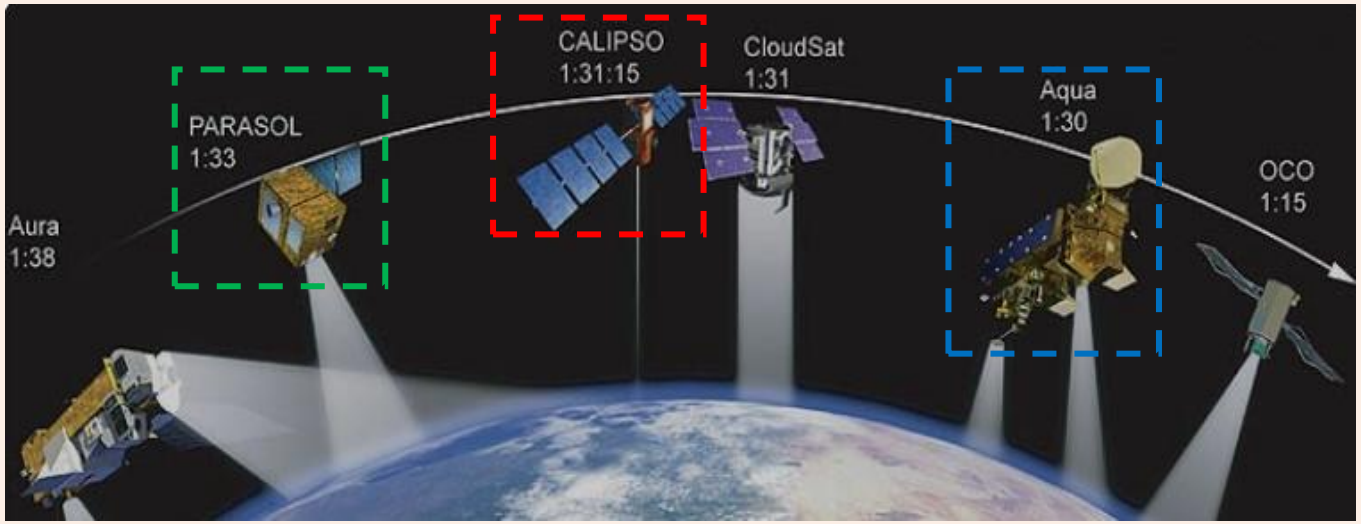
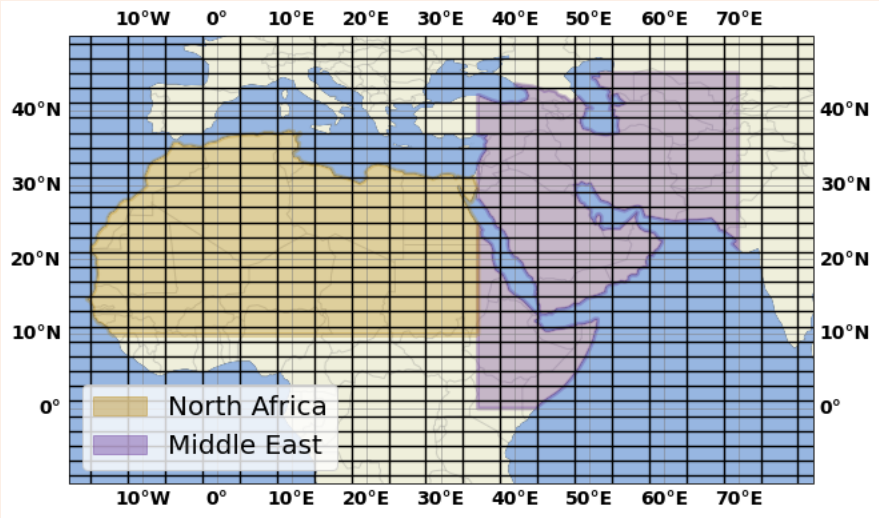
Background image extracted from EUMETSAT

Research objective

Combining retrievals from the **active** and **passive sensors** of the **A-Train constellation** (namely **CALIOP, POLDER-3, MODIS**)



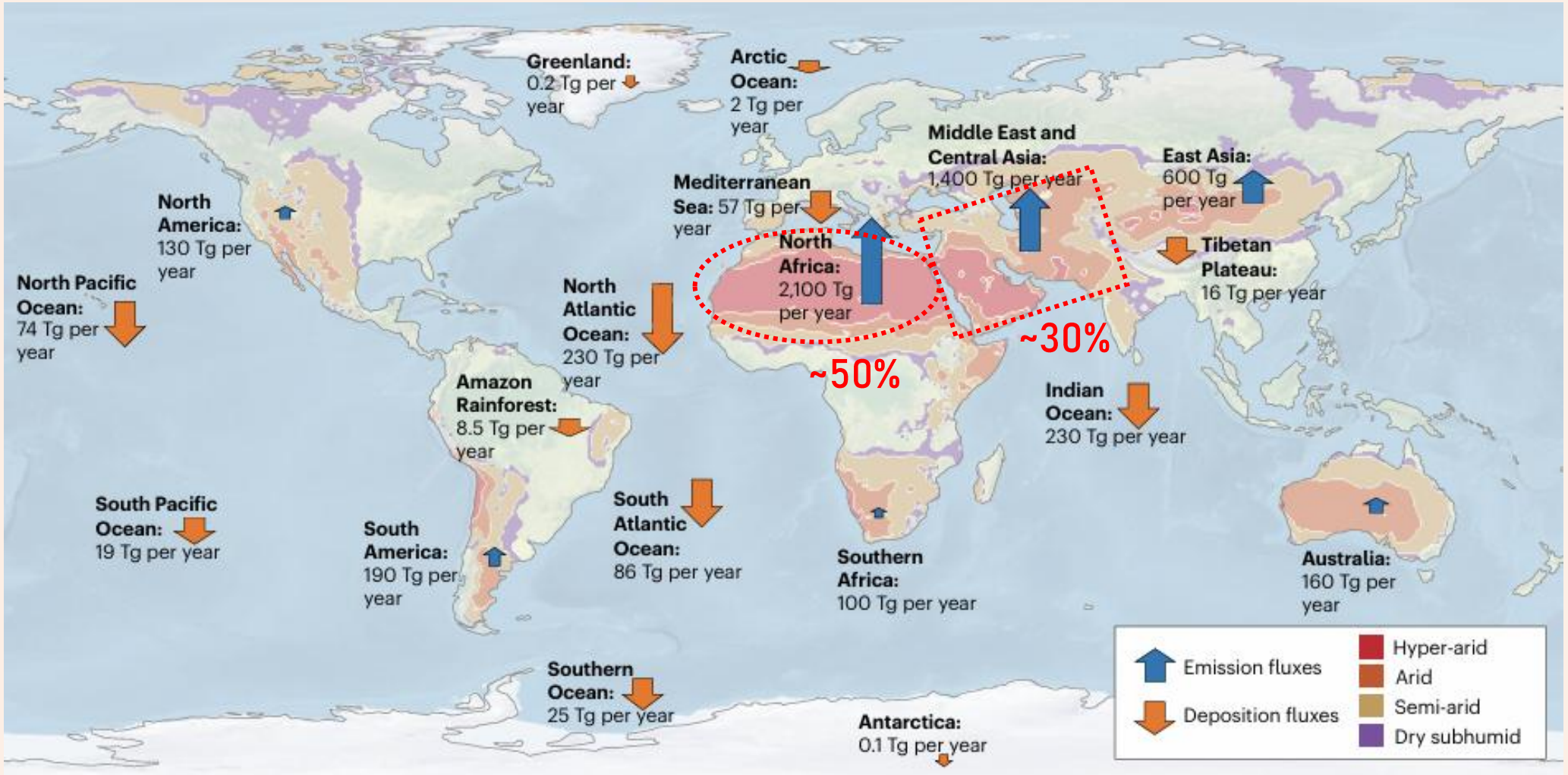
https://atrain.nasa.gov/



Moustaka et al. (2025) – Under review

Definition of **dust lidar ratio** across **North Africa** and the **Middle East**

Sources and sinks in the global dust cycle



Kok et al. (2023)

Aerosol-speciated Lidar Ratio at 532 nm

Sea salt

Smoke

Volcanic ash

Dust

Floutsi et al. (2023)

Pollution

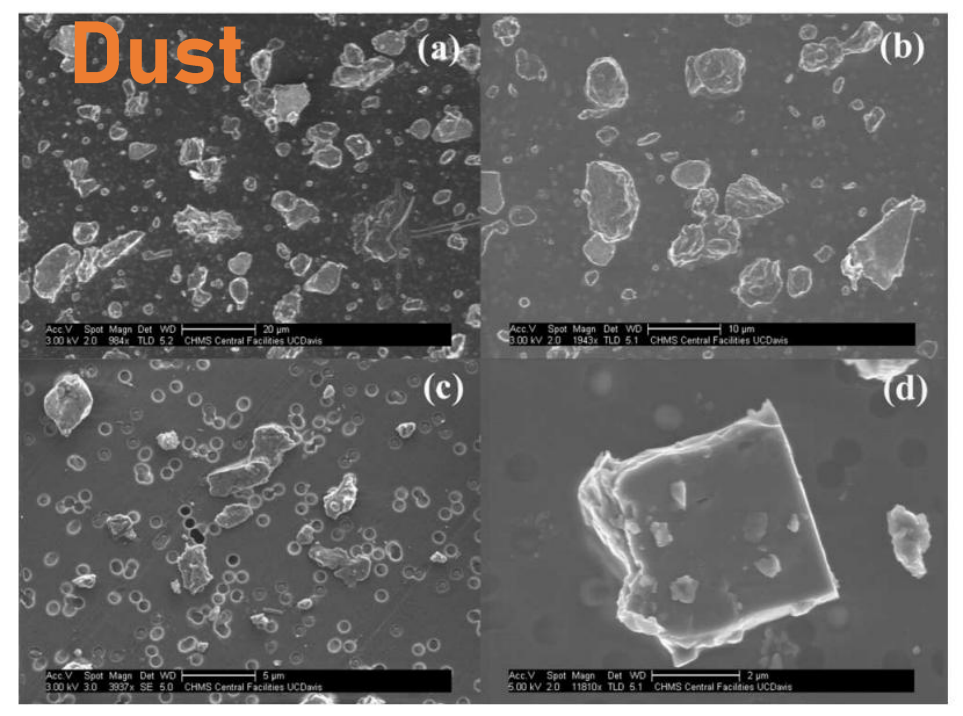
Why does Lidar ratio vary?

