Overview of the GRASP applications

Anton Lopatin, O. Dubovik*, T. Lapyonok*, P. Litvinov, B. Torres*, C. Chen*, C. Matar, C. Li, M. Herreras, S. Zhai, M. Herrera, M. Momoi, W. Lin, Zh. Liu, K. Kuznetsov, A. Kumar, E. Llopis, P. Tytgat, S.Panda and Y. Zhen

D. Fuertes, J-C. Antuna Sanchez, A. Garcia, G. Cancio, G. Alonso, F. Rejano, M. Veloso and A. Cano and P. Lopez

V. Martins, R. Kleidman, L. Remer, J.G. McDaniel, M. Gibson and J. Hall

Funded by the European Union

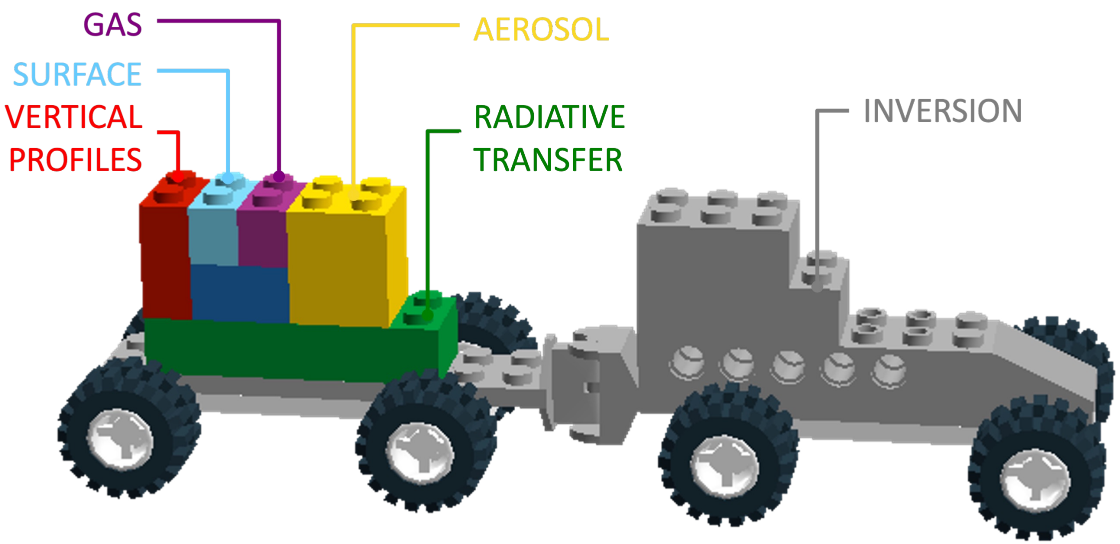
GRASP: Generalized Retrieval of Atmosphere and Surface Properties

GRASP is advanced algorithm for retrieval of aerosol, gas and surface properties from diverse remote sensing observations and any combination of them based on:

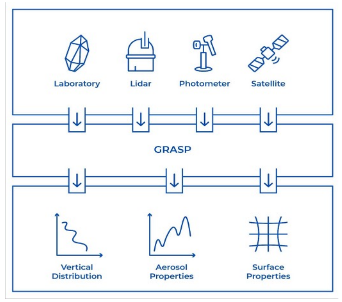
Forward Model for rigorous simulation of atm. radiation.

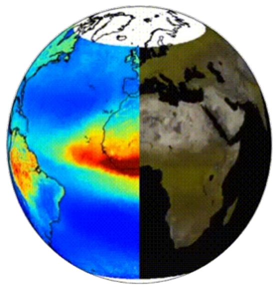
+

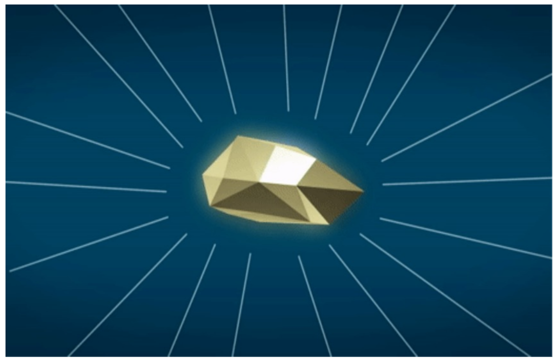
Inversion with *ap*plying multiple *a priori* constraints



