Toward an operational NRT GRASP processor for EPS-SG/3MI

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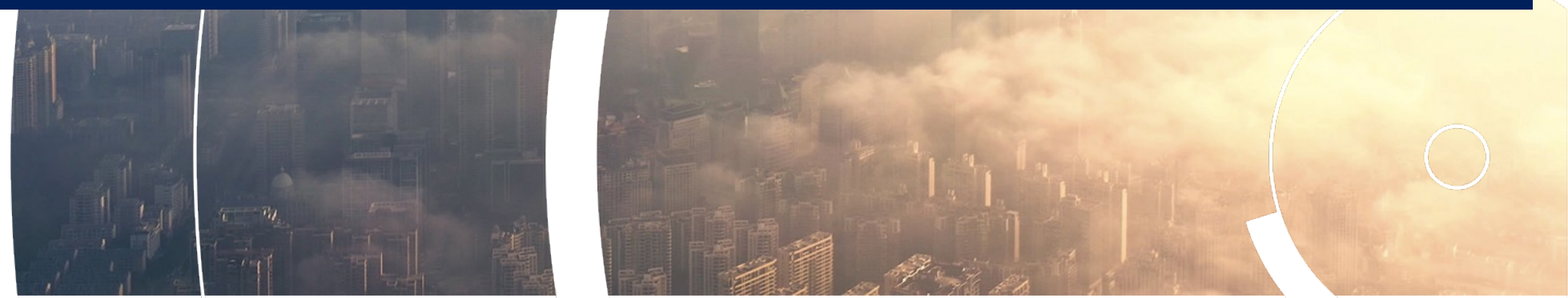
EUMETSAT **Remote Sensing & Products / *Cloud & Aerosol* (RSP/CLA)**

1) EUMETSAT *2) Rhea Systems GmbH* *3) Vision Space Technologies*

November 2023



Outline

3MI Multi-view Polarimeter and L1C data

Simulated data with GRASP-RTM

3MI L2 retrieved using GRASP

Aerosol and surface properties

Cal/Val activities

Analysis and development of tools

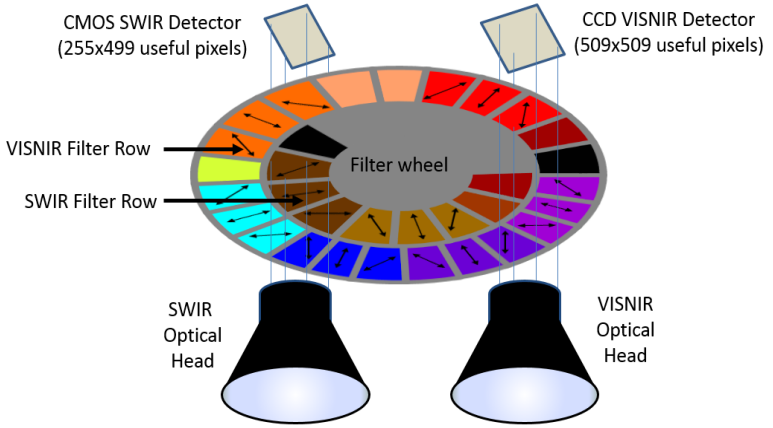
Conclusion

Overview of the status and outlook

3MI : Multi-viewing Multi-channel Multi-polarisation imager

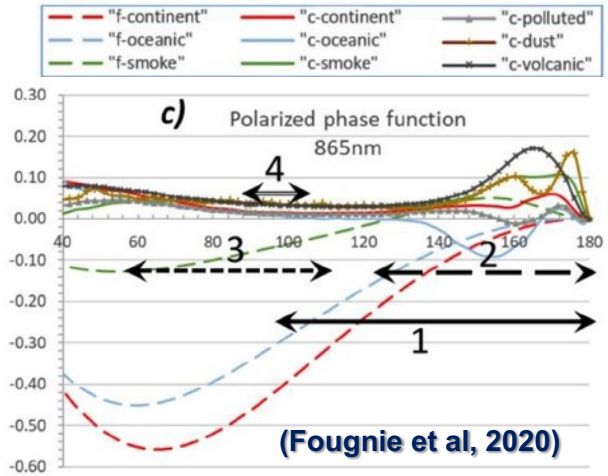
- The primary objective of the 3MI mission is to provide high quality imagery of aerosol variables over ocean and land;
- The 3MI instrument concept has a direct heritage from the POLDER instrument;
- EPS-SG : Polar orbit at 09:30 – launch 2025, 3 redundant instrument/platforms → 25 y. of operation
- 12 bands from 410 to 2130nm + Polarization
- 4km nadir – 2200x2200km² swath (for VISNIR)

Filter wheel = spectral and polarization

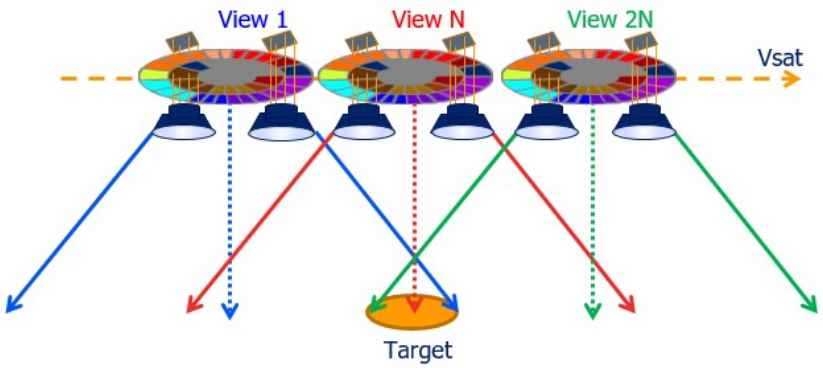


The added-value of directional polarimetr

Associated Information Content



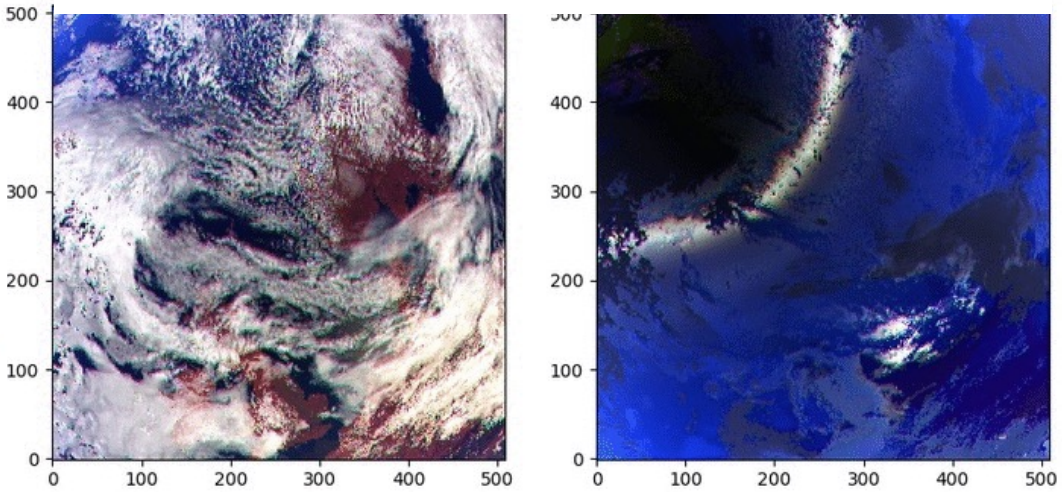
(Fougnie et al, 2020)



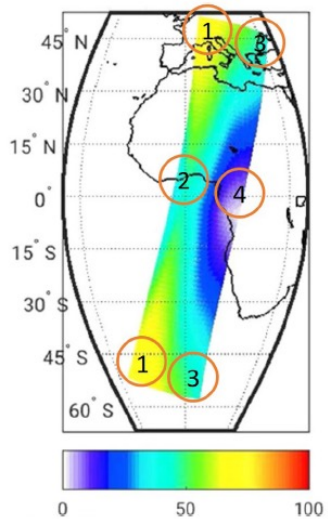
(Marbach et al, 2015)

Standard RGB

Polarisation



(Fougnie et al, 2018)



3MI TOA and L1C

The data prepared using Hygeos & LOA TDS in form of:

- ❑ Reformatted TOA L1B to L1C;
- ❑ Generation of L1C using in-house prototypes;

- This TDS contains clouds, gas absorption, Aerosol and surface properties from climatology (MACC)

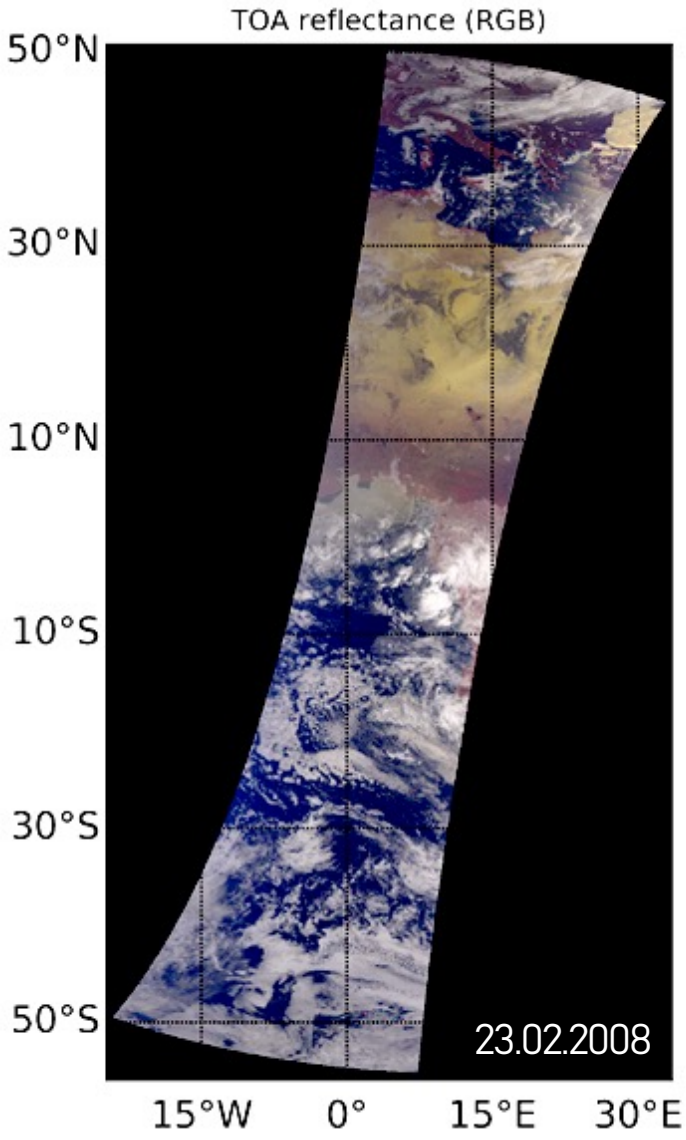
The 3MI TOA data simulated using GRASP forward mode:

- To produce this data, the geometry is taken from Hygeos/LOA simulated data and Climatology of POLDER/PARASOL and MODIS used for aerosol and surface properties;
- No gas absorption and no cloud.