- Shape
- Size
- Chemical composition

Smaller particle

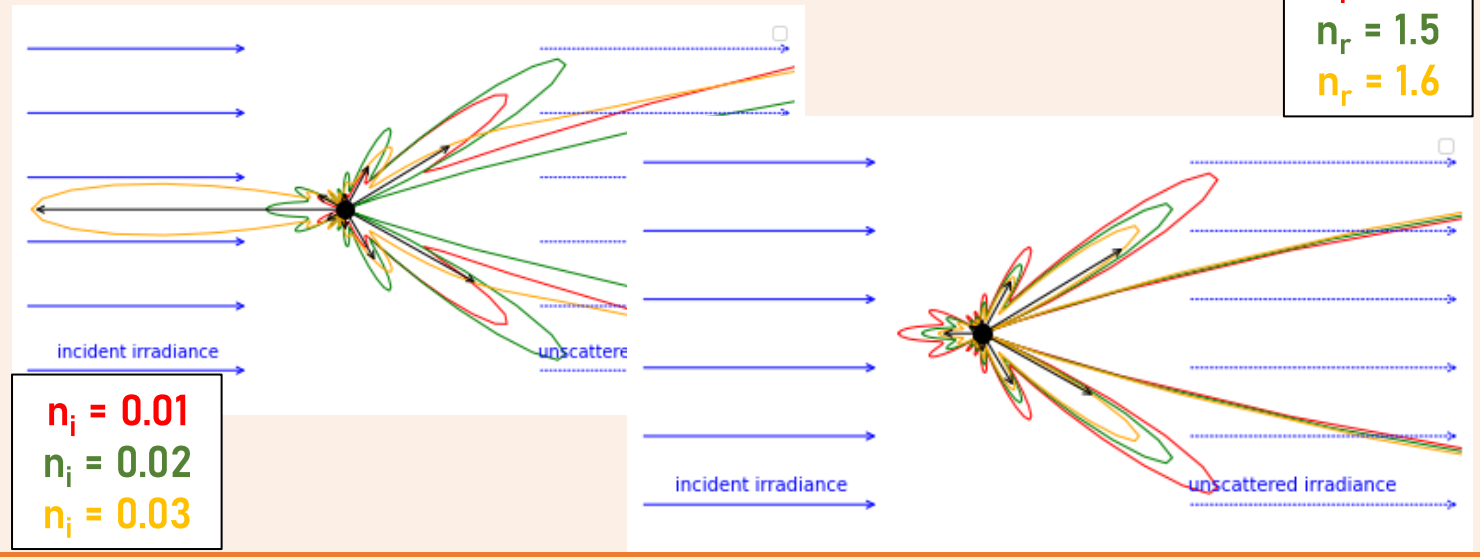
Bigger particle

Reid et al. (2003)



Complex refractive index

$$m = n_r - i \cdot n_i$$

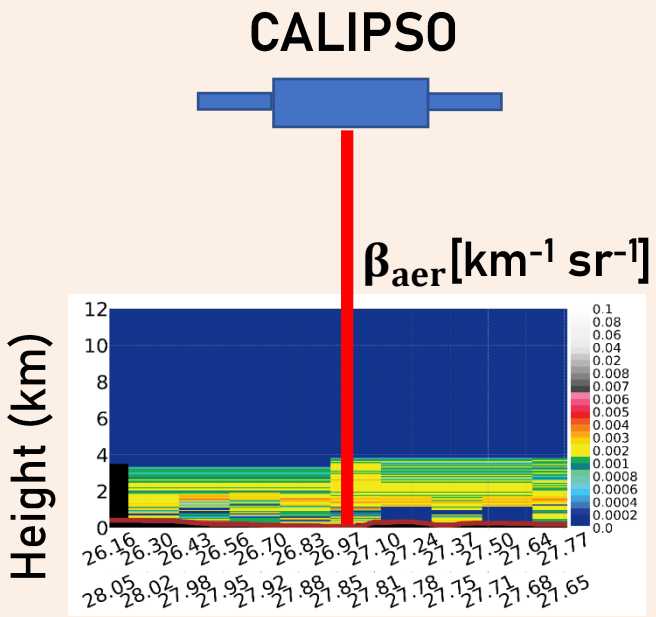


n_r = 1.4
n_r = 1.5
n_r = 1.6

n_i = 0.01
n_i = 0.02
n_i = 0.03

Why is Lidar ratio important?

- **Aerosol Optical Depth [AOD]**
- Aerosol typing
- Aerosols' microphysical properties

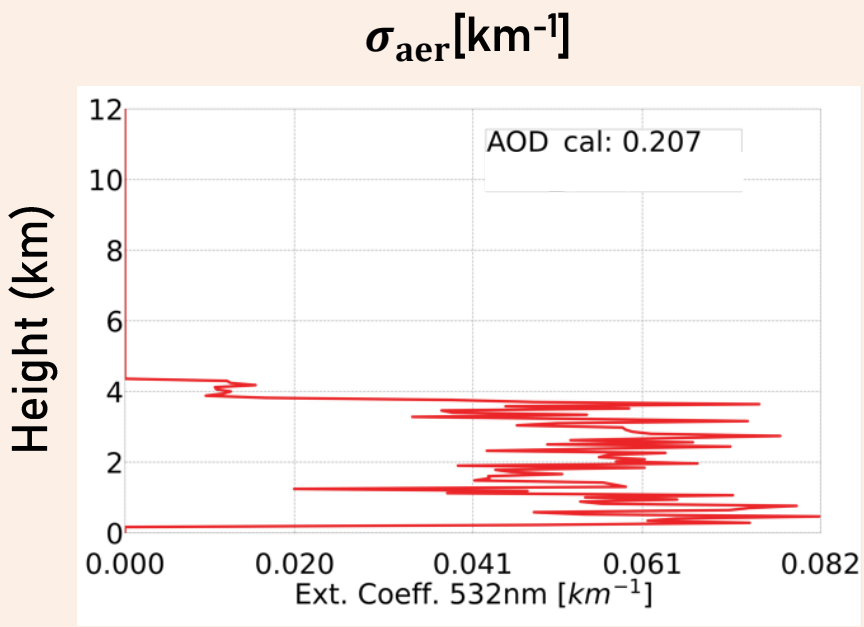


$$S_{aer} = \frac{\sigma_{aer}}{\beta_{aer}}$$

????

$$\sigma_{aer} = S_{aer} \cdot \beta_{aer}$$

Dust, smoke,...??



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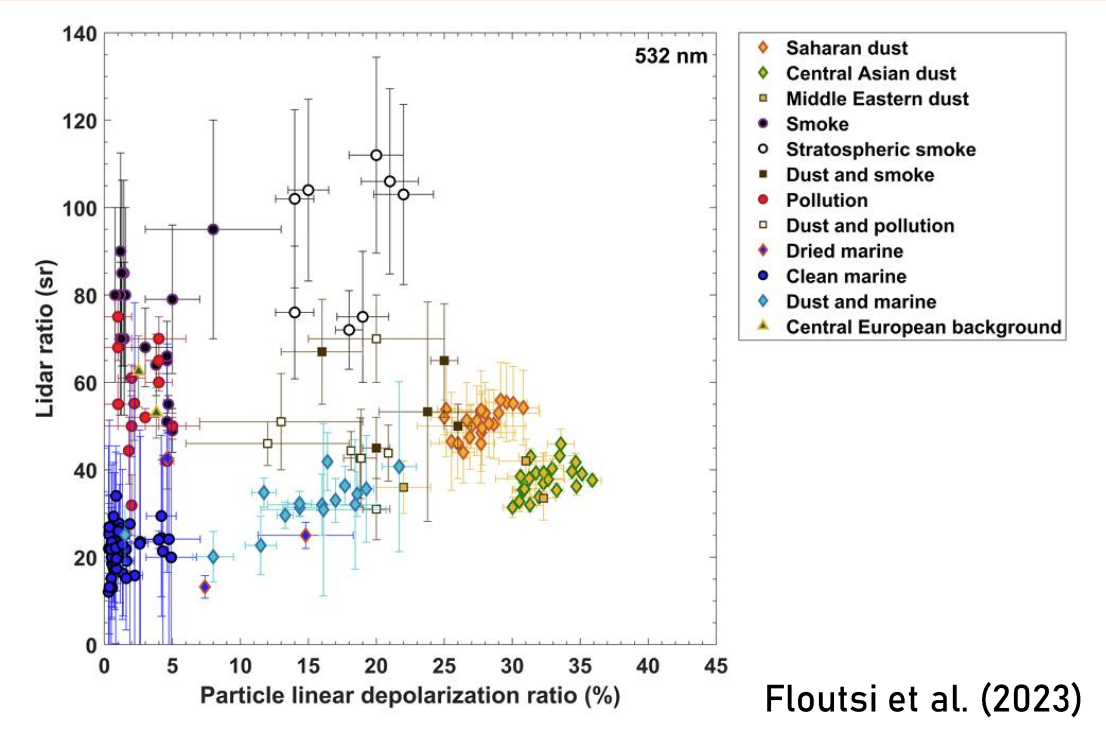


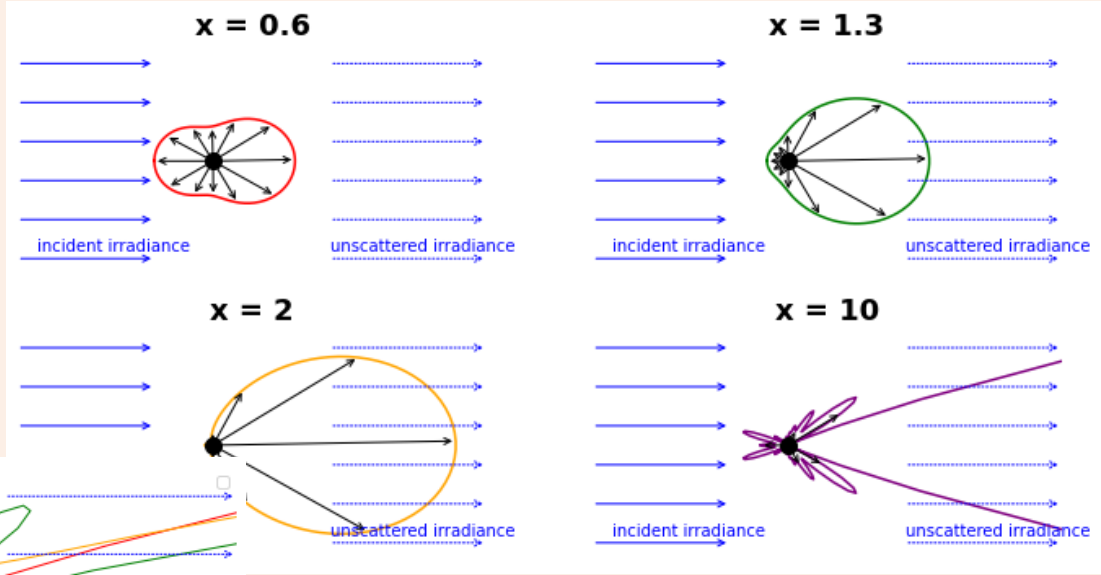
Floutsi et al. (2023)

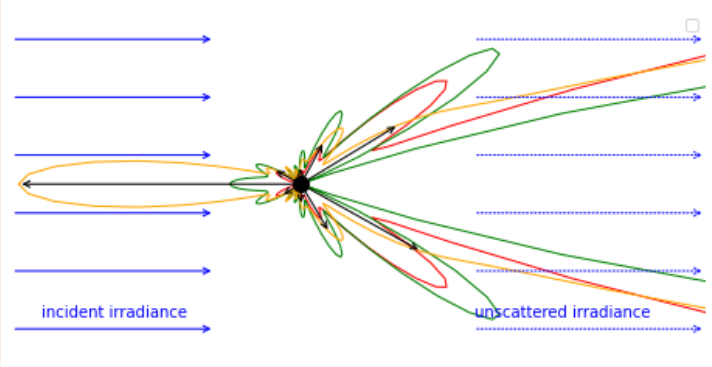
e.g. ATLID on EARTHCARE mission

Why is Lidar ratio important?