Dubovik et al. "A Comprehensive Description of Multi-Term LSM for Applying Multiple a Priori Constraints in Problems of Atmospheric Remote Sensing: GRASP Algorithm, Concept, and Applications", Front. Remote Sens., 2021

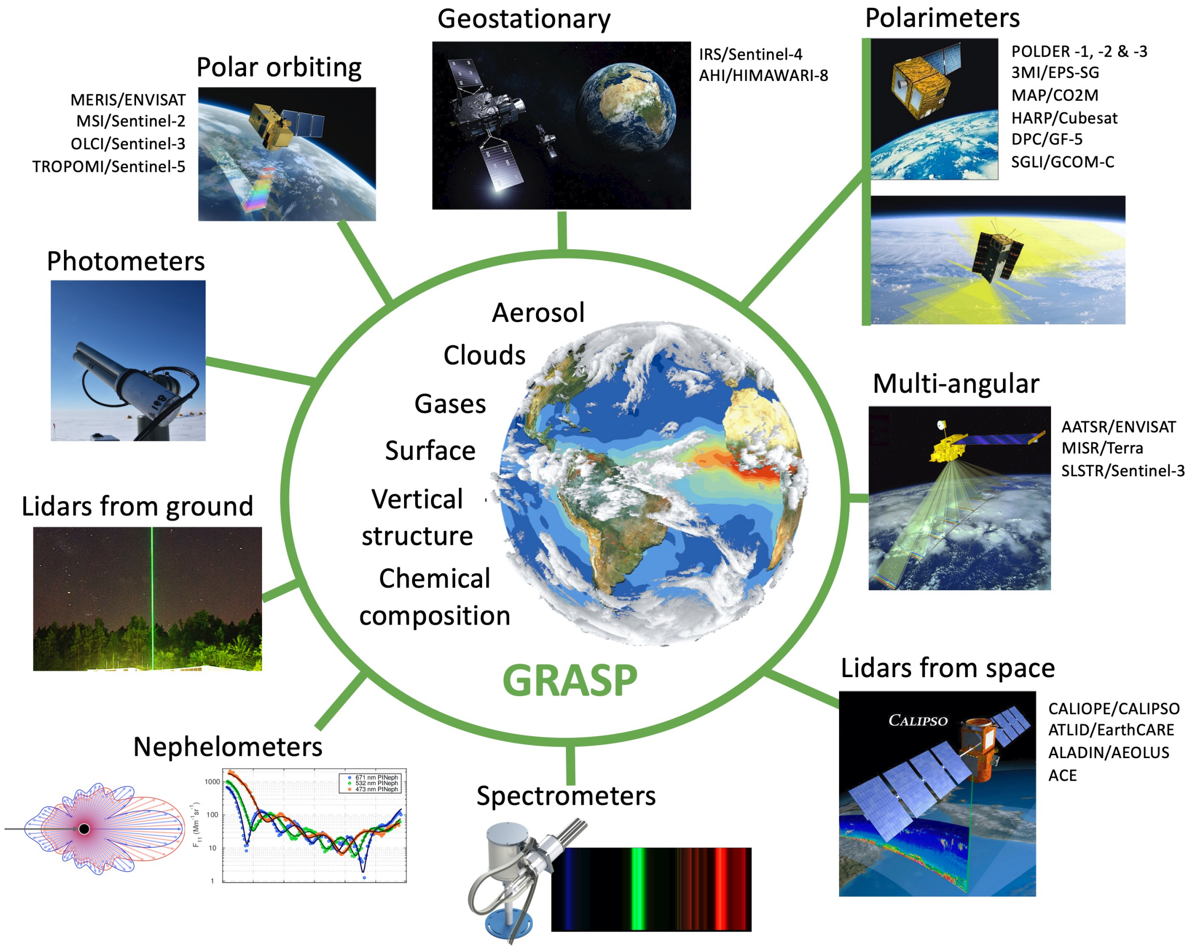






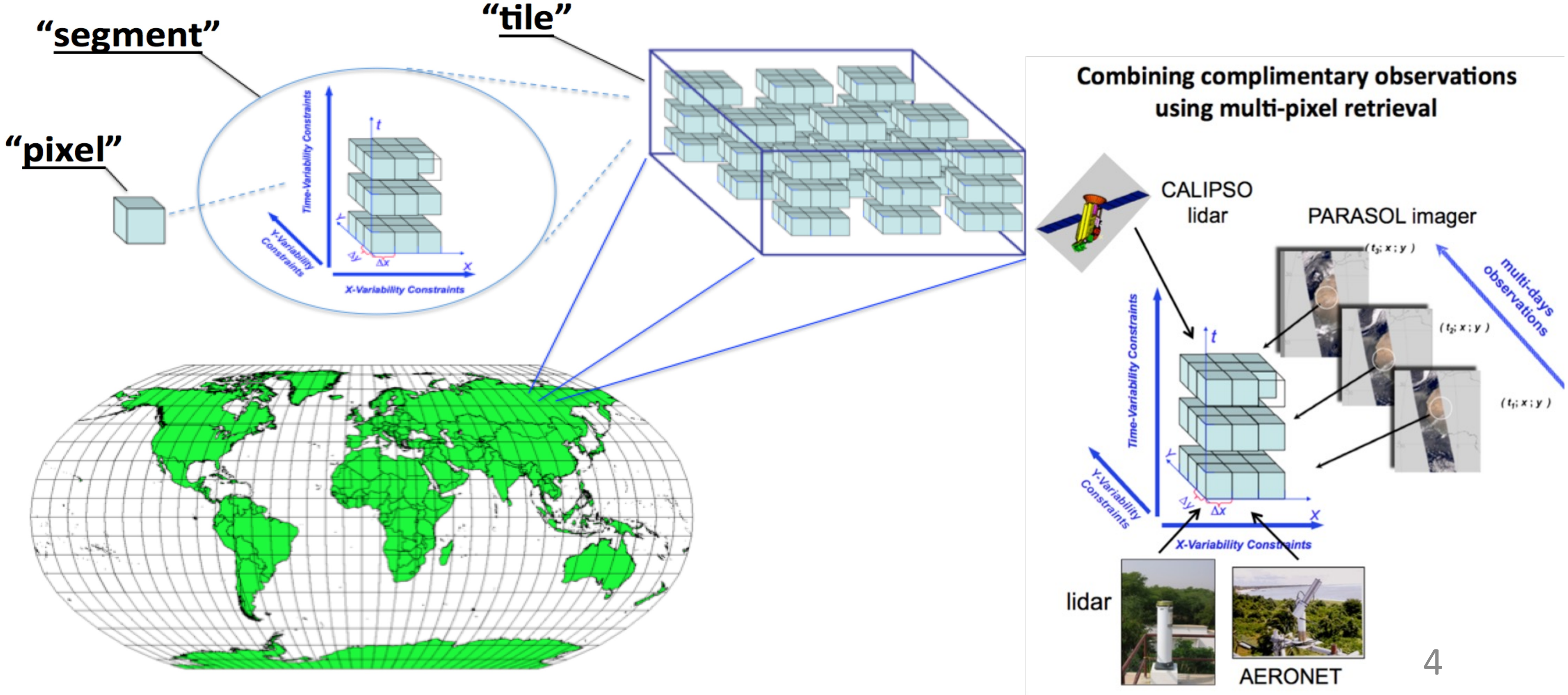
More about inversion @16:00 by Oleg Dubovik