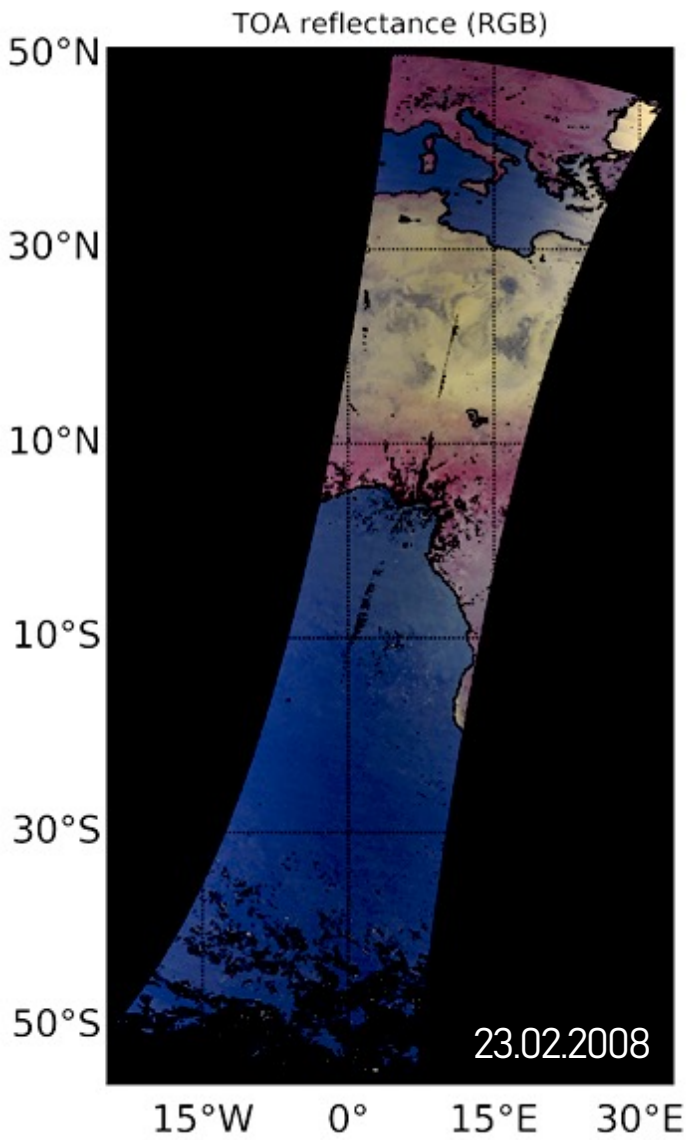
Caveat:

- The differences in inputs and forward model impact the performance of L2 GRASP retrieval.

3MI data simulated by Hygeos & LOA



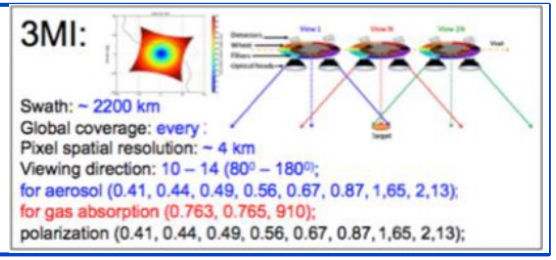
3MI data simulated by EUMETSAT



GRASP: Generalized Retrieval of Atmosphere and Surface Properties

3MI:

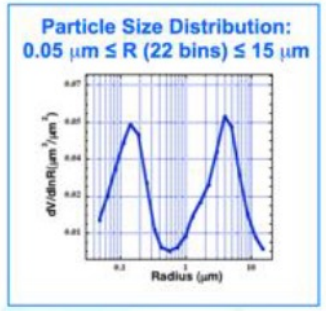
- Radiances and polarization
  (410, 440, 490, 560, 670, 870, 1650, 2103 nm)
- 10-14 viewing directions

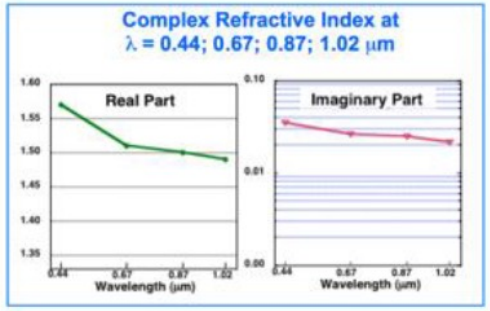


240 – 336
measurements

AEROSOL

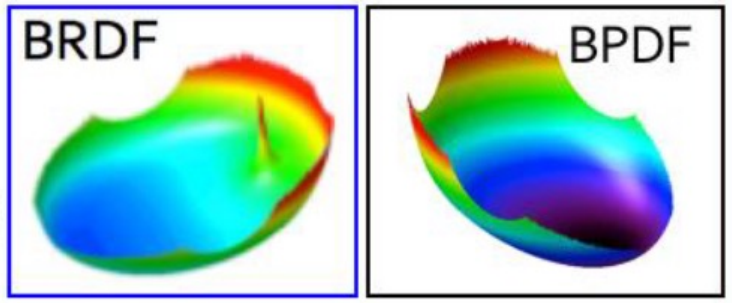
- AOD (8 wavelengths)
- Size distribution
- Spectral index of refraction (8 wavelengths)
- Sphericity fraction
- Aerosol height
- SSA
- Absorbing AOD (8 wavelengths)
- Angstrom Exponent





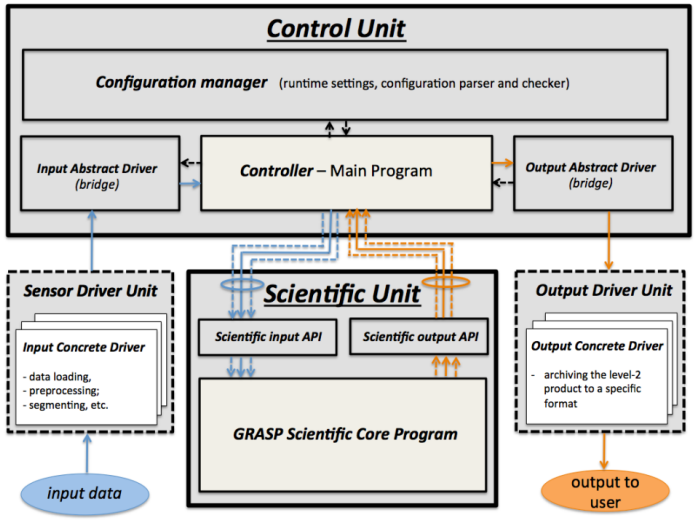
Surface

- BRDF (3 Spectrally dependent parameters)
- BPDF (1 or 2 spectrally dependent parameters)



See the presentation on Friday:
Aerosol retrieval products retrieved from different satellite observation using GRASP platform by Oleg Dubovik

Architecture of the GRASP



104 = 8 (AOD) + 5(SD) + 16 (ref. ind.) + 1 (nonsp.) + 24 (BRDF) + 8 (BPDF) + 1 (height) + 1 (AEx) + 8(AAOD) + 8 (SSA) + 24 (CoxMunk)

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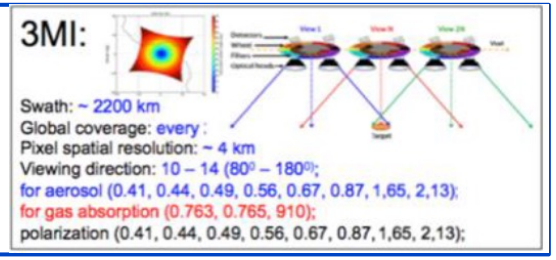

Retrieved & derived parameters in GRASP HighPrecision version: ⇩ 240 – 336 measurements

AEROSOL

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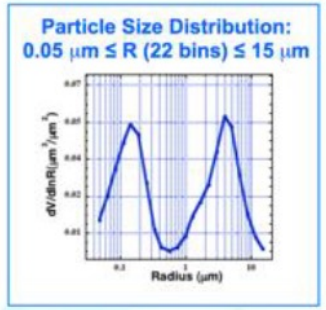

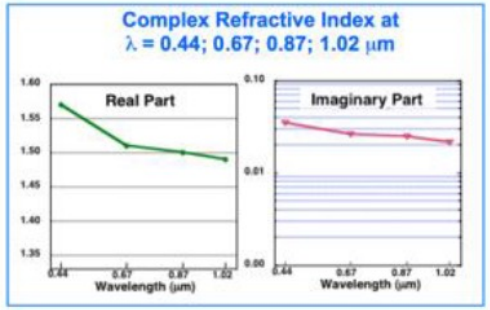

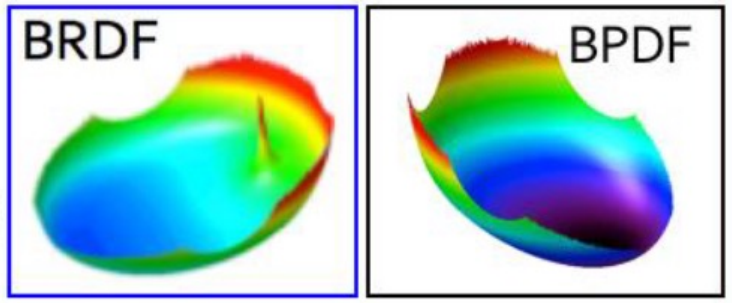

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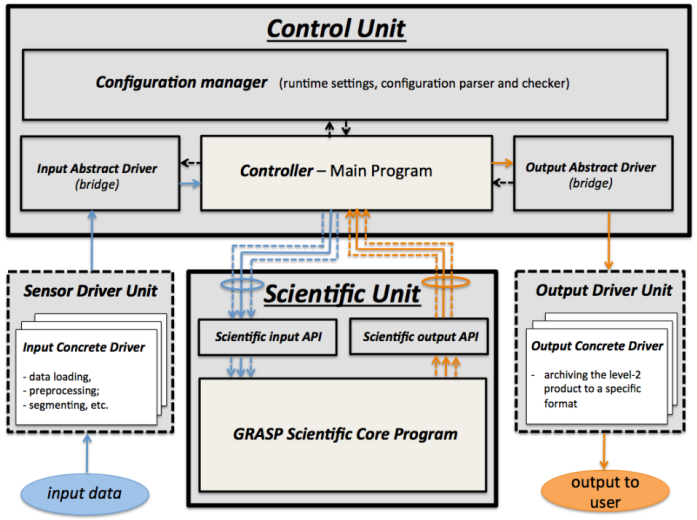