- Aerosol Optical Depth [AOD]
- Aerosol typing
- **Aerosols' microphysical properties**

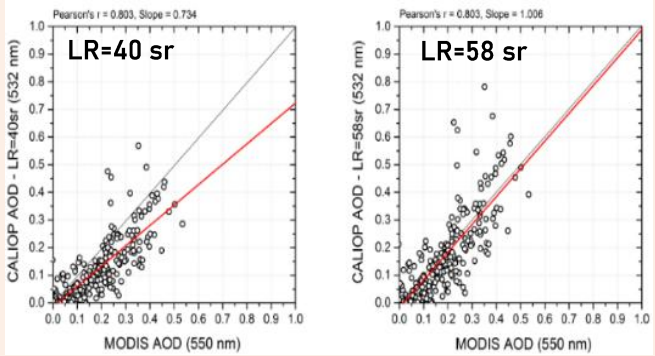
  - Shape
  - Size
  - Chemical composition



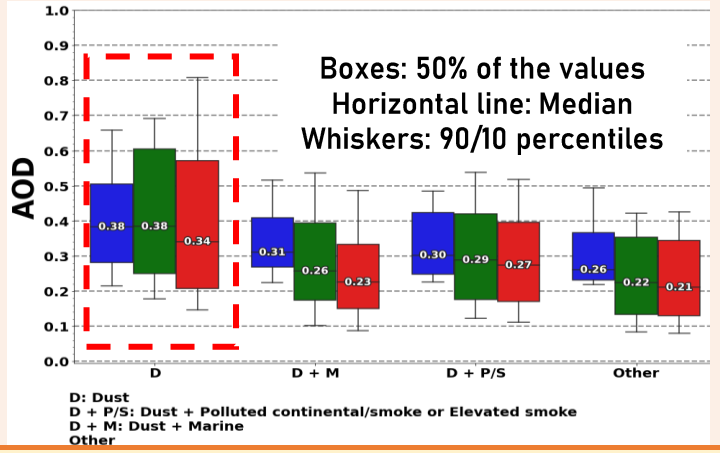


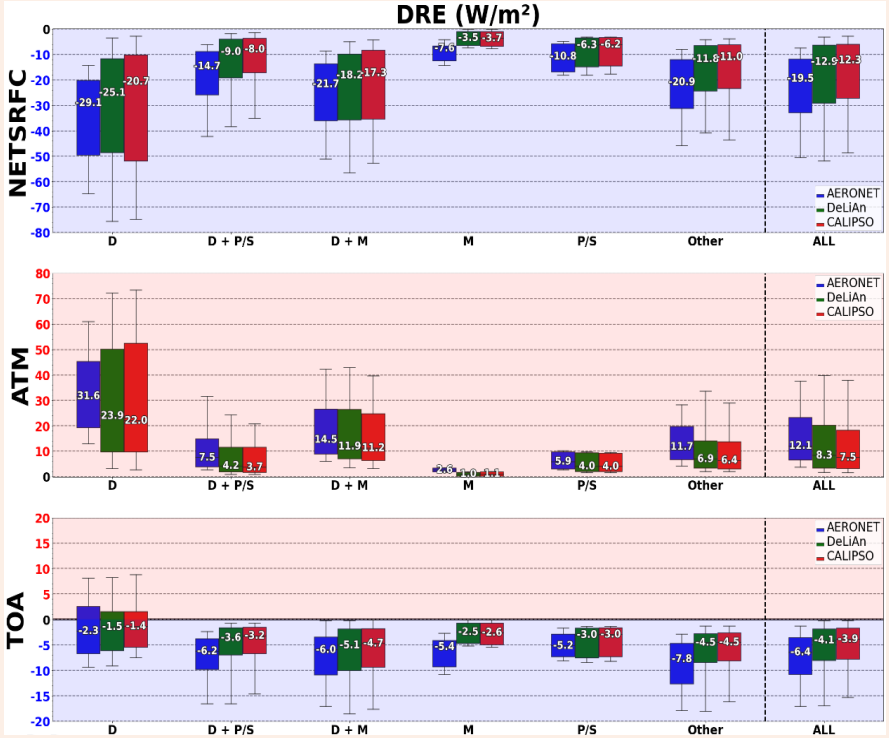
Dust Lidar ratio

- Studies.. LR redifinition towards a better representation of AOD and DREs
- Easy to identify due to its non-spherical shape



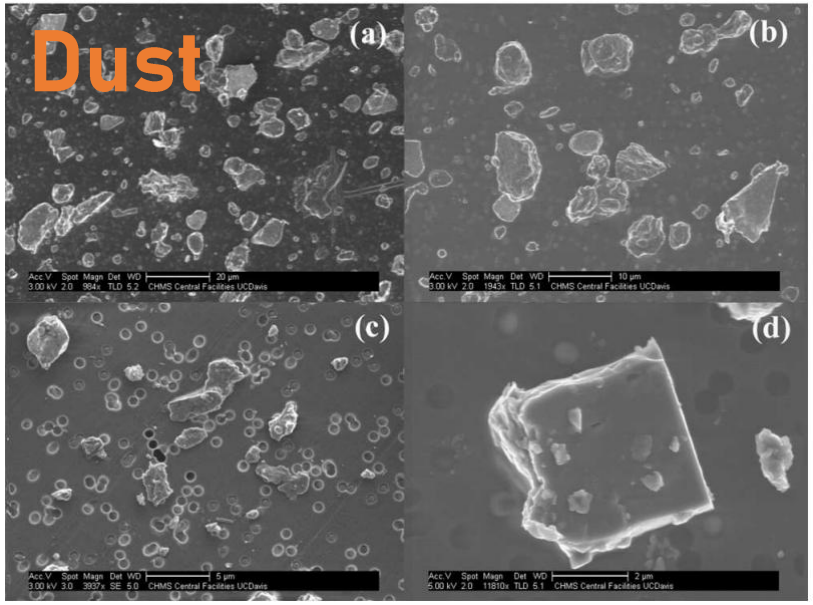
Amiridis et al. (2013)



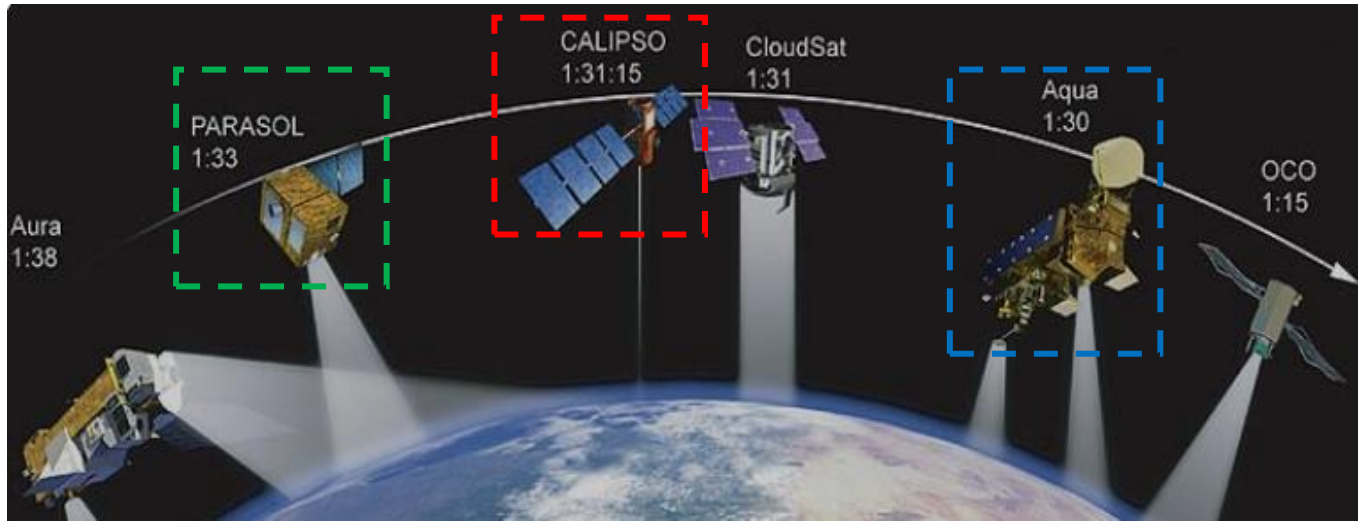


Moustaka et al. (2024)

Reid et al. (2003)



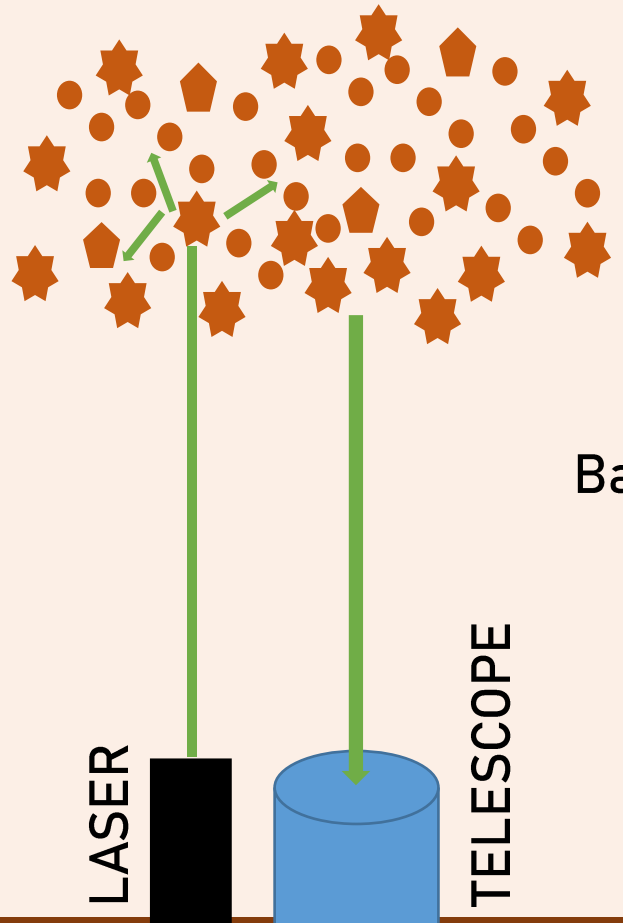
Datasets



https://atrain.nasa.gov/

CALIOP onboard CALIPSO

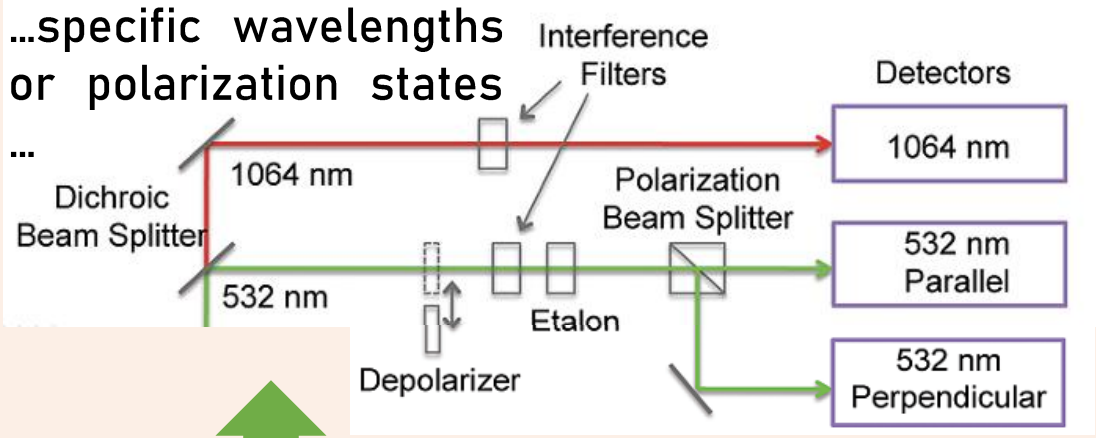
LIght Detection And Ranging … LIDAR



Elastic backscatter lidar

Backscatter signal

…specific wavelengths or polarization states …



Winker et al. (2010)

Optical analyzer/ Detectors

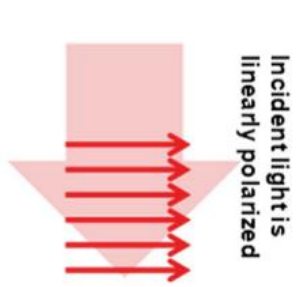
$\delta_\lambda = 0$ Spherical

$\delta_\lambda > 0$ Non-Spherical

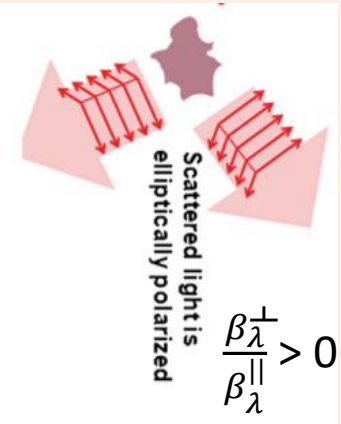
Dust identification

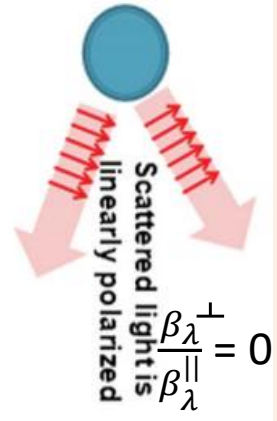
Accurate depolarization measurements

$$\delta_\lambda = \frac{\beta_\lambda^{\perp}}{\beta_\lambda^{||}}$$



Baumgardner et al. (2014)