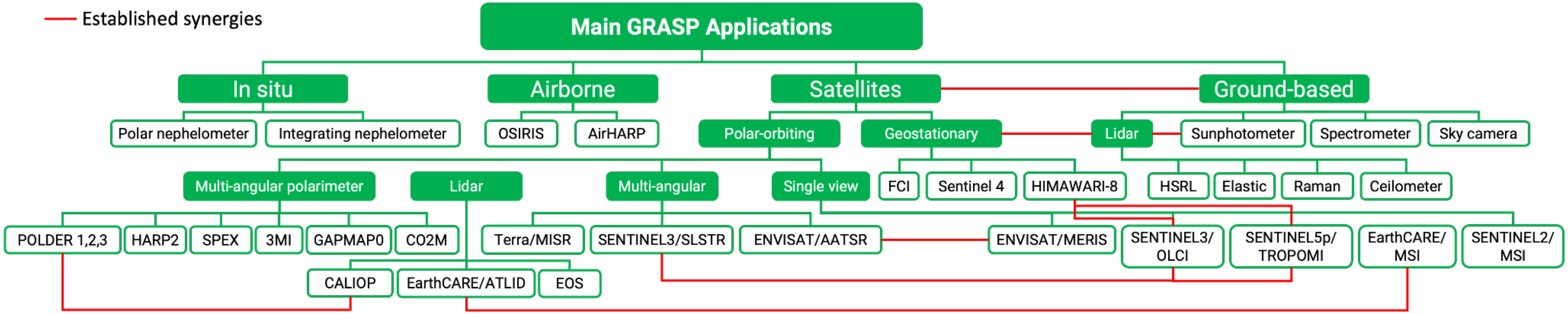
Generalized forward model

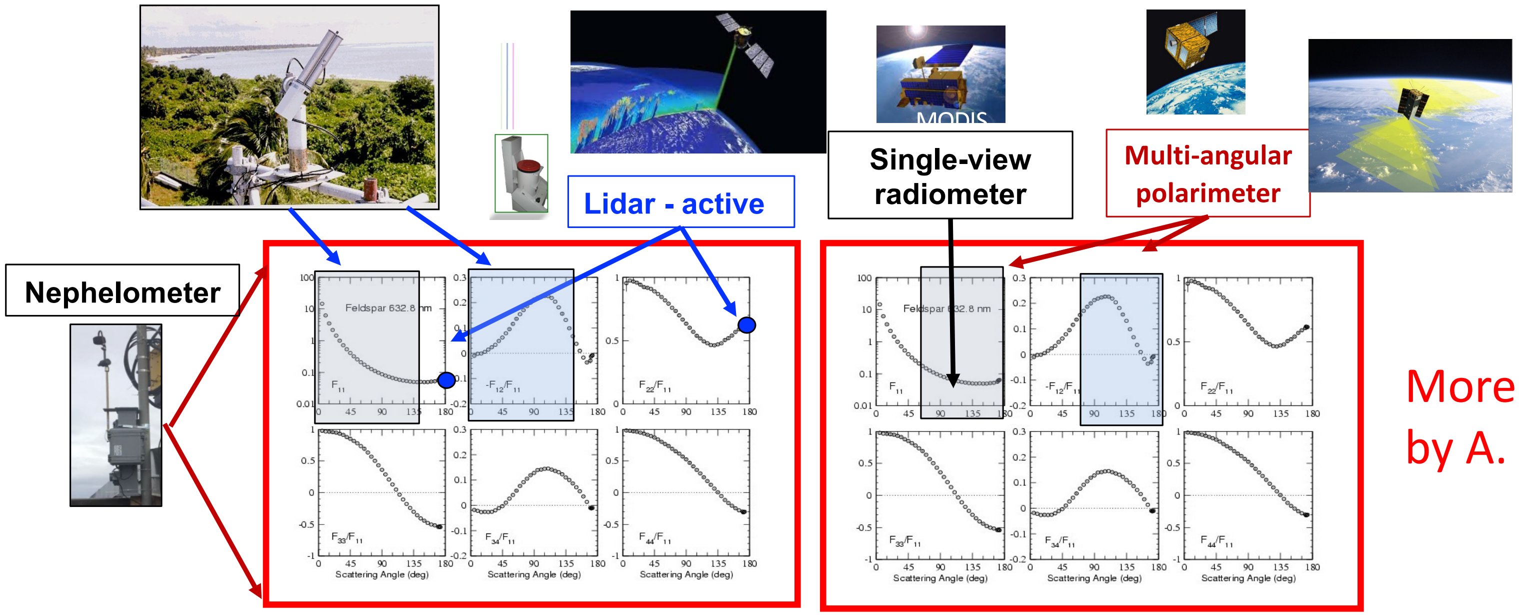