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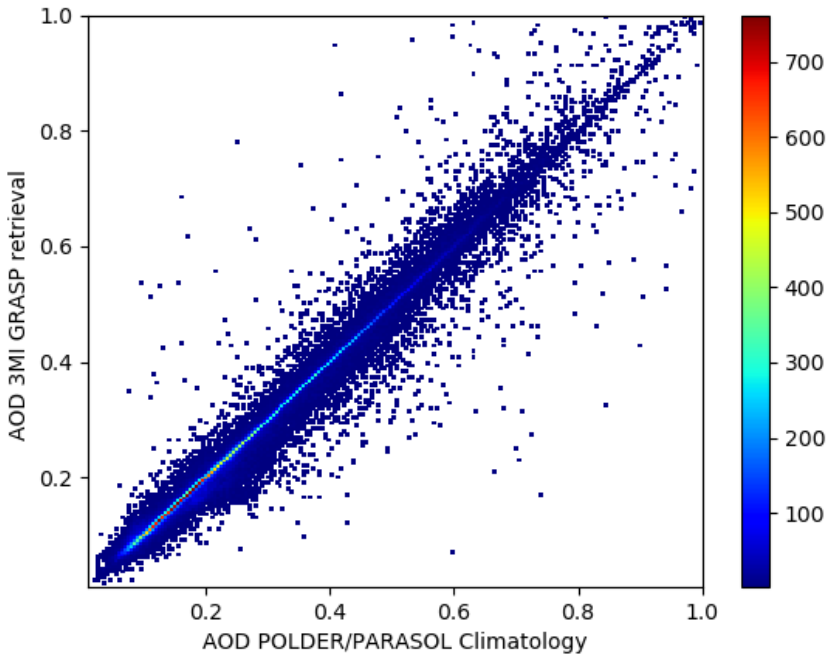
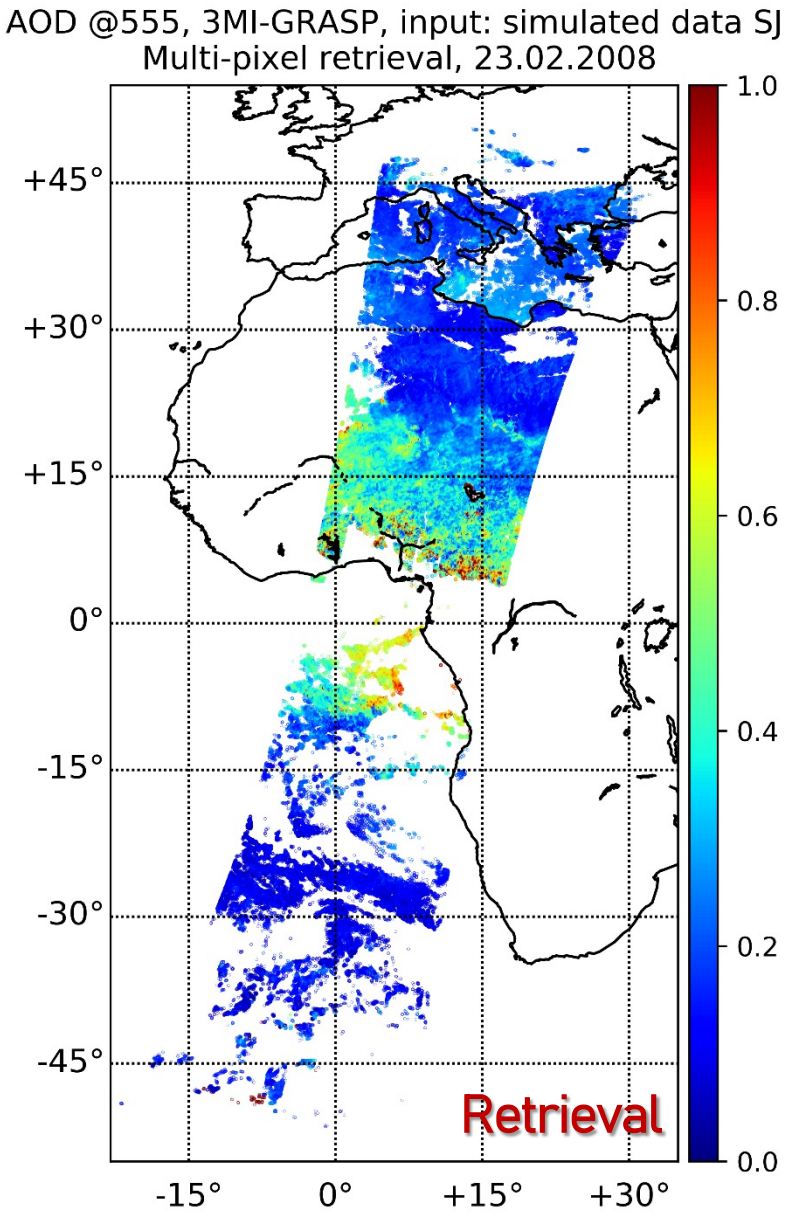
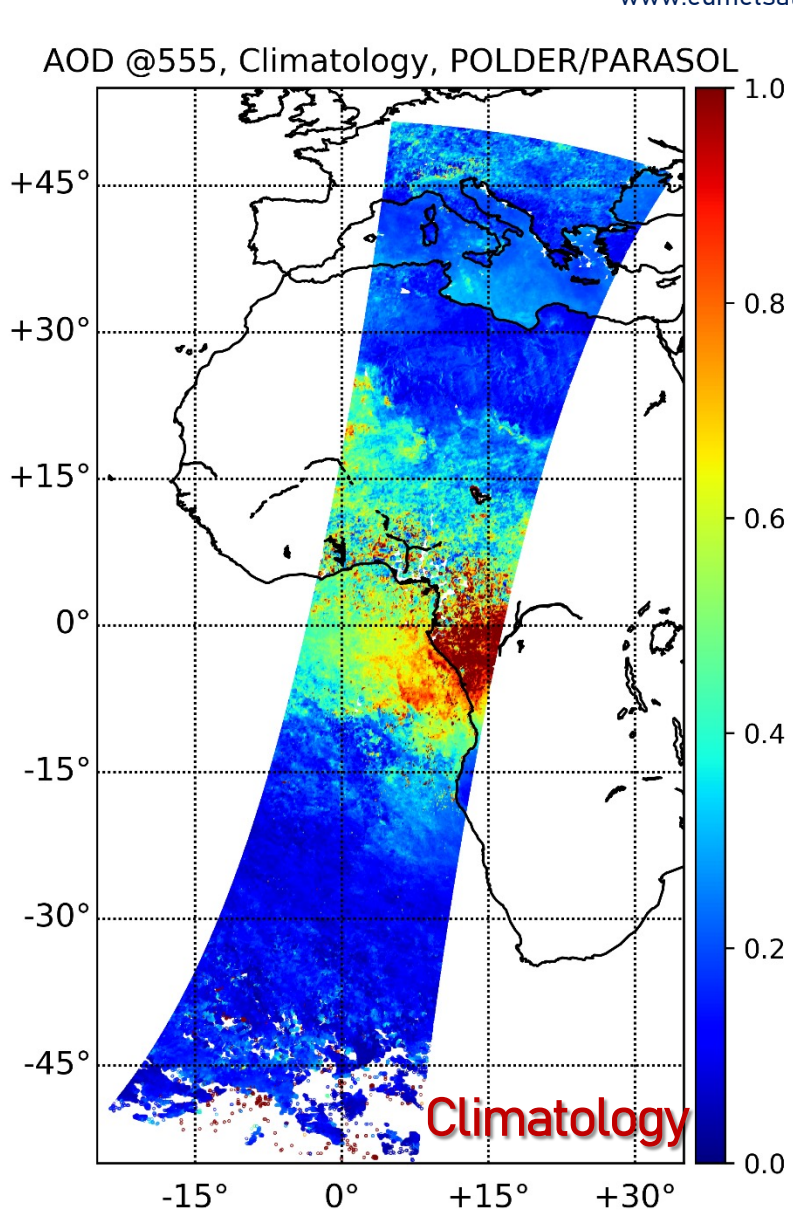
3MI – AOD

- Aerosol and surface properties are retrieved using 3MI-GRASP;
- The comparison of retrieved AOD to the AOD of climatology shows a high agreement and therefore indicates the consistency in the GRASP inversion;
- Areas to be investigated in input, e.g. Mediterranean sea.