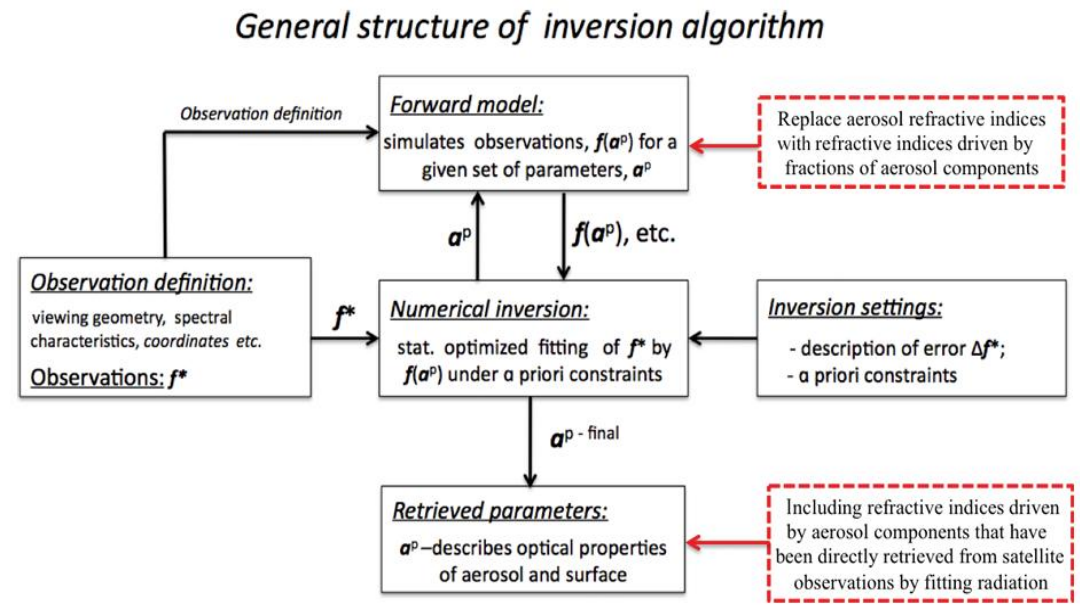


POLDER-3 onboard PARASOL

POLarization and Directionality of the Earth's Reflectances

… passive instrument … reflectance at the top of the atmosphere (TOA)

POLDER-3/GRASP-Components



Li et al. (2019)

AOD along with other aerosol and surface properties..

Parameters	Dimension	Description
AOD	(λ, latitude, longitude)	Aerosol optical depth
AExp	(latitude, longitude)	AE (670/865 nm)
AODF	(λ, latitude, longitude)	Fine-mode AOD
AODC	(λ, latitude, longitude)	Coarse-mode AOD
AAOD	(λ, latitude, longitude)	Aerosol absorption optical depth
SSA	(λ, latitude, longitude)	Single-scattering albedo
RealRefIndSpect	(λ, latitude, longitude)	Real part of refractive index
ImagRefIndSpect	(λ, latitude, longitude)	Imaginary part of refractive index
SizeDistrLogNormBin	(five, latitude, longitude)	Five bins of size distribution
SphereFraction	(latitude, longitude)	Sphere fraction
VertProfileHeight	(latitude, longitude)	Aerosol scale height (unit: m)
LandPercentage	(latitude, Longitude)	Land percentage (%)
ResidualRelative	(latitude, longitude)	Relative residual

λ = 443, 490, 565, 670, 865 and 1020 nm.

Dubovik et al. (2011, 2014, 2021); Li et al. (2019)

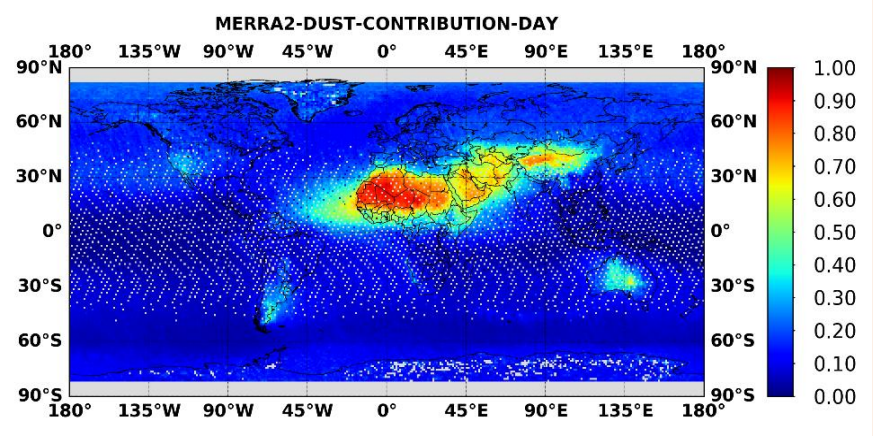
MODIS onboard Aqua

MODerate resolution Imaging Spectroradiometer

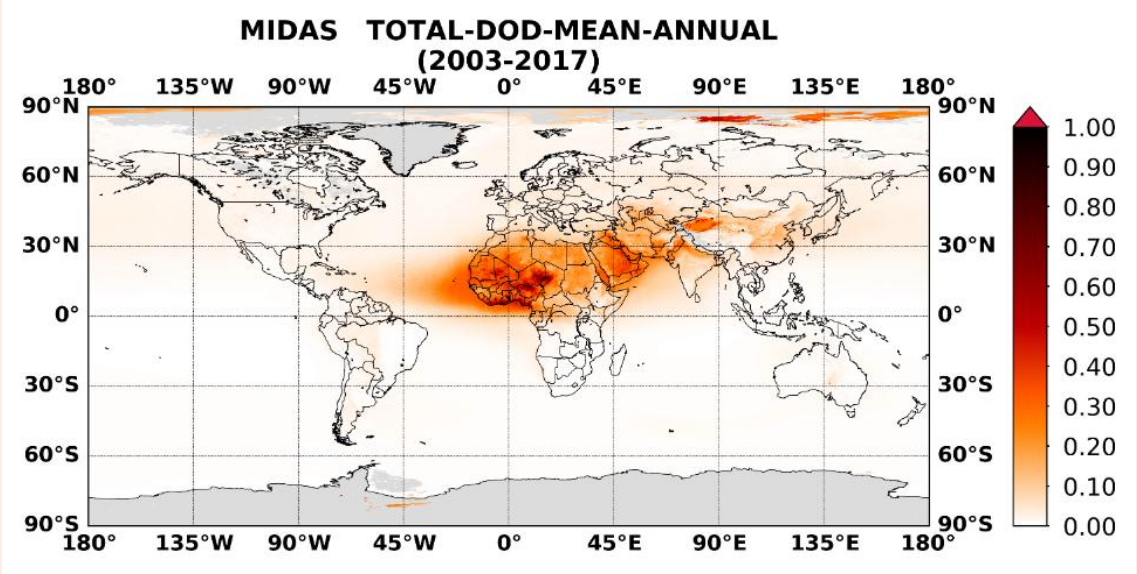
… passive instrument … reflectance at the top of the atmosphere (TOA)

MODIS-Aqua AOD

MERRA-2 Dust Fraction (MDF)

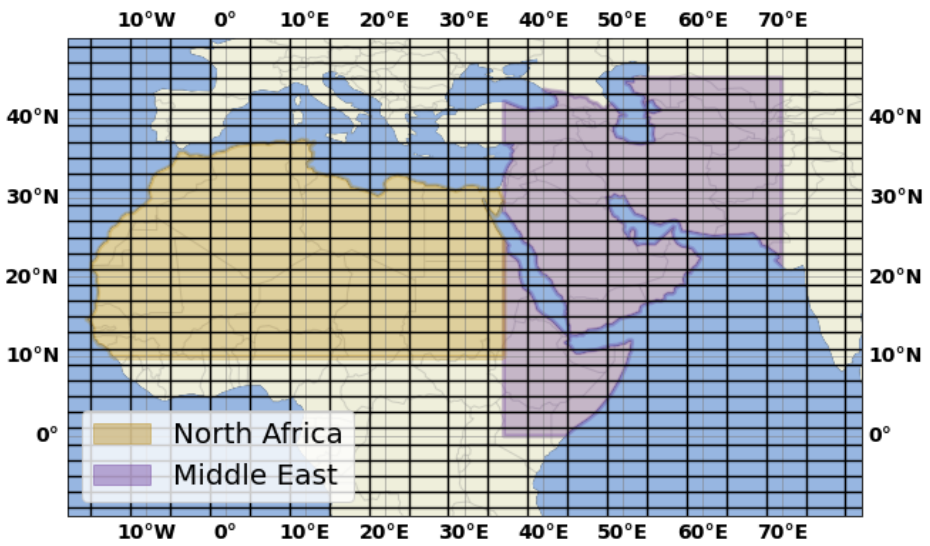


MIDAS DOD



Gkikas et al. (2021)

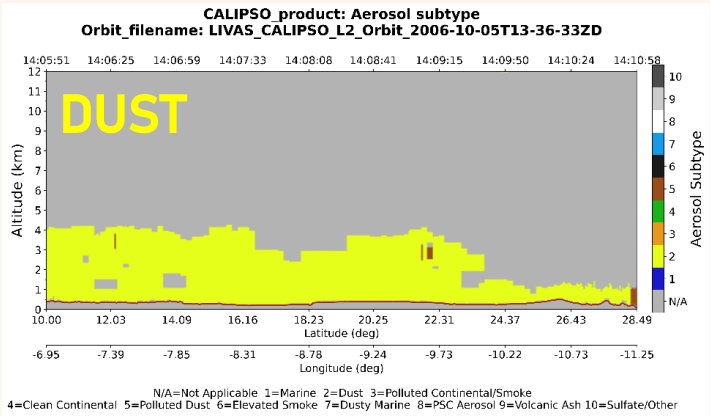
Methodology



Ginoux et al. (2012); Winker et al. (2013)

CALIOP-CALIPSO

Dust identification



POLDER-3/GRASP-Components

[1°x1°]

Time period: 2006-2009

- AOD
- SSA
- Refractive Indices,
- ...

Dubovik et al. (2011, 2014, 2021); Li et al. (2019)

MIDAS

[1°x1°]

Time period: 2007-2017

- DOD

Gkikas et al., (2021)

Dust identification

$DOD_{CALIPSO}$

$DOD_{POLDER\text{-}3/GRASP}$

DOD_{MIDAS}

Adjustment of dust LR until..