The concept of multi-pixel retrieval

Dubovik et al. 2011





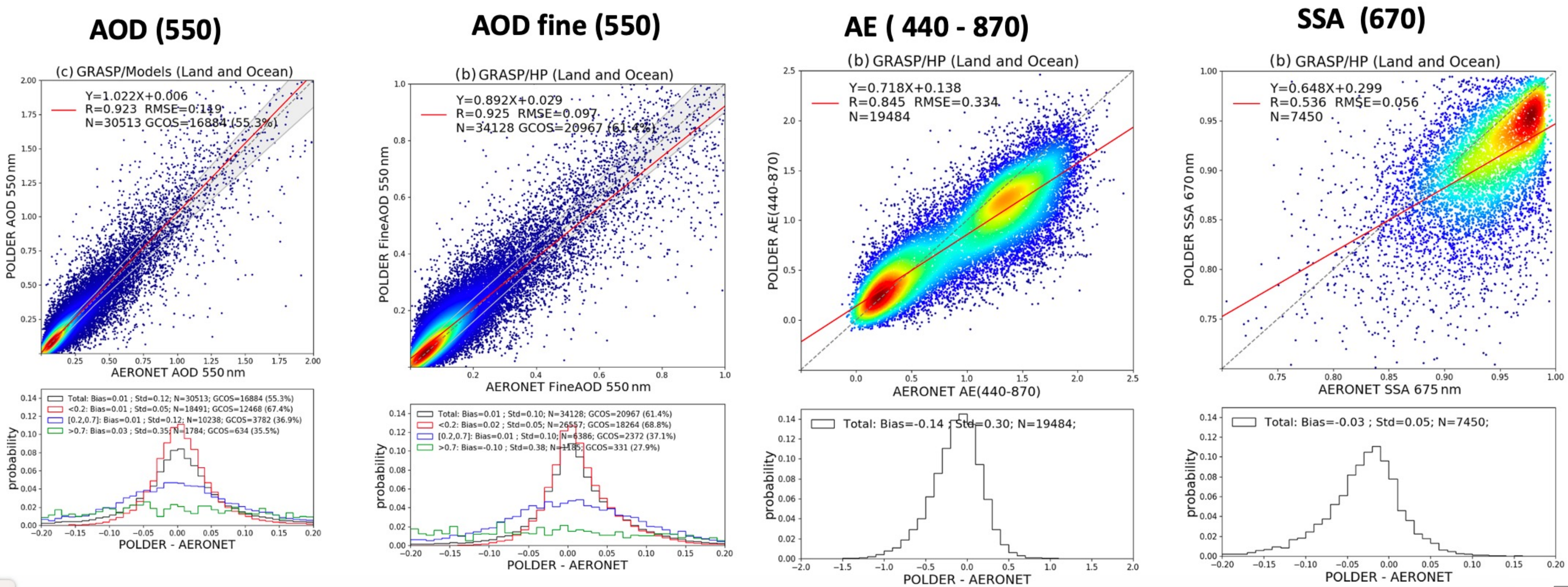


More in next talk by A. Lopatin!