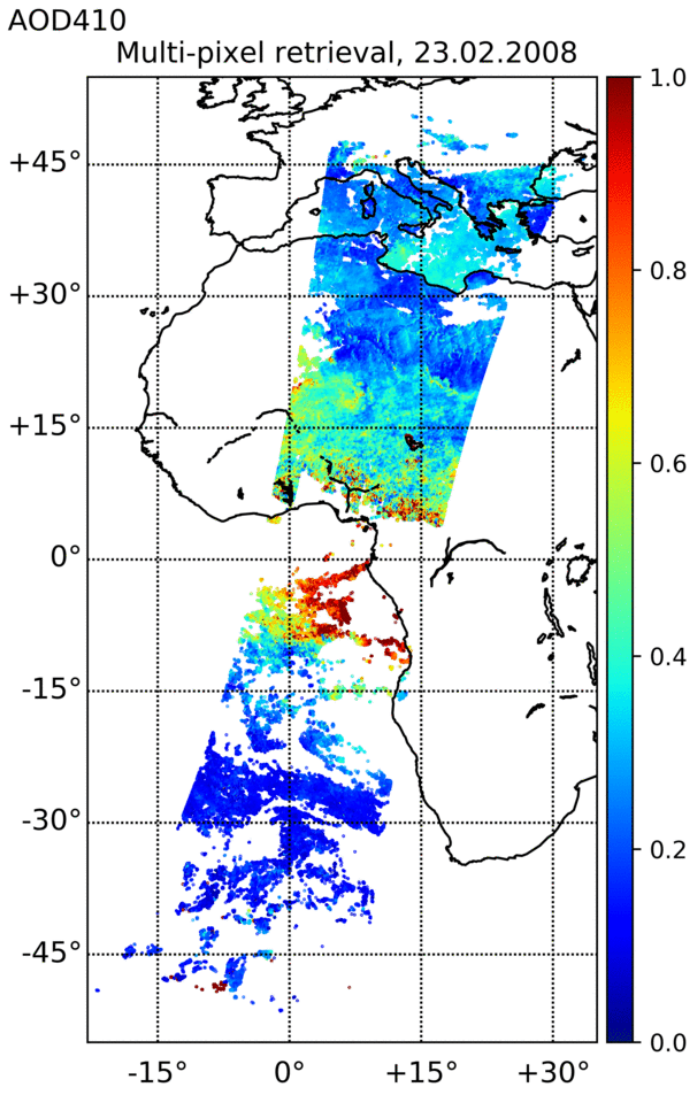




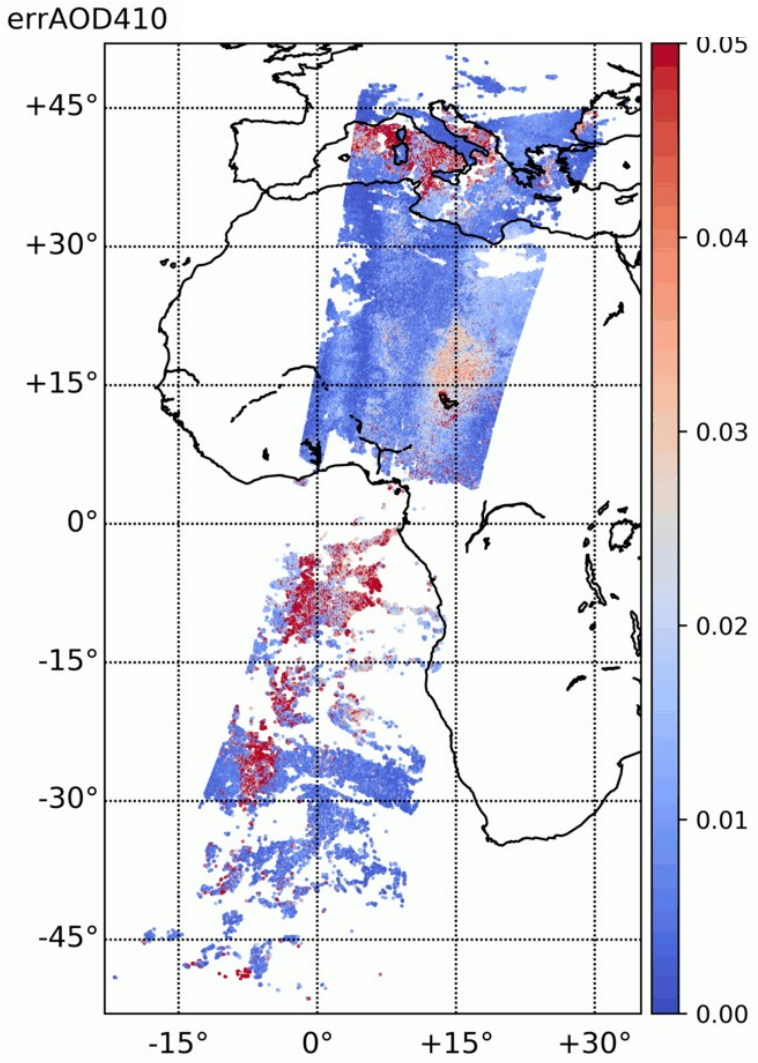


AOD, error estimation and surface reflectance

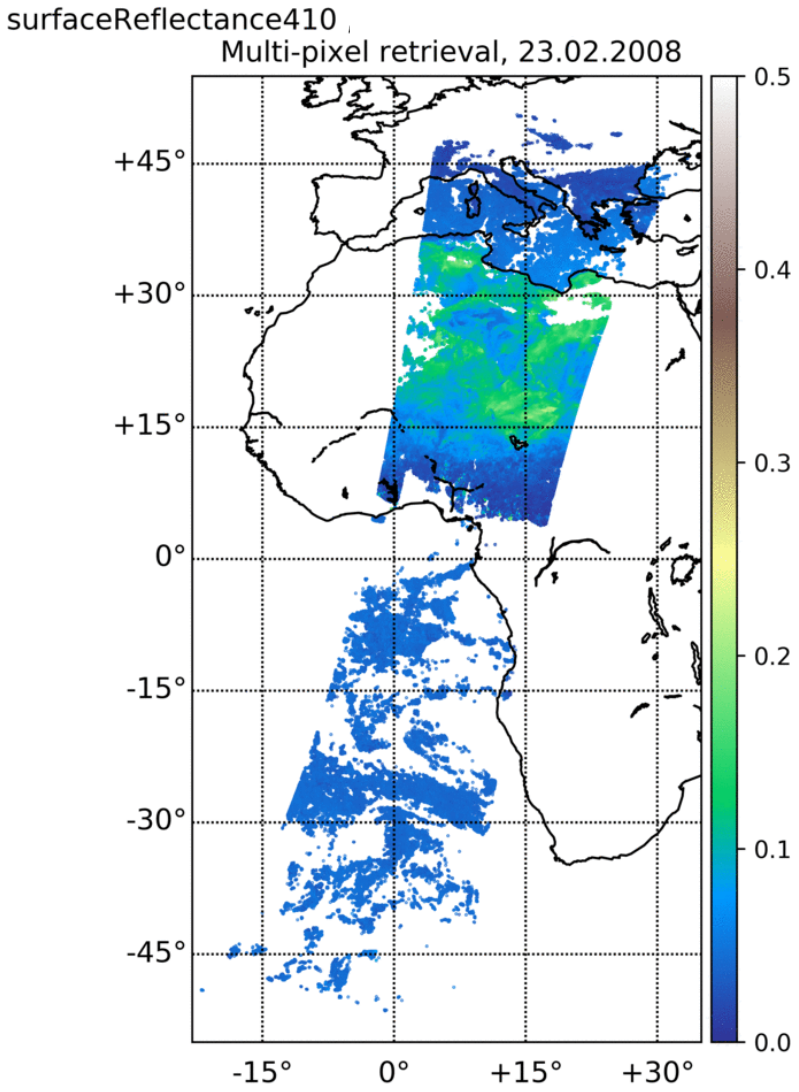
Spectral AOD



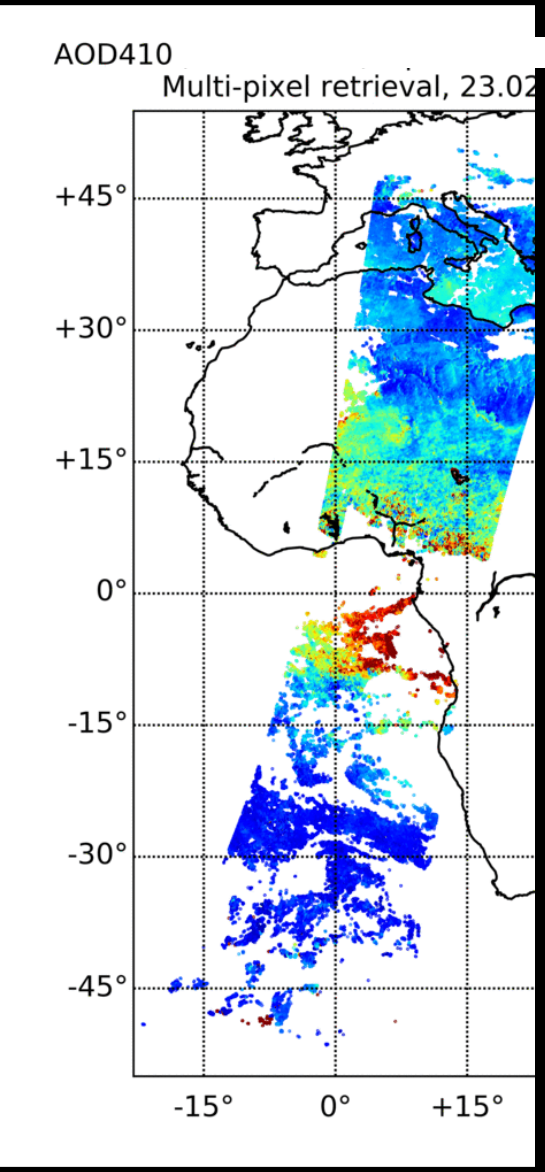
Error estimation

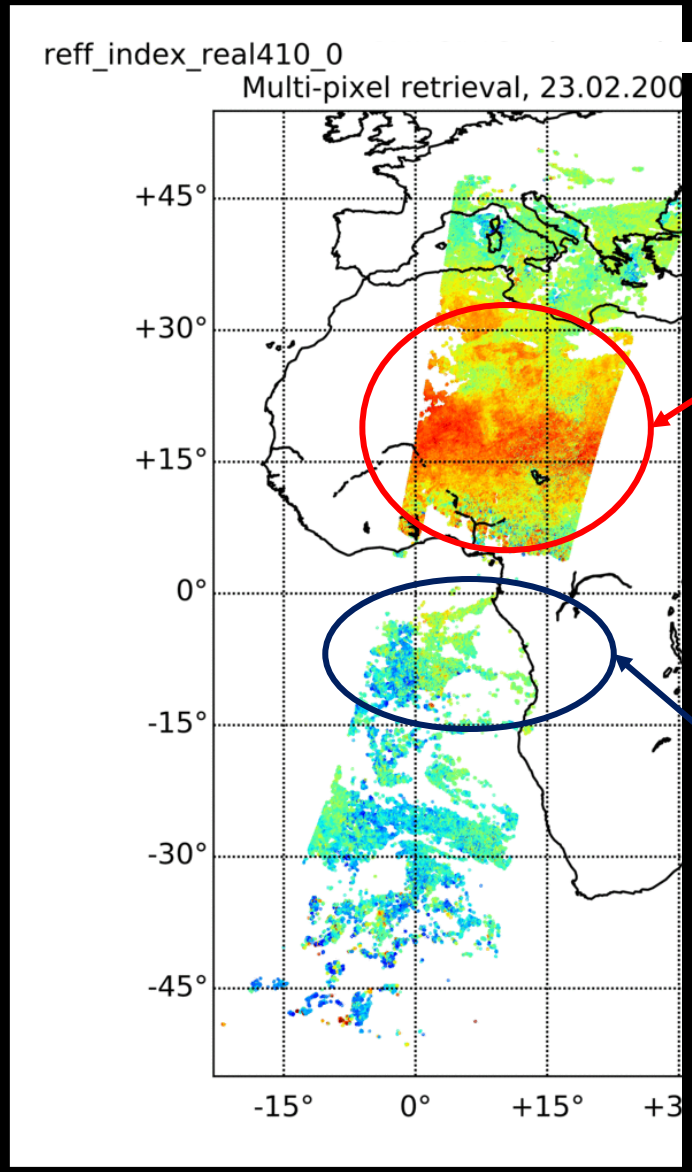


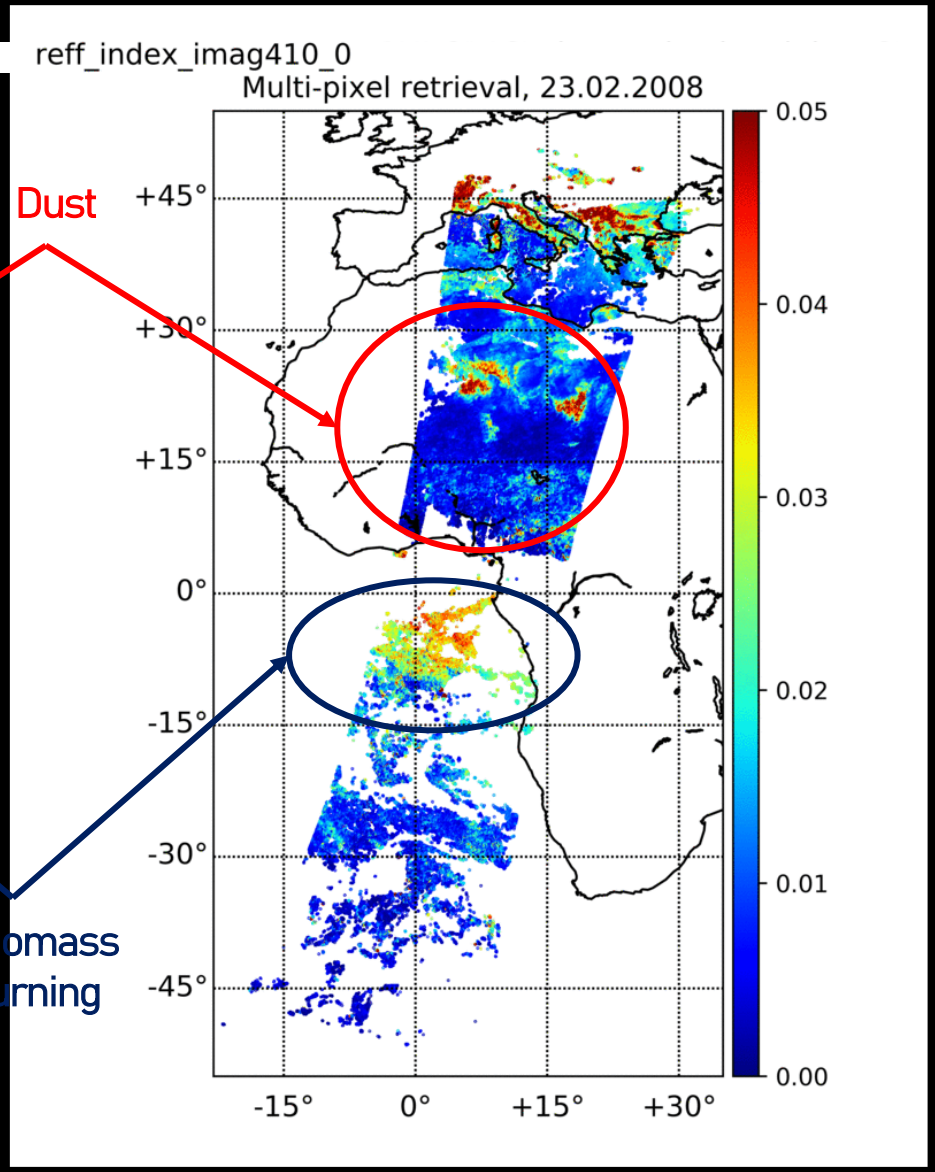
Spectral surface reflectance



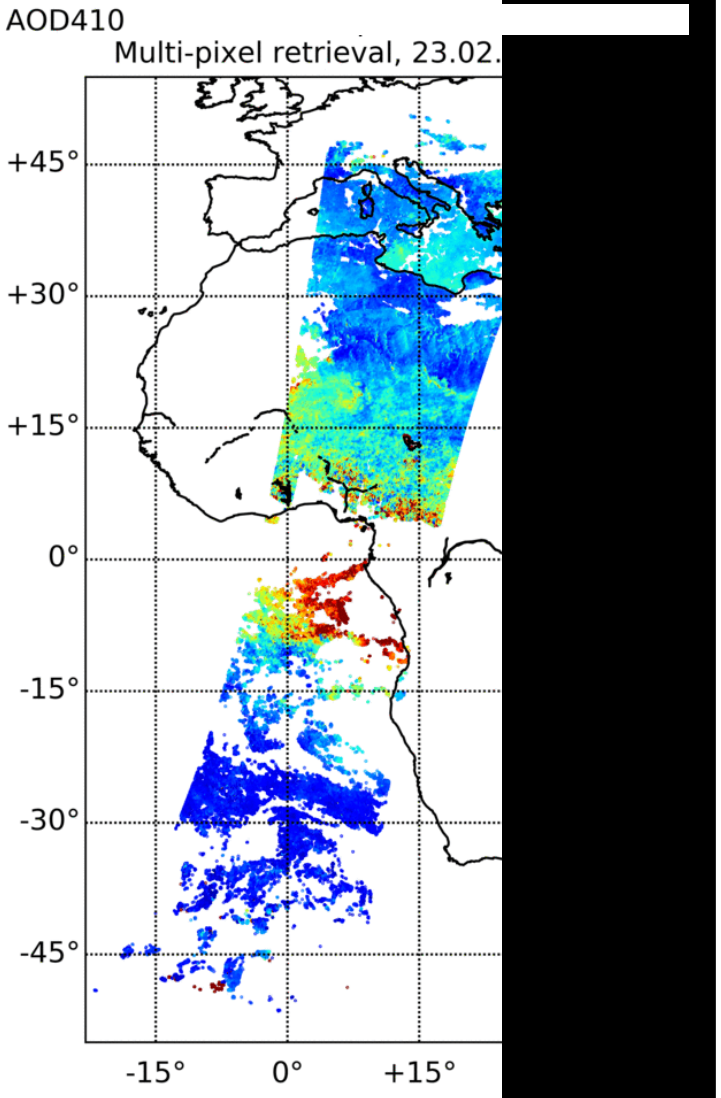
Refractive index parameters

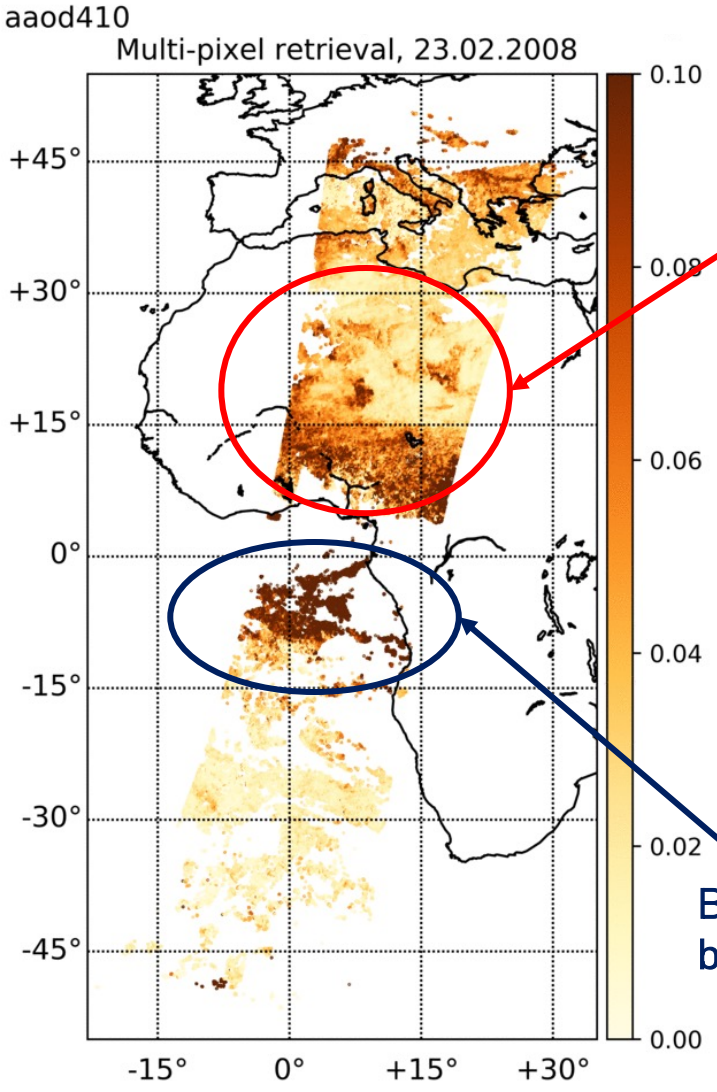


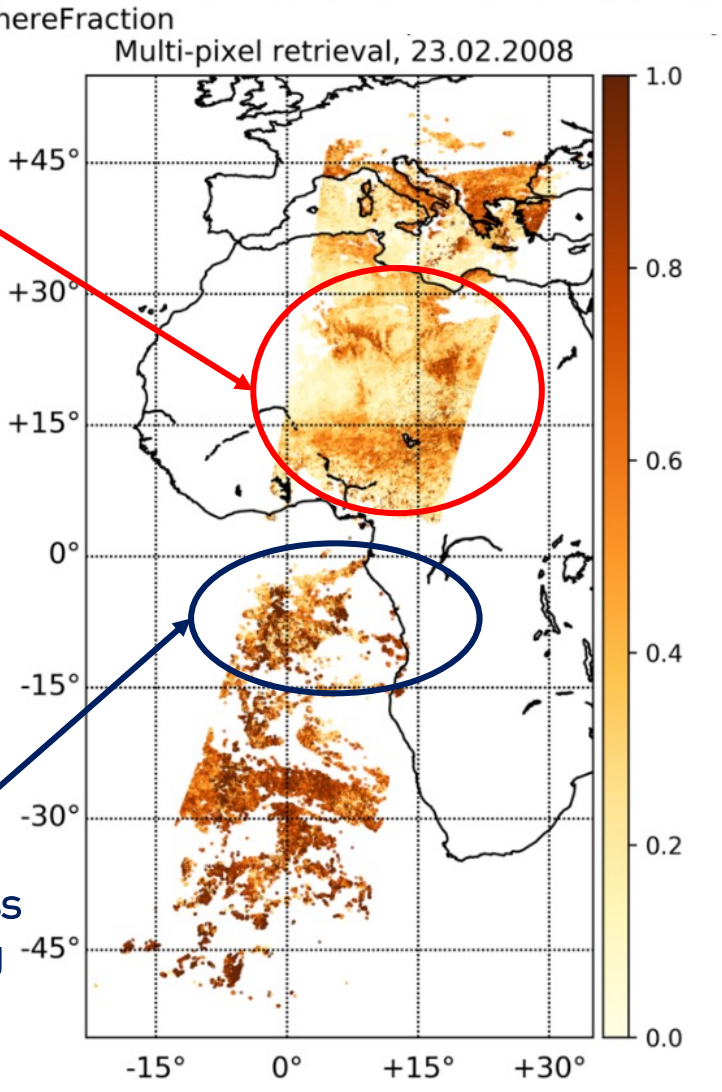