$DOD_{CALIOP}=DOD_{POLDER\text{-}3/GRASP}$

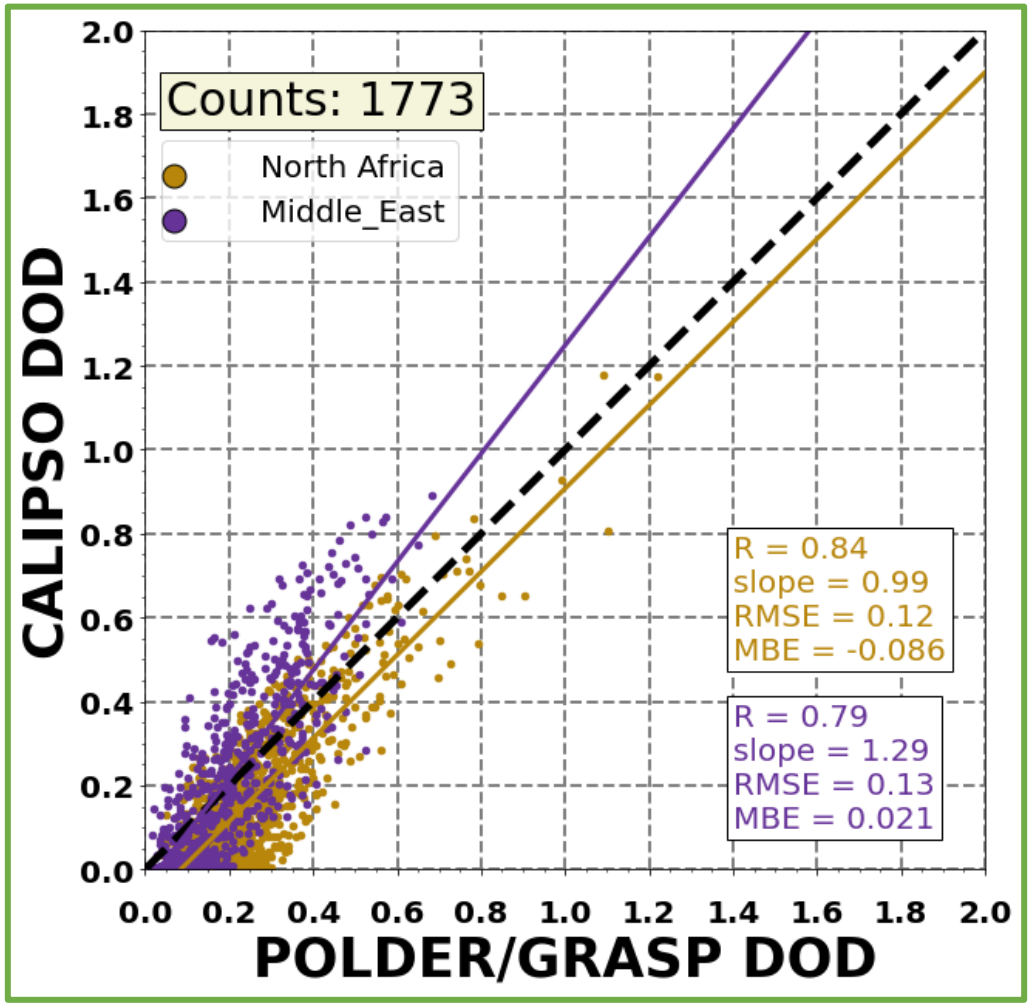
$DOD_{CALIOP}=DOD_{MIDAS}$

$LR_{updated}$ instead of 44 sr

pmod wrc

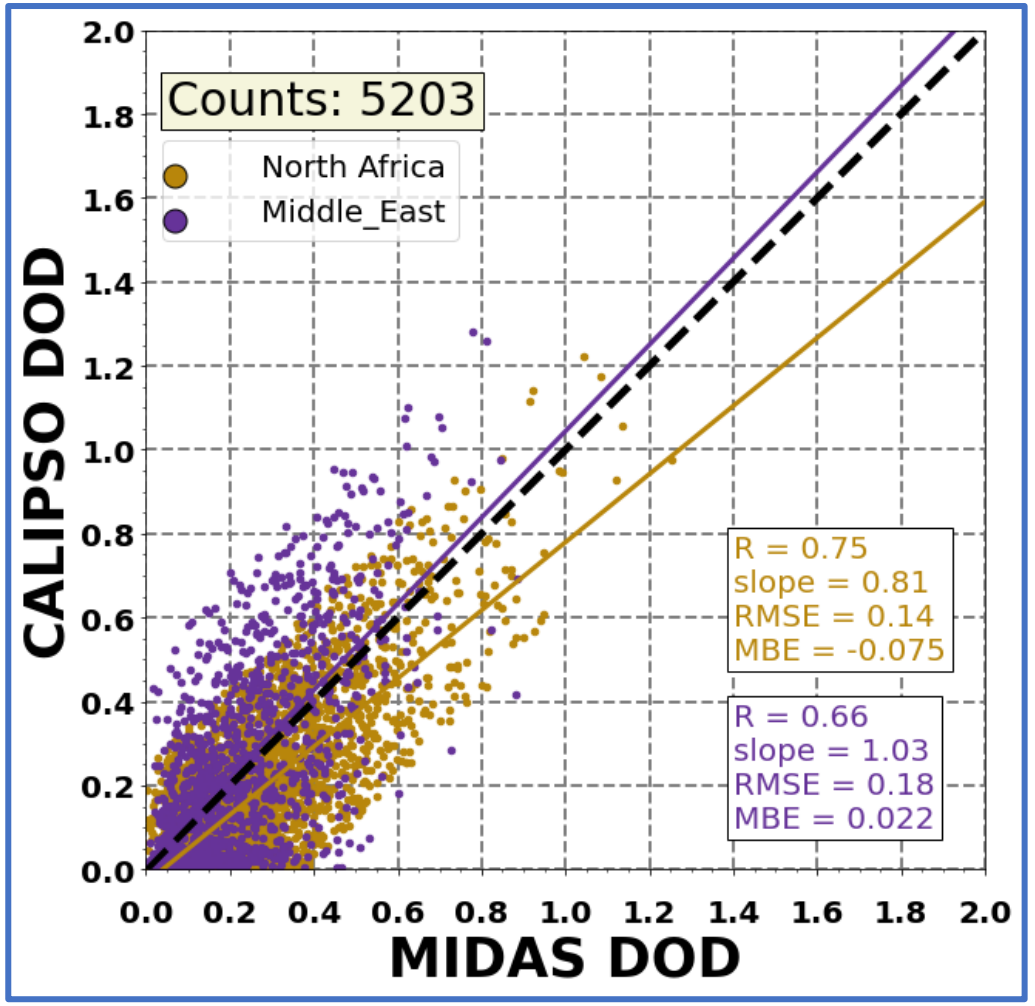
Results

Comparison of DOD retrievals



North Africa Underestimation of DOD

Middle East Overestimation of DOD



Over/UnderEstimation of DOD can be reduced after adjusting dust lidar ratio

Moustaka et al. (2024); Konsta et al. (2018); Amiridis et al. (2013); Omar et al. (2013) , and others..

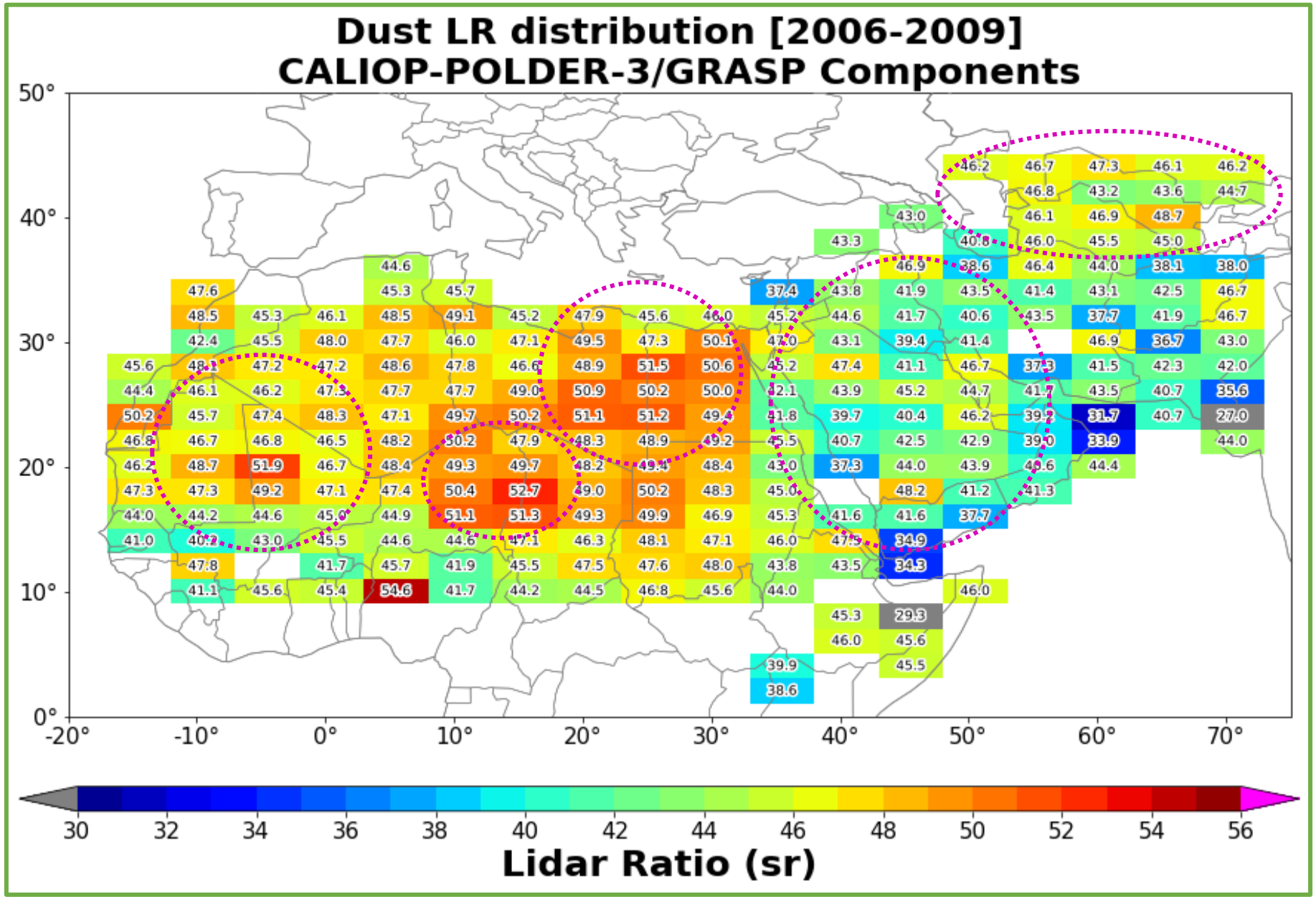
Dust LR

Adjustment of dust LR until..

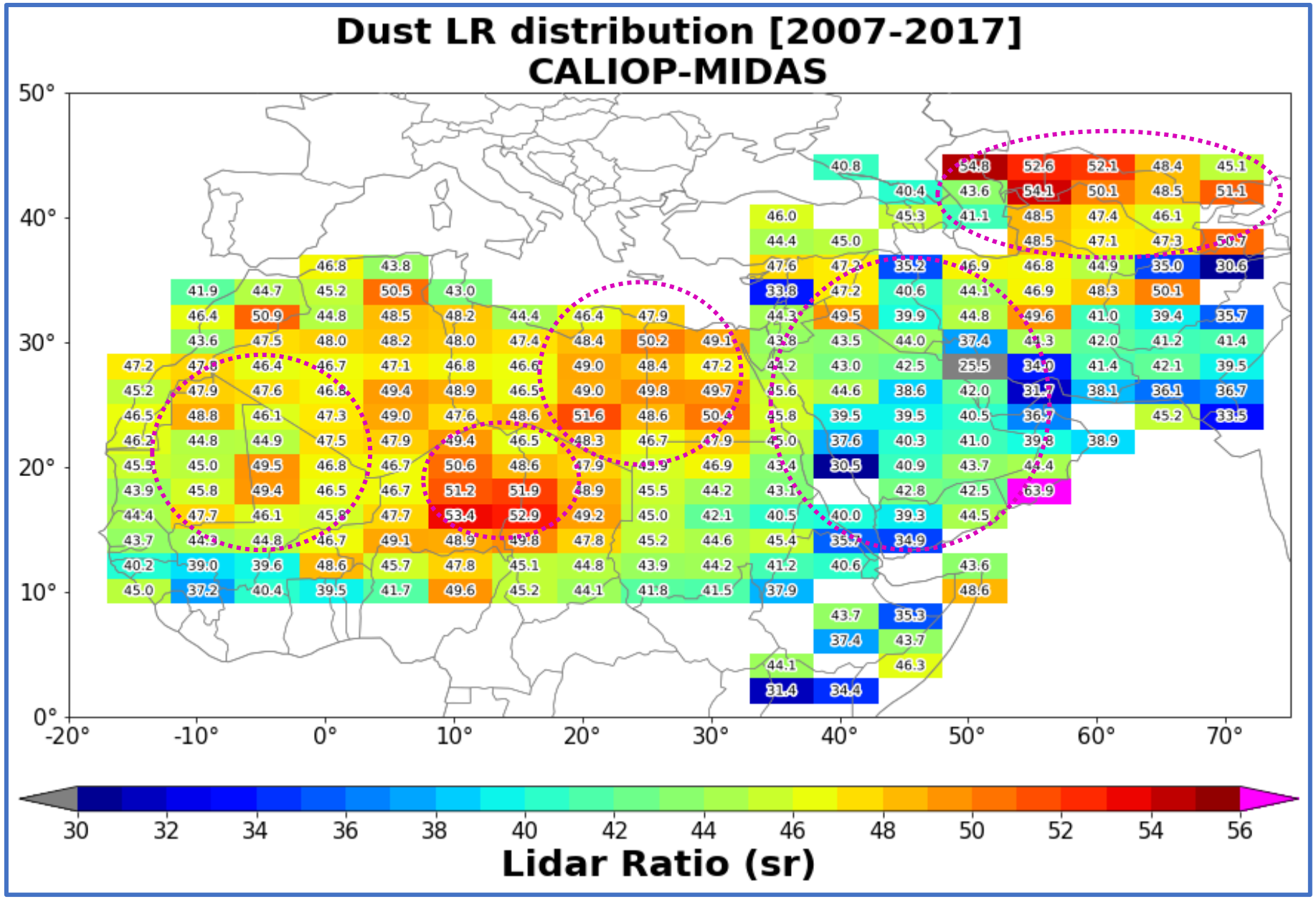
$DOD_{CALIOP} = DOD_{POLDER\text{-}3/GRASP}$

$DOD_{CALIOP} = DOD_{MIDAS}$

$LR_{updated}$ instead of 44 sr

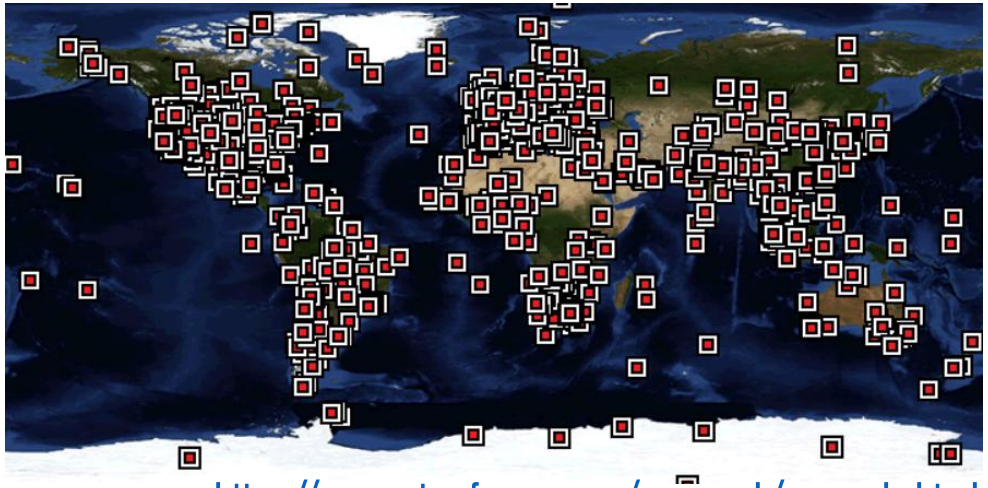

Dust LR distribution [2006-2009]
CALIOP-POLDER-3/GRASP Components
50°
40°
30°
20°
10°
0°
-20°
-10°
0°
10°
20°
30°
40°
50°
60°
70°
30
32
34
36
38
40
42
44
46
48
50
52
54
56
Lidar Ratio (sr)

pmod wrc


Dust LR distribution [2007-2017]
CALIOP-MIDAS
50°
40°
30°
20°
10°
0°
-20°
-10°
0°
10°
20°
30°
40°
50°
60°
70°
30
32
34
36
38
40
42
44
46
48
50
52
54
56
Lidar Ratio (sr)

pmod wrc

Evaluation against AERONET



https://aeronet.gsfc.nasa.gov/new_web/aerosols.html

Selection criteria

- 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

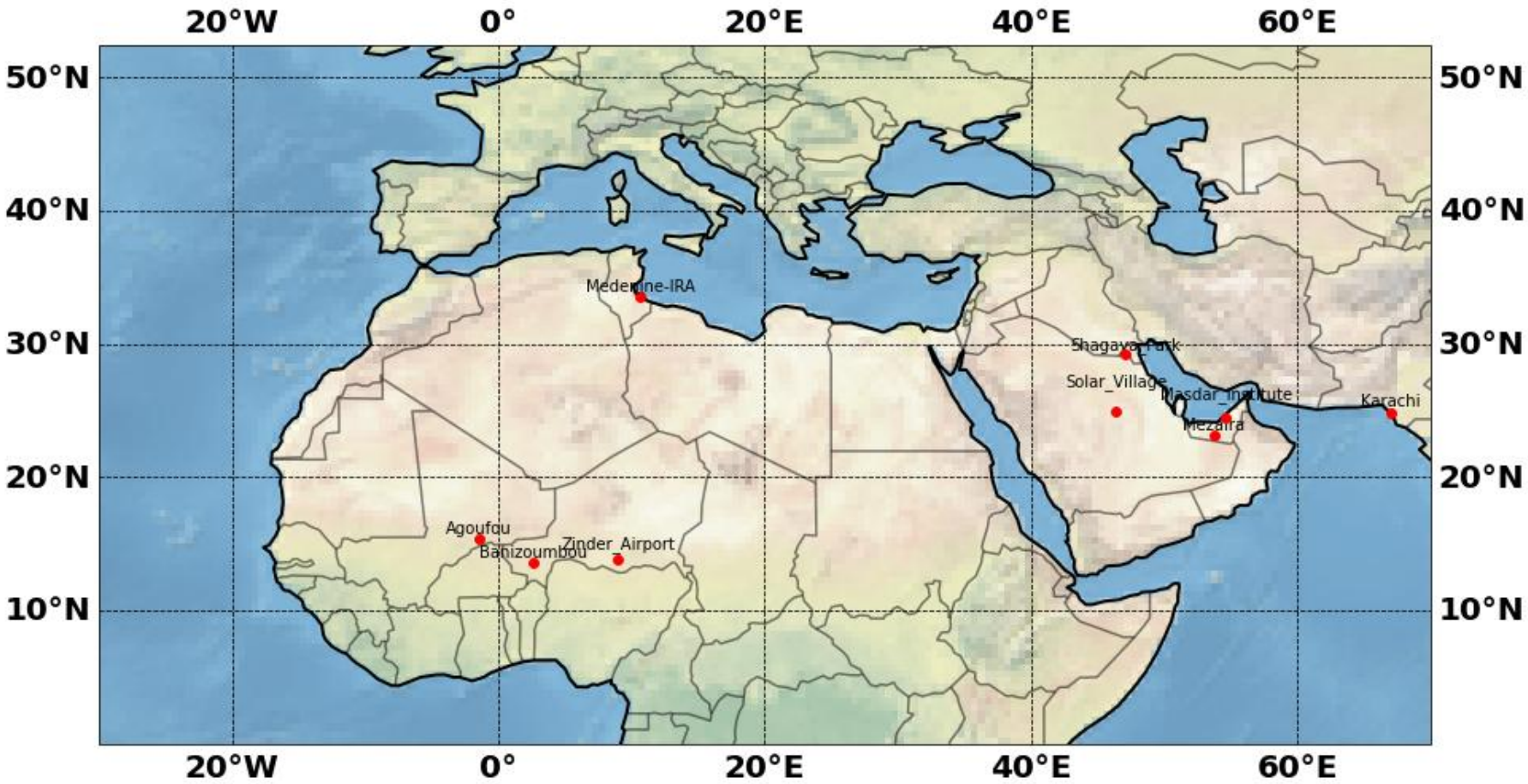
- Clear sky conditions based on the CALIPSO classification scheme

- Laser beam penetrates throughout the atmosphere reaching at the ground level

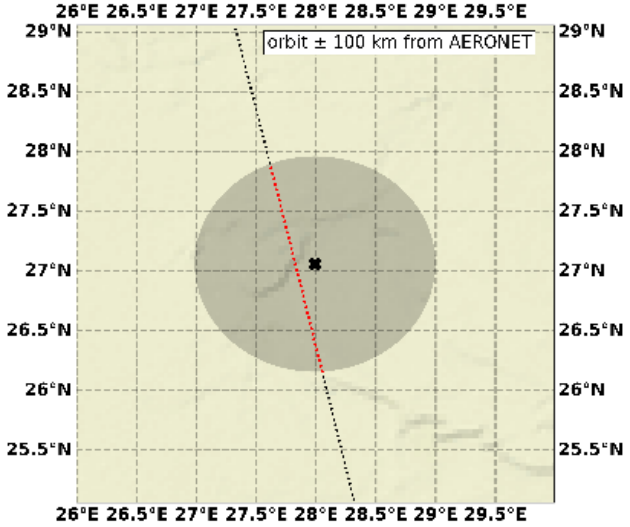
- Dust should be at least the 95% of the total aerosol records

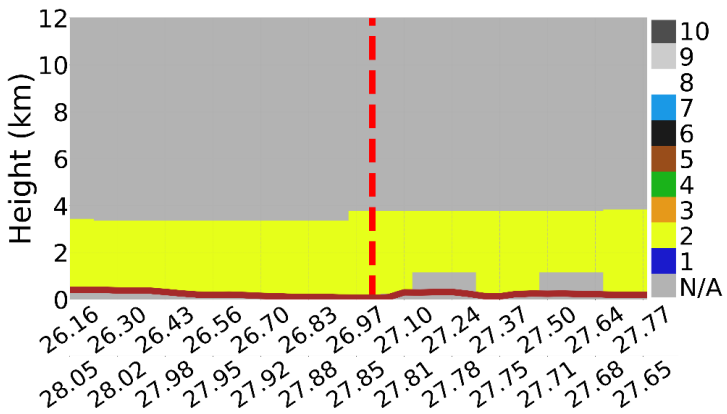
- The elevation difference between the AERONET site and CALIPSO mean ground track elevation should be below 100 m (Amiridis et al. 2015)

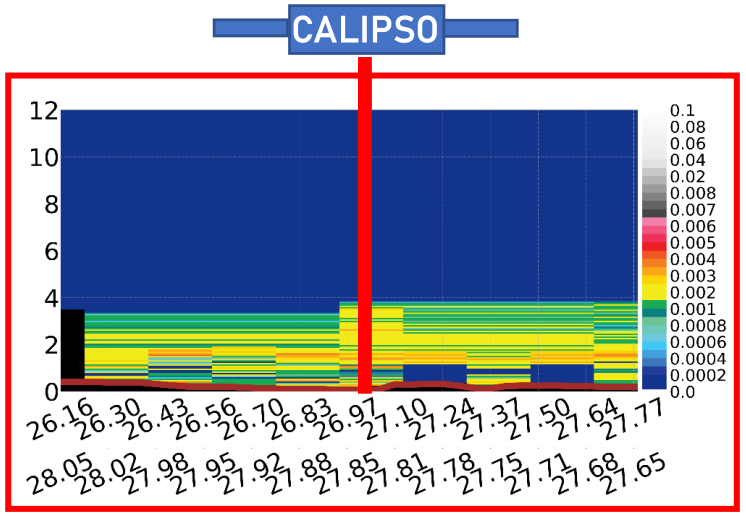
- The elevation slope in the CALIPSO overpass are constrained to be less than 400 m (Amiridis et al. 2015)


20°W
0°
20°E
40°E
60°E
50°N
40°N
30°N
20°N
10°N
Medenine-IRA
Shagaya_Park
Solar_Village
Masdar_Institute
Mezaira
Karachi
Agoufou
Banizoumbou
Zinder_Airport

pmod wrc







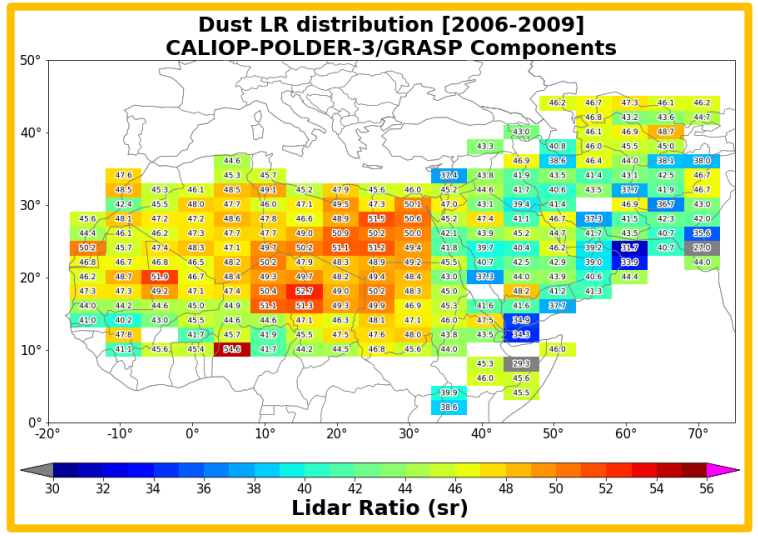
????