Absorbing AOD and Spherical fraction





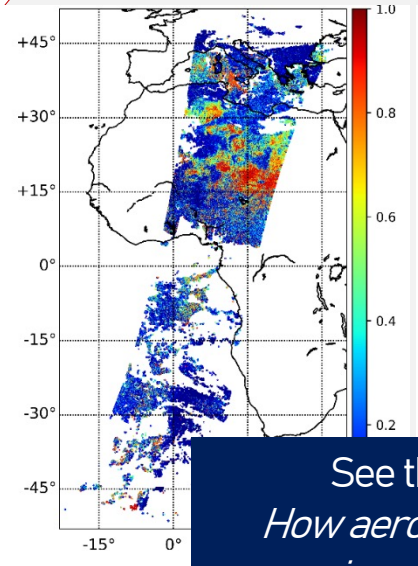


Dust

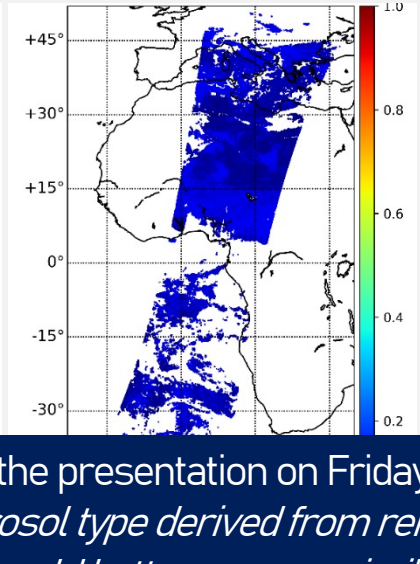
Biomass burning

More parameters

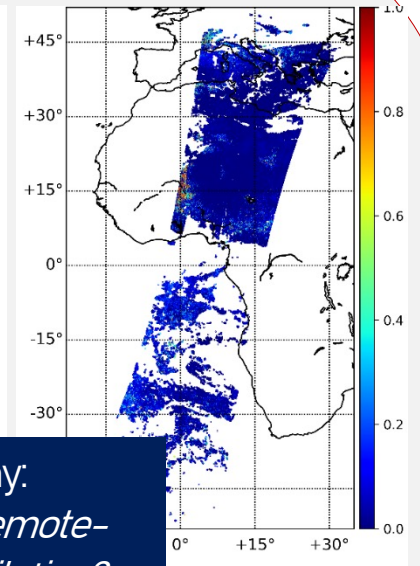
Quartz (fine)



Black Carbon

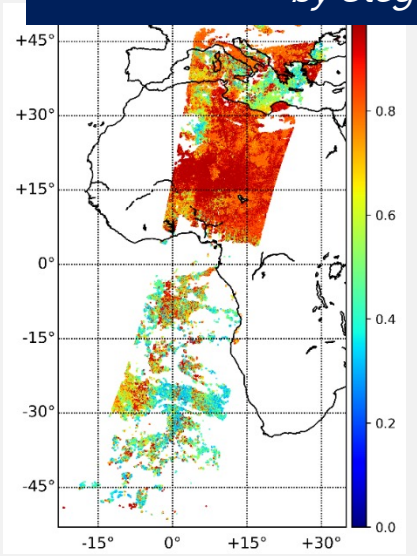


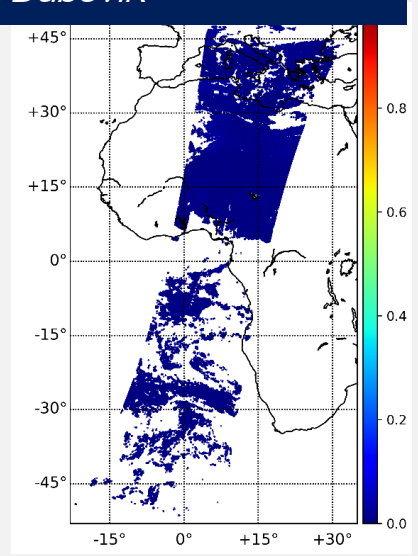
Brown Carbon



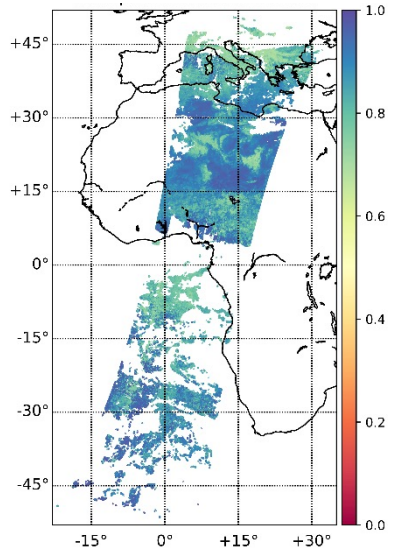
See the presentation on Friday:
How aerosol type derived from remote-sensing could better serve assimilation?
by Oleg Dubovik