$$\sigma_{aer} = S_{aer} \cdot \beta_{aer}$$

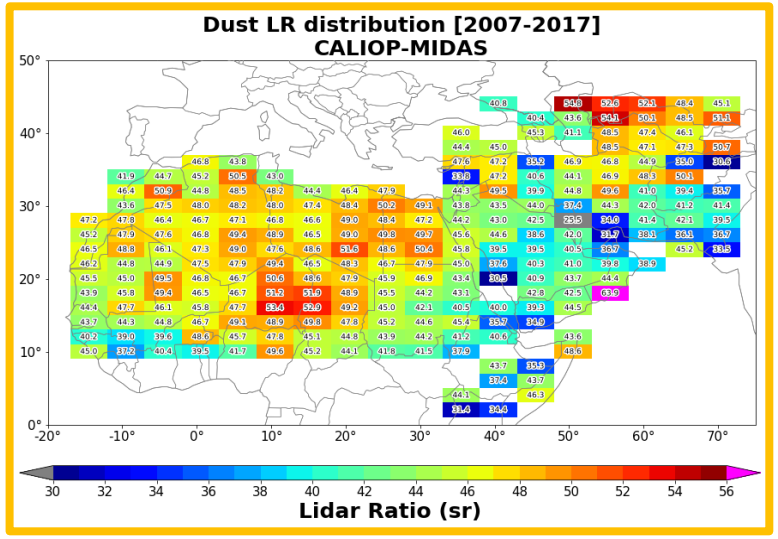
Station	DOD CALIPSO	DOD AERONET
#	0.23	0.26

4. 44 sr – CALIPSO def

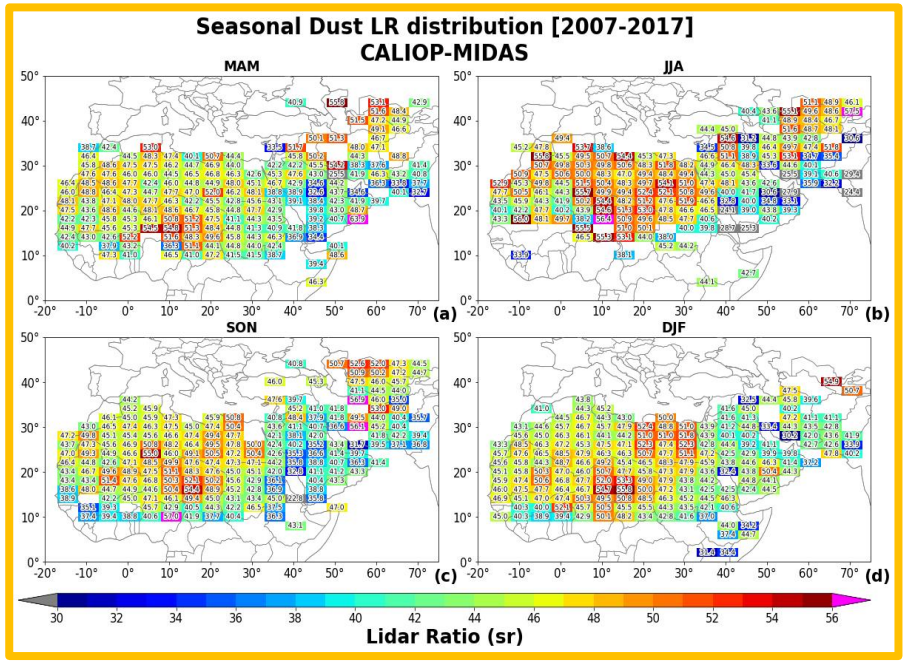
1.

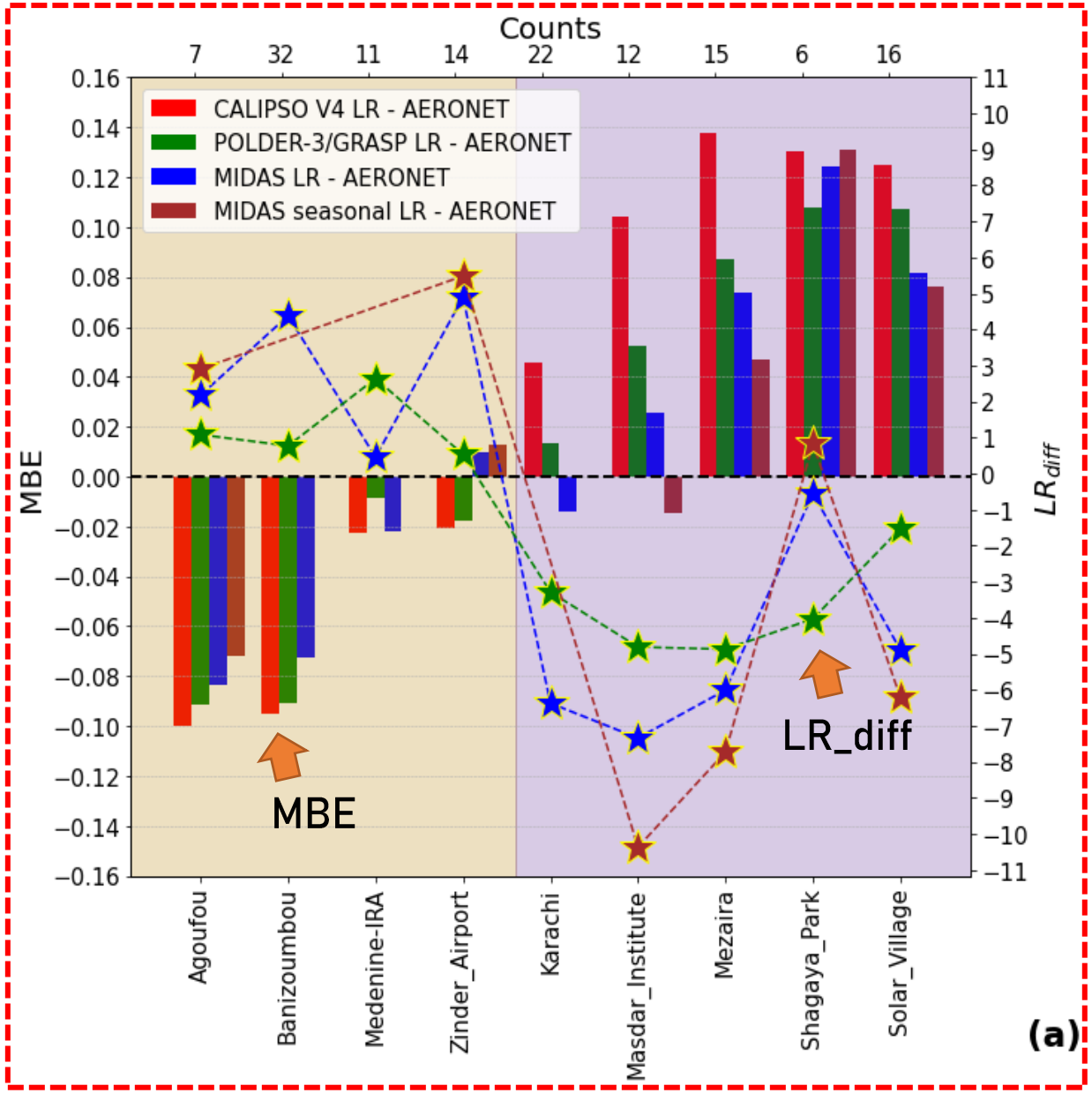


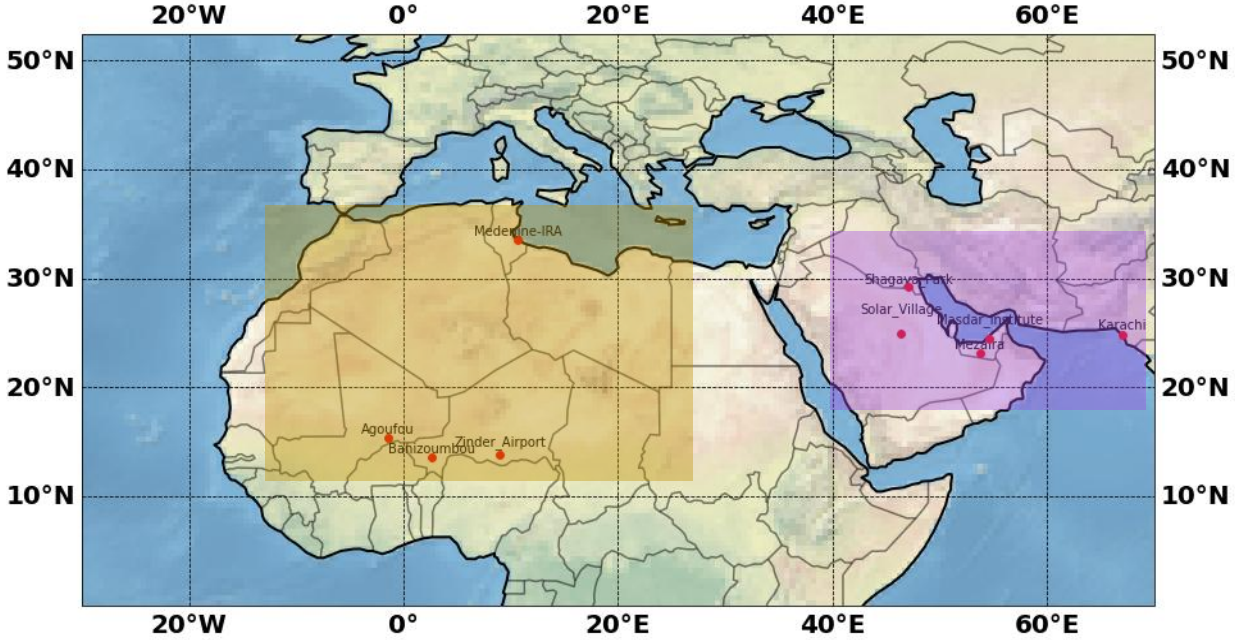
2.



3.







- LR_diff <0 means the upgraded LR value is smaller than the default (44 sr)
- LR_diff >0 means the upgraded LR value is larger than the default (44 sr)