Fraction of chemical components

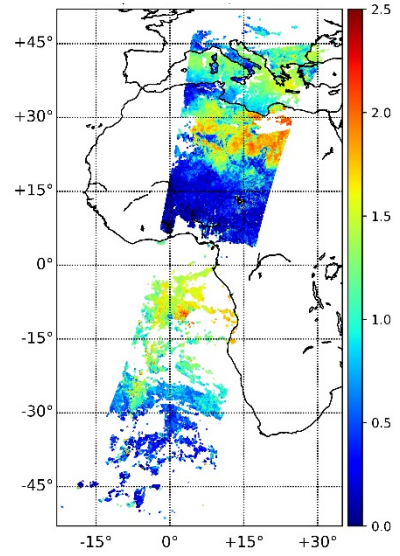




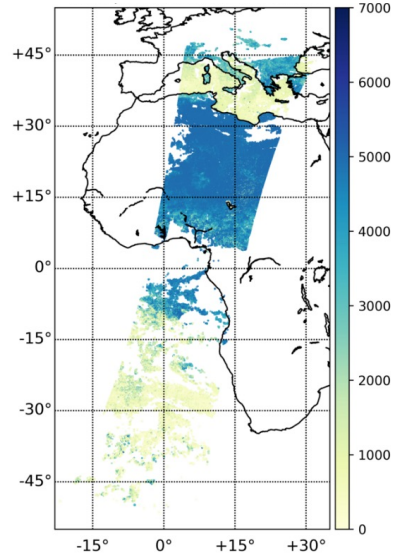
SSA 555nm



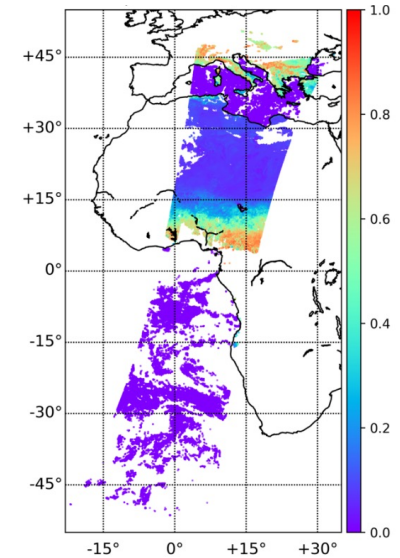
Angstrom exponent



Vertical Profile Height



NDVI



Cal/Val approach for Aerosol validation

- 1/ **Qualitative analysis**:
  - Visualisation of AOD maps, associated parameters (error, surface, geometry, models…)
- 2/ **Space-based comparative analysis:**
  - Other space references: MODIS, VIIRS…
  - Other EUMETSAT sensors: PMAp, SLSTR
- 3/ **Ground-based validation:**
  - AERONET matchups (diversity of situations, time-series…)
  - Other sources: ACTRIS
- 4/ **Consistency with aerosol sources (detection and type):**
  - Use of Fire products (FIR/FRP)
  - Volcano bulletin…
- 5/ **Model-based validation:**
  - EMACS, CAMS…
- 6/ **Alternative algorithms:**
  - SRON (3MI), GRASP (S3)…

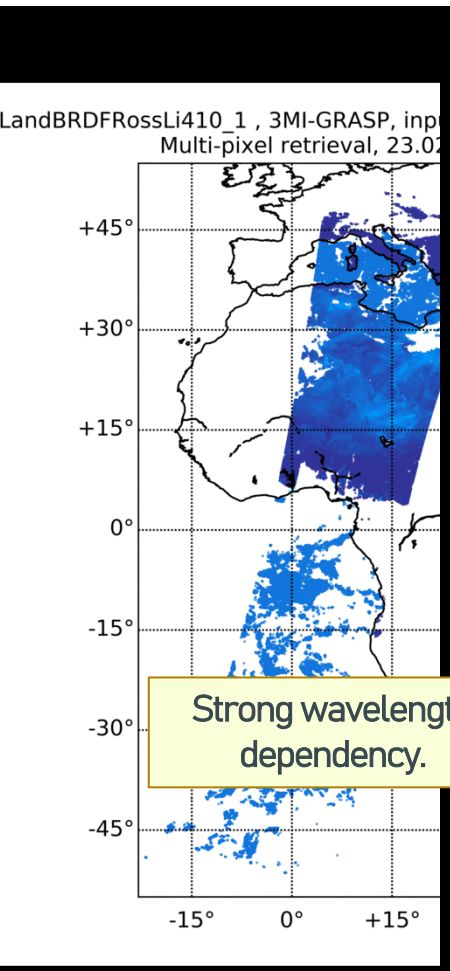
See the presentation on Thursday:
Harmonised Cal/Val strategy, and FRM requirements by Bertrand Fougnie

Qualitative analysis

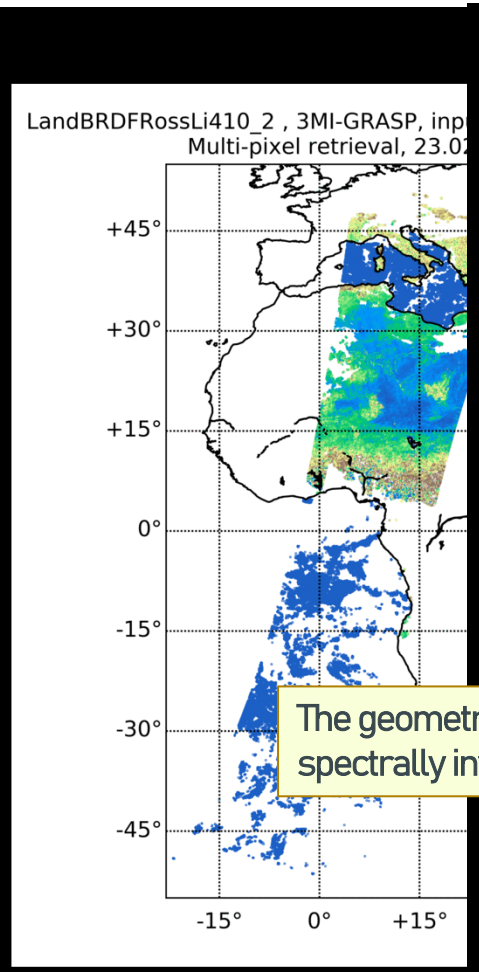
Analysis of the Land surface parameters:

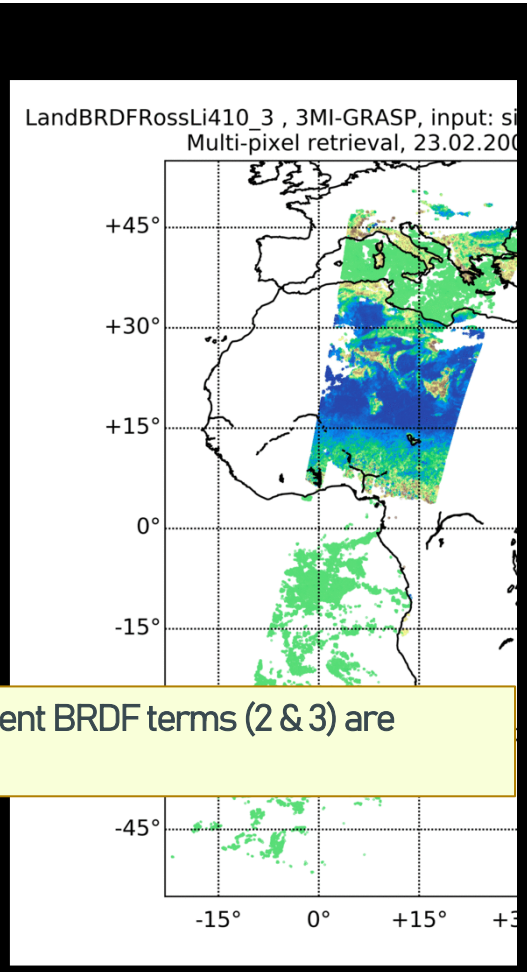
GRASP BRM is presented as the sum of:

- The semi-empirical Ross-Li sparse BRDF model = linear combination of 3 kernels representing isotropic (fiso), volumetric (fvol), and geometric (fgeom) optics surface scattering
- The reflection matrix based on semi-empirical Maignan-Breon BPDF (Bidirectional Polarization Distribution Function) model

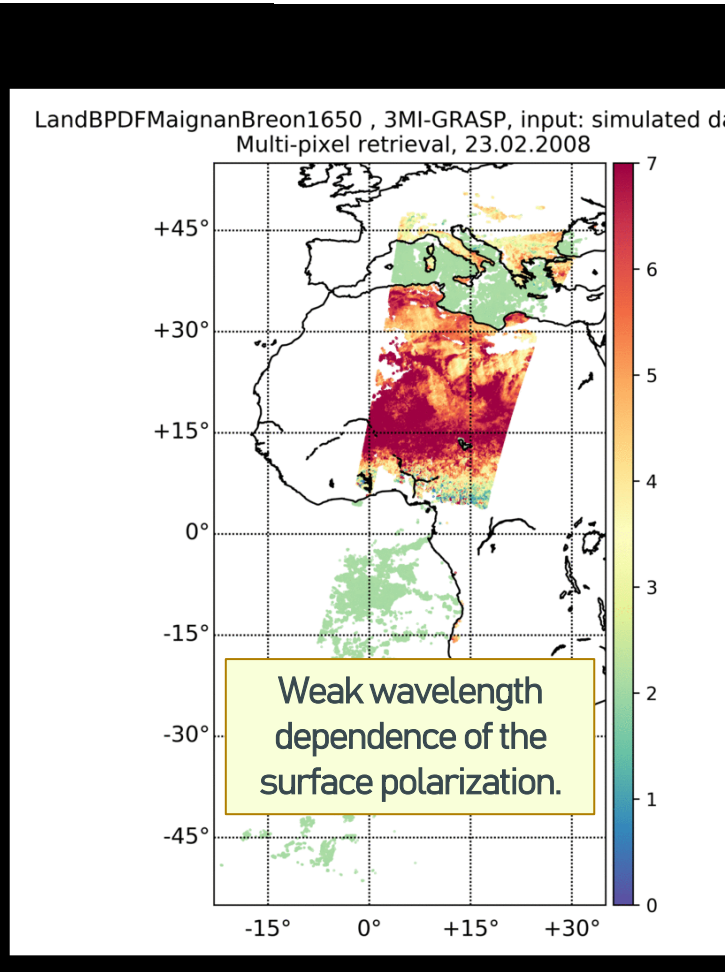


Strong wavelength dependency.





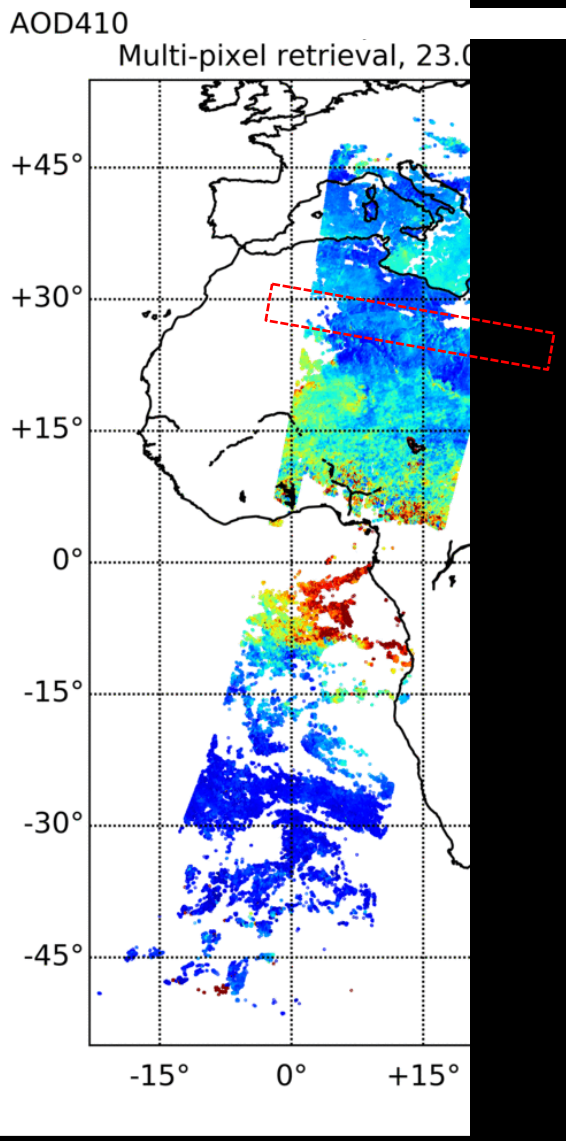
The geometry dependent BRDF terms (2 & 3) are spectrally invariant.