★ $LR_{POLDER\text{-}3/GRASP}$ – 44 sr
★ LR_{MIDAS} – 44 sr
★ $LR_{MIDAS\ SEASONAL}$ – 44 sr

pmod wrc

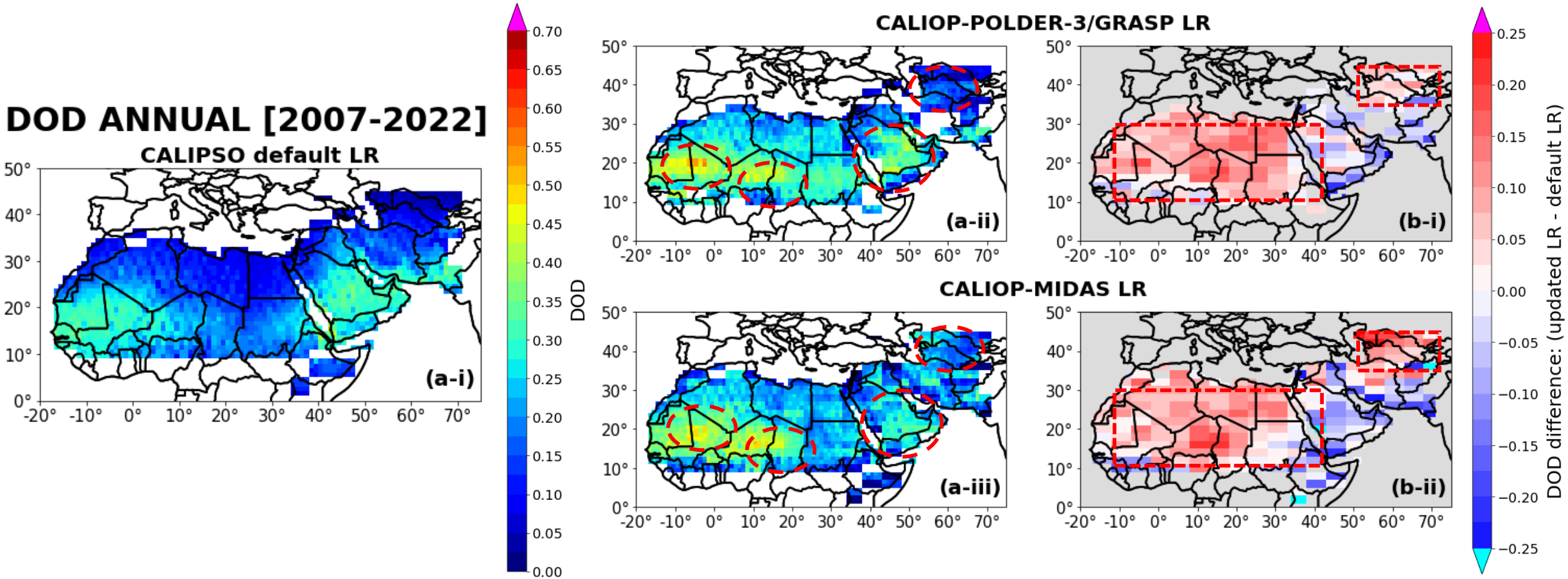
DOD climatology

From 2007-2022

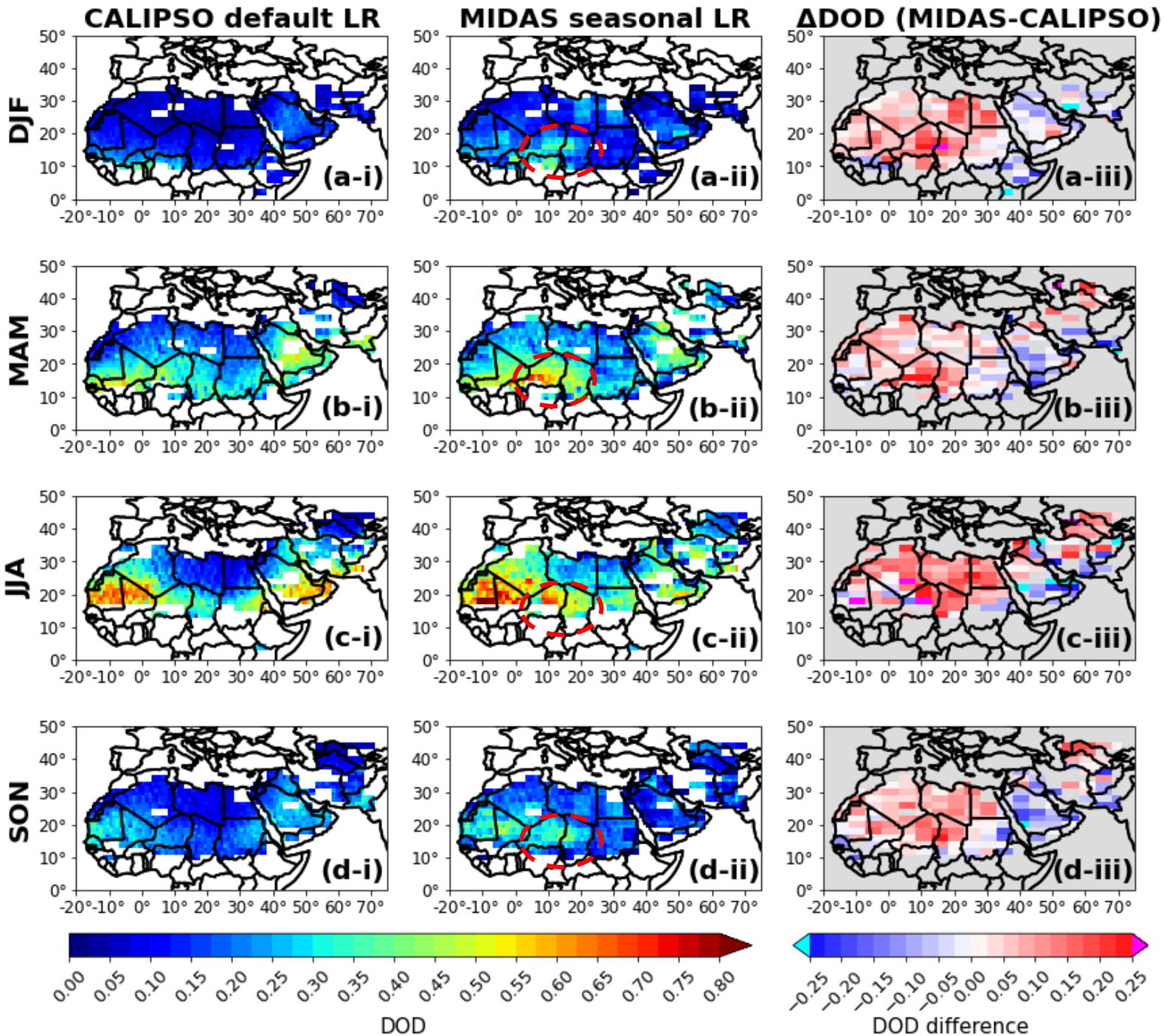
1°x1°

- Do LR maps change the DOD?

DOD ANNUAL [2007-2022]



pmod wrc


CALIPSO default LR
MIDAS seasonal LR
ΔDOD (MIDAS-CALIPSO)
DJF
MAM
JJA
SON
(a-i)
(a-ii)
(a-iii)
(b-i)
(b-ii)
(b-iii)
(c-i)
(c-ii)
(c-iii)
(d-i)
(d-ii)
(d-iii)
50° 40° 30° 20° 10° 0°
-20° -10° 0° 10° 20° 30° 40° 50° 60° 70°
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80
DOD
−0.25 −0.20 −0.15 −0.10 −0.05 0.00 0.05 0.10 0.15 0.20 0.25
DOD difference

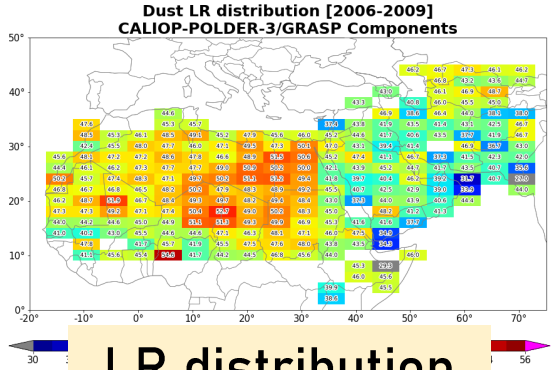
pmod wrc

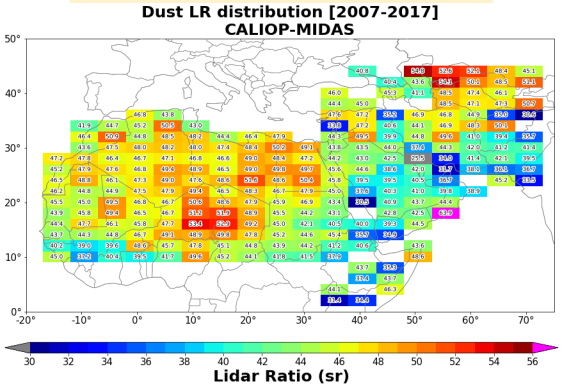
Summary

Combining retrievals from active and passive sensors of the A-Train satellite constellation (**CALIOP**; **POLDER-3**; **MODIS**) towards:

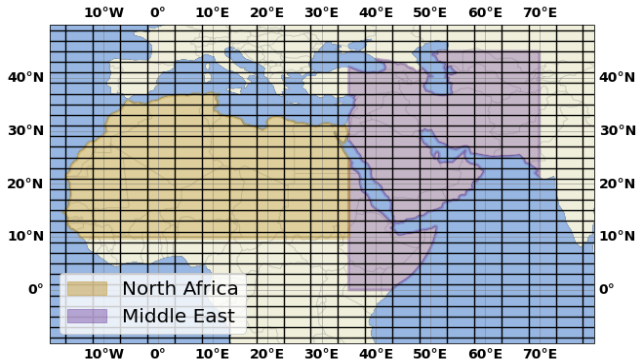
- **Defining the Annual and Seasonal Dust LR distribution over North Africa and the Middle East**
- **Performing Climatological analysis** across various spatiotemporal scales utilizing the revised **Dust LR**
- **Refined dust LRs improve CALIOP performance in terms of DOD (against AERONET)**

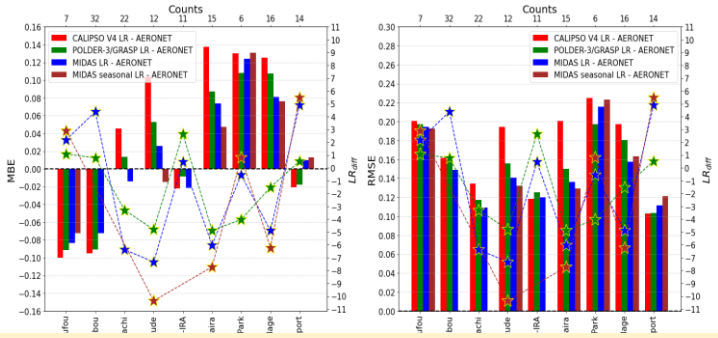
Moustaka et al. 2025 – Under review



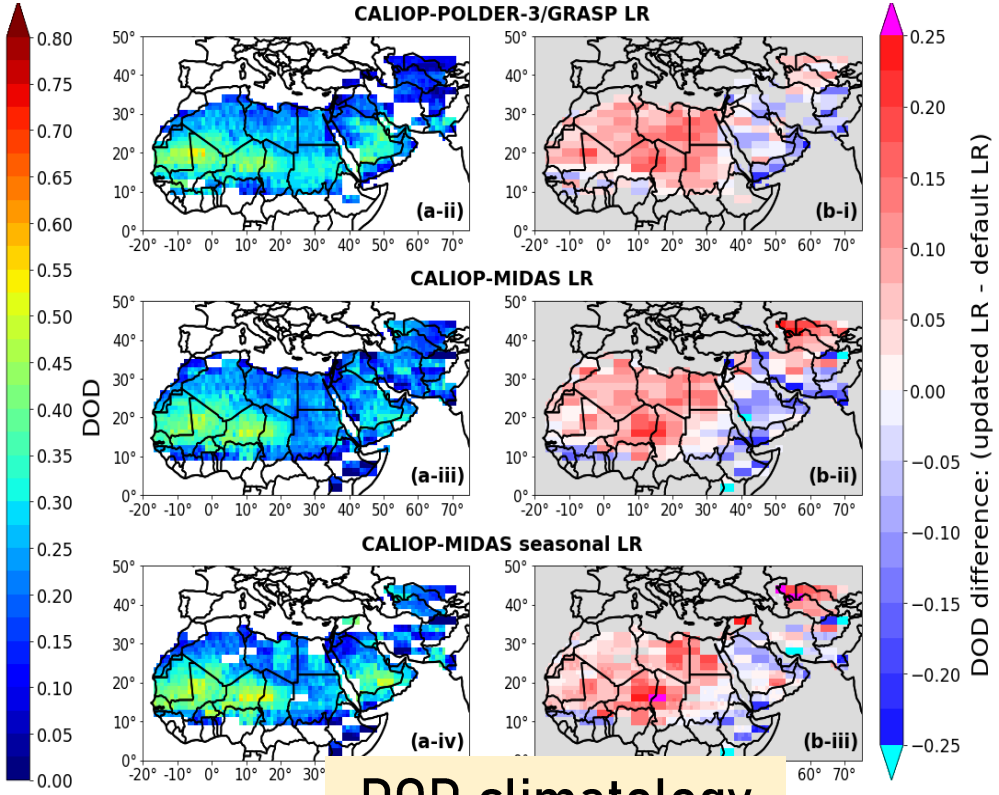


LR distribution





Evaluation against AERONET



DOD climatology

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Thank you for your attention!!!

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Image Credit: NASA