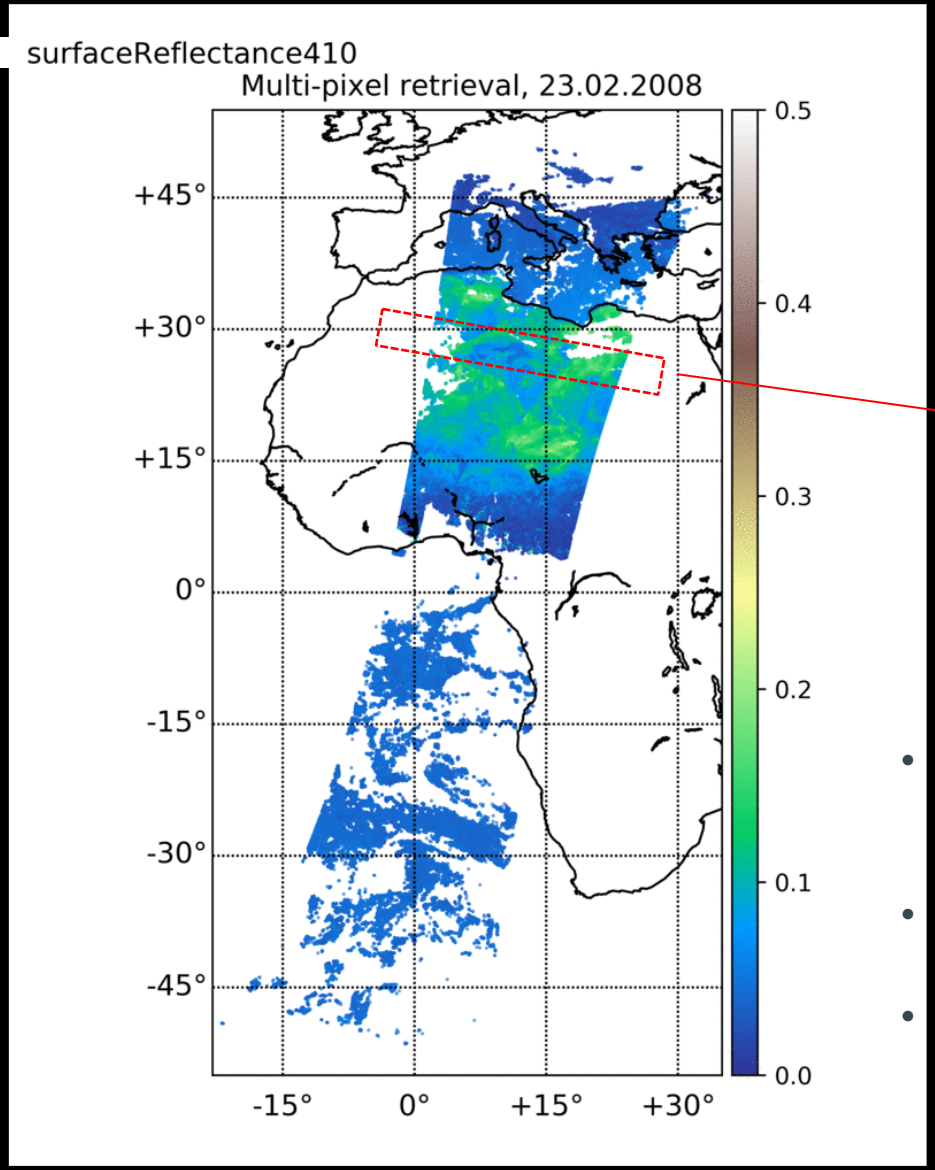
Weak wavelength dependence of the surface polarization.

Qualitative analysis

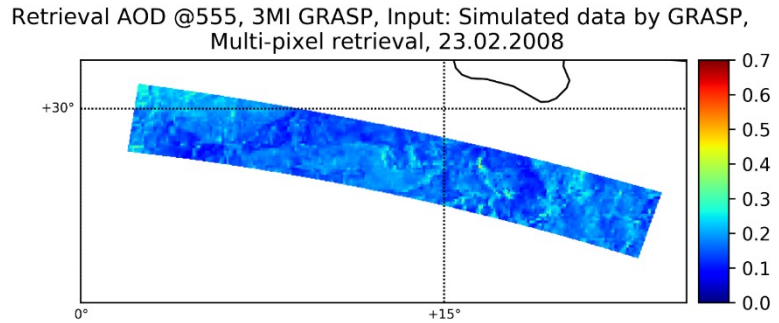
Spectral AOD

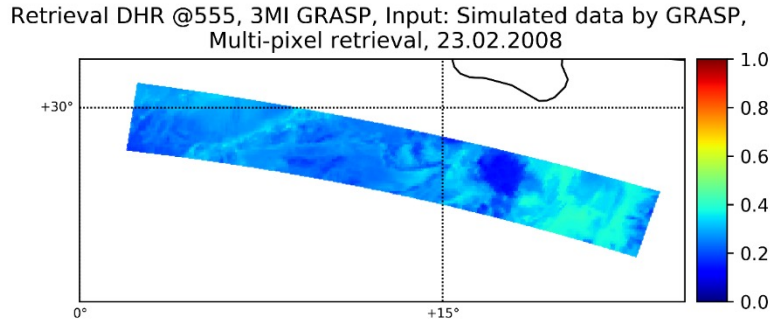


Spectral surface reflectance



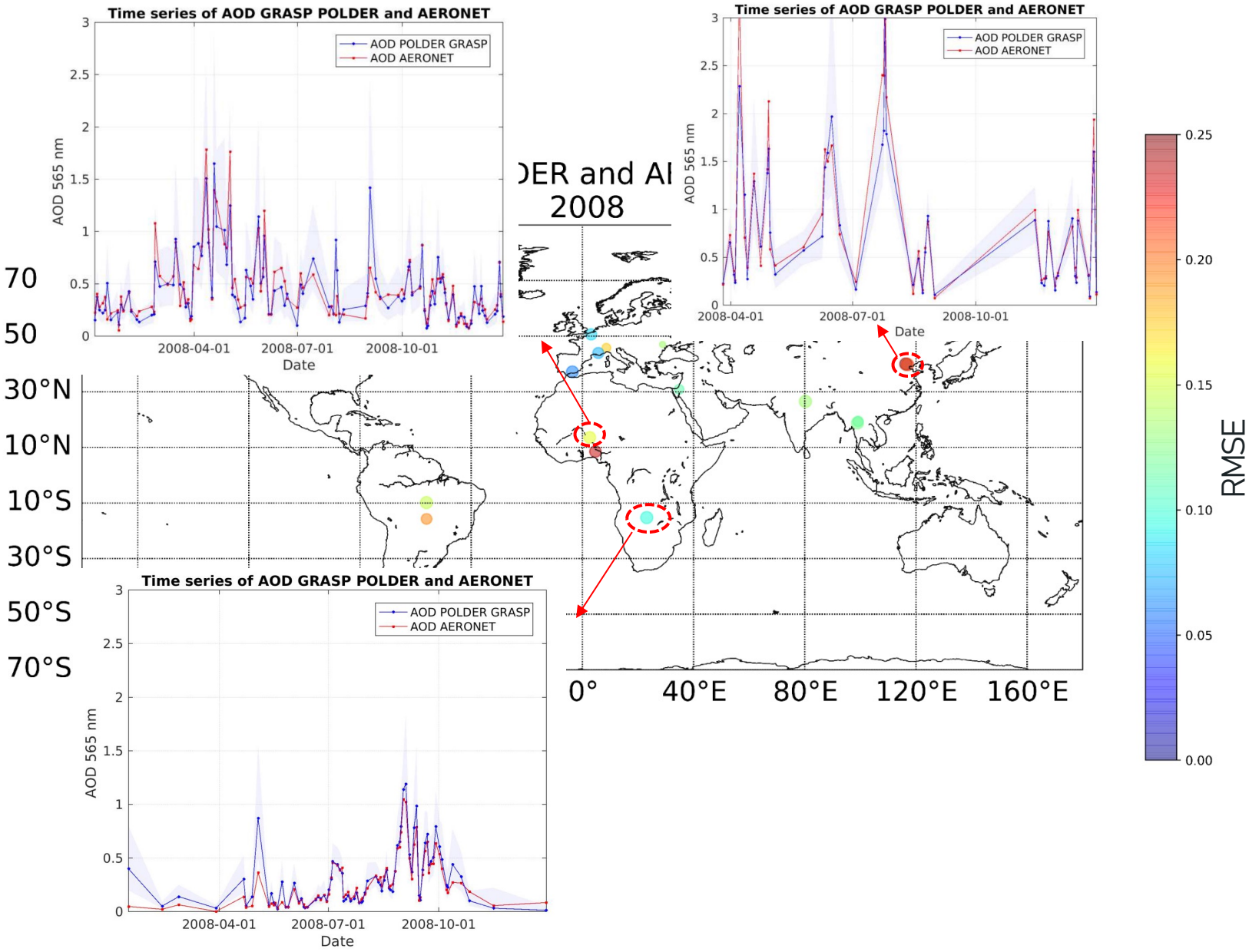
Correlation between AOD and surface reflectance

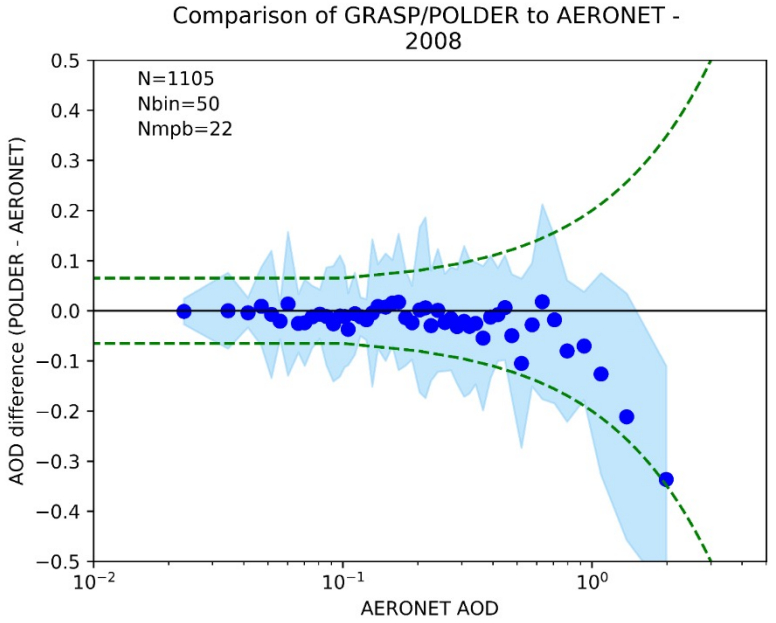


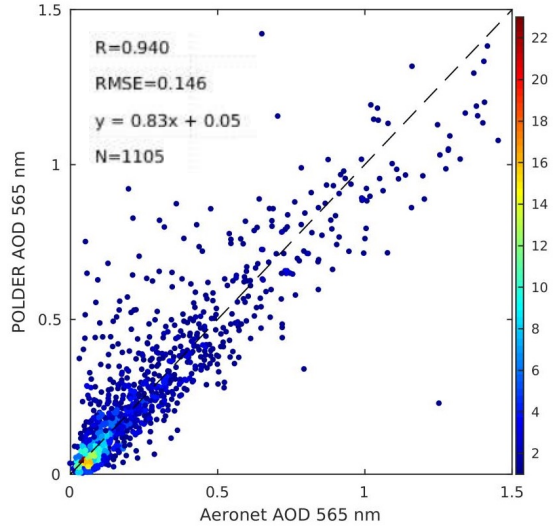


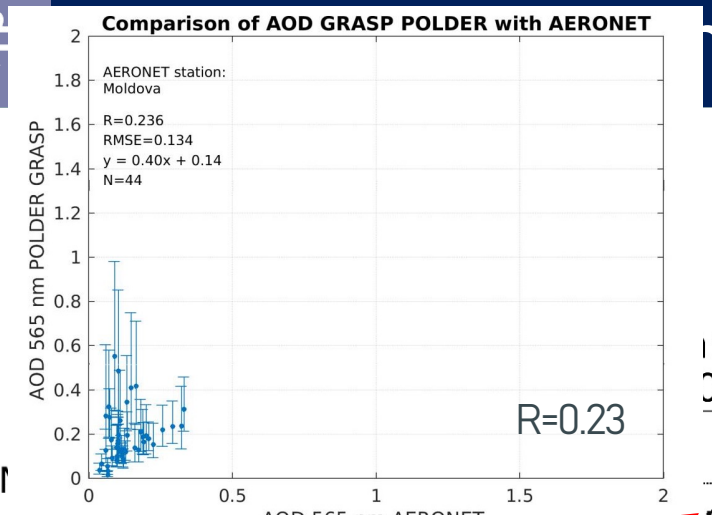
- AOD can be naturally correlated with the surface signal (topography, surface type, dynamics…)
- But could be the sign of a deficient SSAR retrieval
- The (potential) residual surface contribution impacting the aerosol product has to be documented

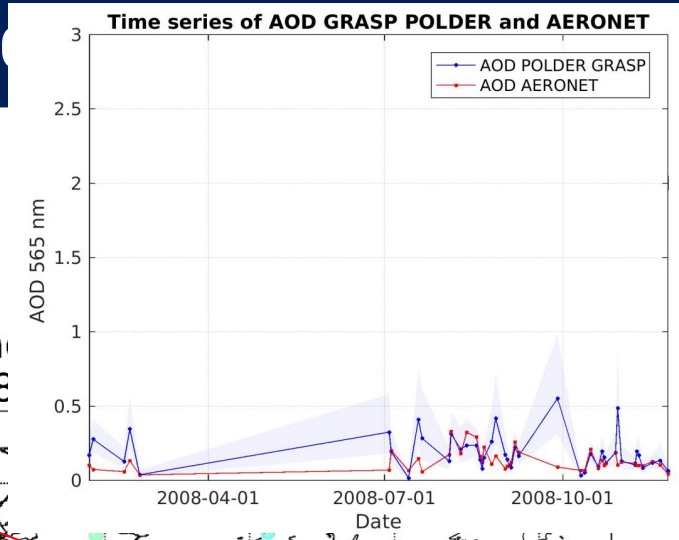
Ground-based validation: Global performance of GRASP/ POLDER

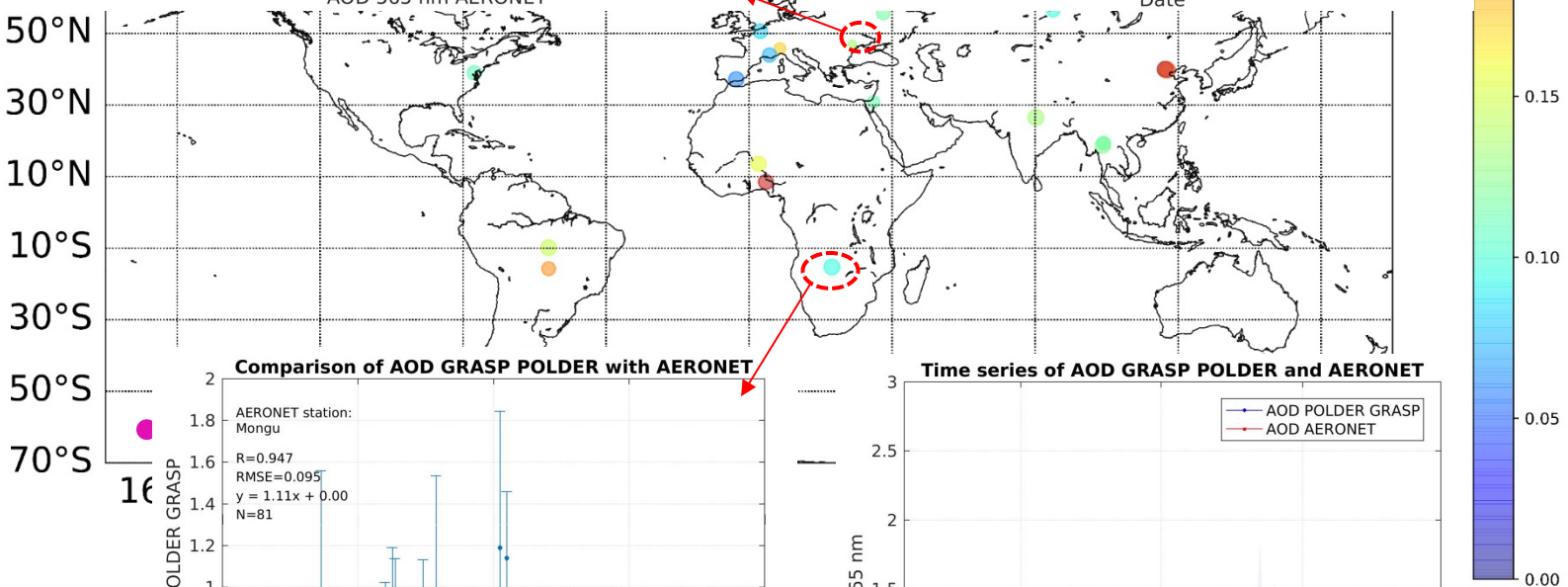


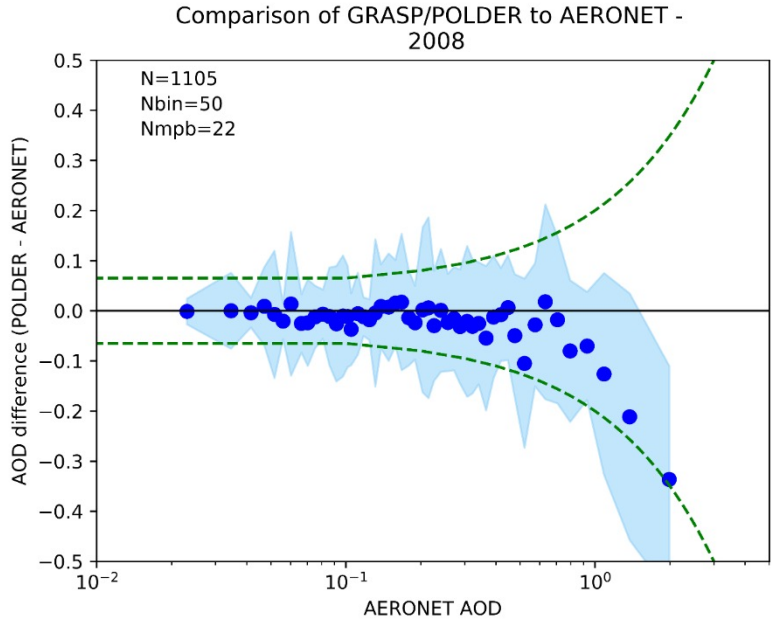


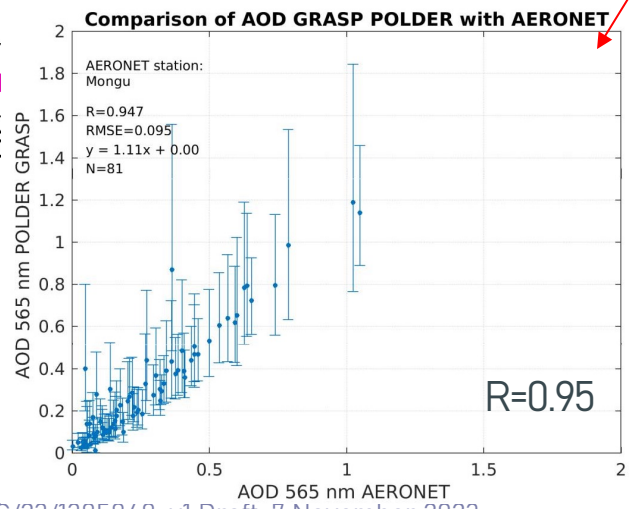


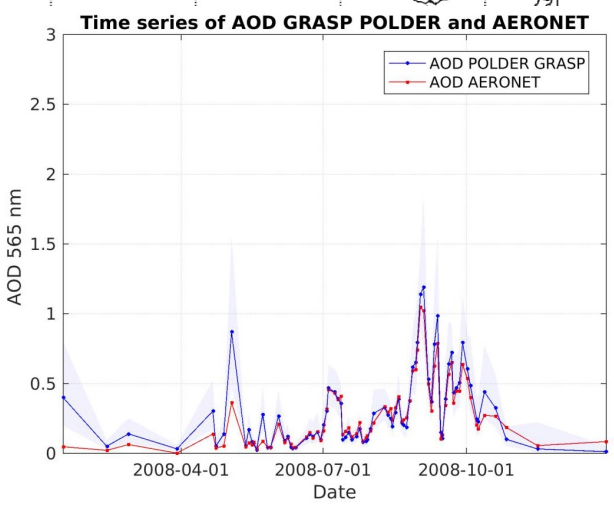

Comparison of AOD GRASP POLDER with AERONET
AERONET station:
Moldova
R=0.236
RMSE=0.134
y = 0.40x + 0.14
N=44
R=0.23
AOD 565 nm POLDER GRASP
AOD 565 nm AERONET

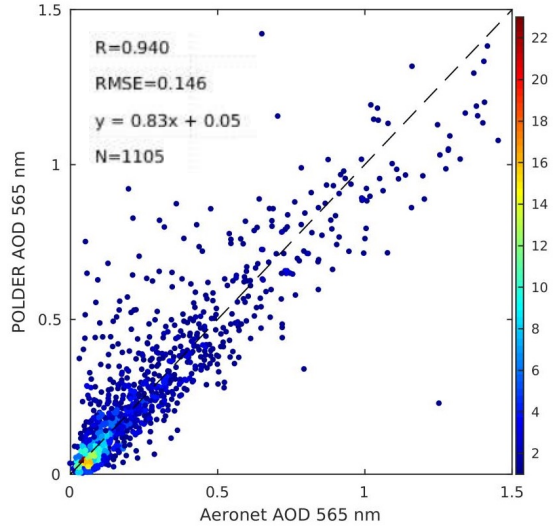

Time series of AOD GRASP POLDER and AERONET
AOD POLDER GRASP
AOD AERONET
AOD 565 nm
2008-04-01
2008-07-01
2008-10-01
Date


70°N
50°N
30°N
10°N
10°S
30°S
50°S
70°S
RMSE
0.25
0.20
0.15
0.10
0.05
0.00


Comparison of GRASP/POLDER to AERONET - 2008
N=1105
Nbin=50
Nmpb=22
AOD difference (POLDER - AERONET)
AERONET AOD


Comparison of AOD GRASP POLDER with AERONET
AERONET station:
Mongu
R=0.947
RMSE=0.095
y = 1.11x + 0.00
N=81
R=0.95
AOD 565 nm POLDER GRASP
AOD 565 nm AERONET


Time series of AOD GRASP POLDER and AERONET
AOD POLDER GRASP
AOD AERONET
AOD 565 nm
2008-04-01
2008-07-01
2008-10-01
Date


R=0.940
RMSE=0.146
y = 0.83x + 0.05
N=1105
POLDER AOD 565 nm
Aeronet AOD 565 nm

Conclusion

- Different versions of GRASP processor has been installed and tested successfully in the offline environment of EUMETSAT,
- The results are evaluated and analysis of retrieved parameters is ongoing to identify and propose the room for improvement;
- An improvement is expected in term of performance compared to previous retrieval algorithms but also wrt the content of the product;
- The prototype of operational processor is under development to transport GRASP to Ground-Segment of EUMETSAT;
- We can tailor the product to better meet the requirement (in term of product content and accuracy) from users.
- 3MI GRASP will be contributing to the MAP synergy product as the scientific core of retrieval algorithm.

References

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[2] Fougnie, B., Marbach, T., Lacan, A., Lang, R., Schlüssel, P., Poli, G., Munro, R., Couto, A. B., The multi-viewing multi-channel multi-polarisation imager – Overview of the 3MI polarimetric mission for aerosol and cloud characterization, Journal of Quantitative Spectroscopy and Radiative Transfer, 2018.

[3] Fougnie, B., Chimot, J., Vázquez-Navarro, M., Marbach, T., Bojkov, B., Aerosol retrieval from space – how does geometry of acquisition impact our ability to characterize aerosol properties, Journal of Quantitative Spectroscopy and Radiative Transfer,
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Thank you for your contribution !