AHI/Himawari
GRASP aerosol and surface product developments
GAPMAP-0
2023-
DPC/GF-5
2022-
DPC Hardware Construction
MAP – Multi – Angular Polarimeters
OLCI/S-3A 2016-
OLCI/S-3B 2018-
TROPOMI/S-5P
2017-
S-4 2024
MAP/CO2M 2026 -
3MI/MetOP-SG
2025 ?
-
2037
Past mission
ENVISAT 2012-2012
MERIS
AATSR
MERIS + AATSR
Copernicus Sentinel missions
esa
atmospheric missions
S-1
Radar
A 3 Apr. 2014
B 25 Apr. 2016
S-2
High Resolution Optical
A 23 Jun. 2015
B 6 Mar. 2017
S-3
Medium Resolution Optical & Altimetry
A 16 Feb. 2016
B 25 Apr. 2018
S-4
Atmospheric Chemistry (GEO)
A 2021
B 2027
S-5P
Atmospheric Chemistry (LEO)
A 13 Oct. 2017
S-5
Atmospheric Chemistry (LEO)
A 2021
B 2027
S-6
Altimetry
A 2020
B 2025
S-7
Candidate
CO_2 Monitoring Mission
envisaged 2025
Past mission
POLDER-1, -2, -3
08/1996- 06/1997
12/2003-09/2004
2004-2013
EUMETSAT
esa
European Space Agency
cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES
NASA

GRASP results validation against AERONET

Globally over Land and Ocean for 2004 – 2013 years (Chen et al., 2020)



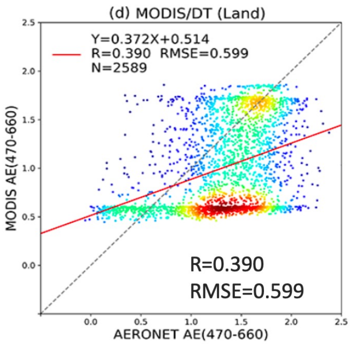
CONSLUSIONS from POLDER aerosol product analysis :

Detailed properties - **AE, fine /coarse AOD** (ocean), from MAP generally notably more accurate than from MODIS like instruments;

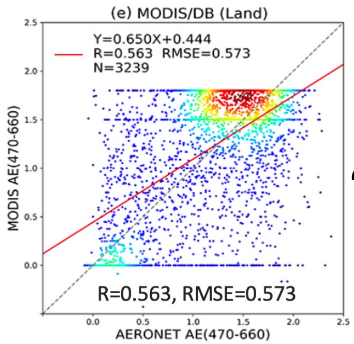
Angstrom Exponent, 2008 (LAND) Validation against AERONET

AE , 2008 (LAND)

MODIS/DT

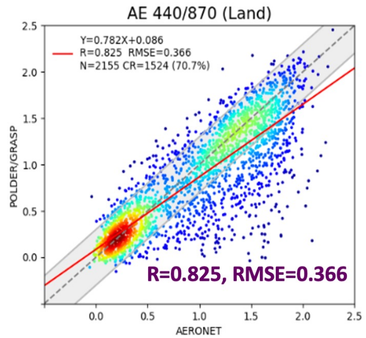


MODIS/DB

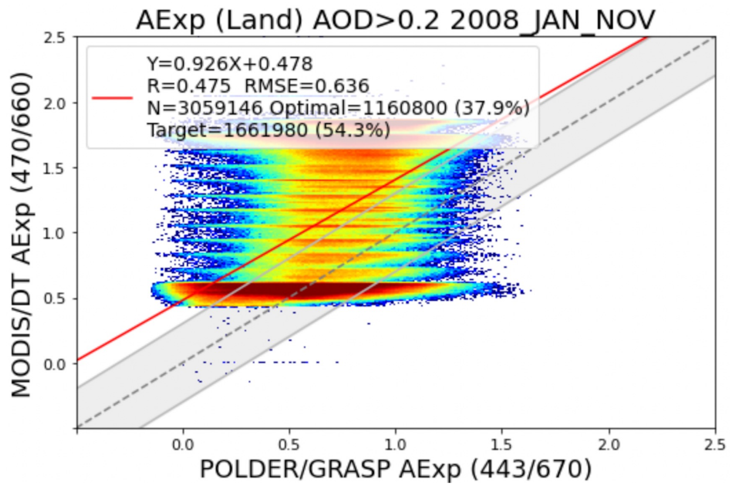


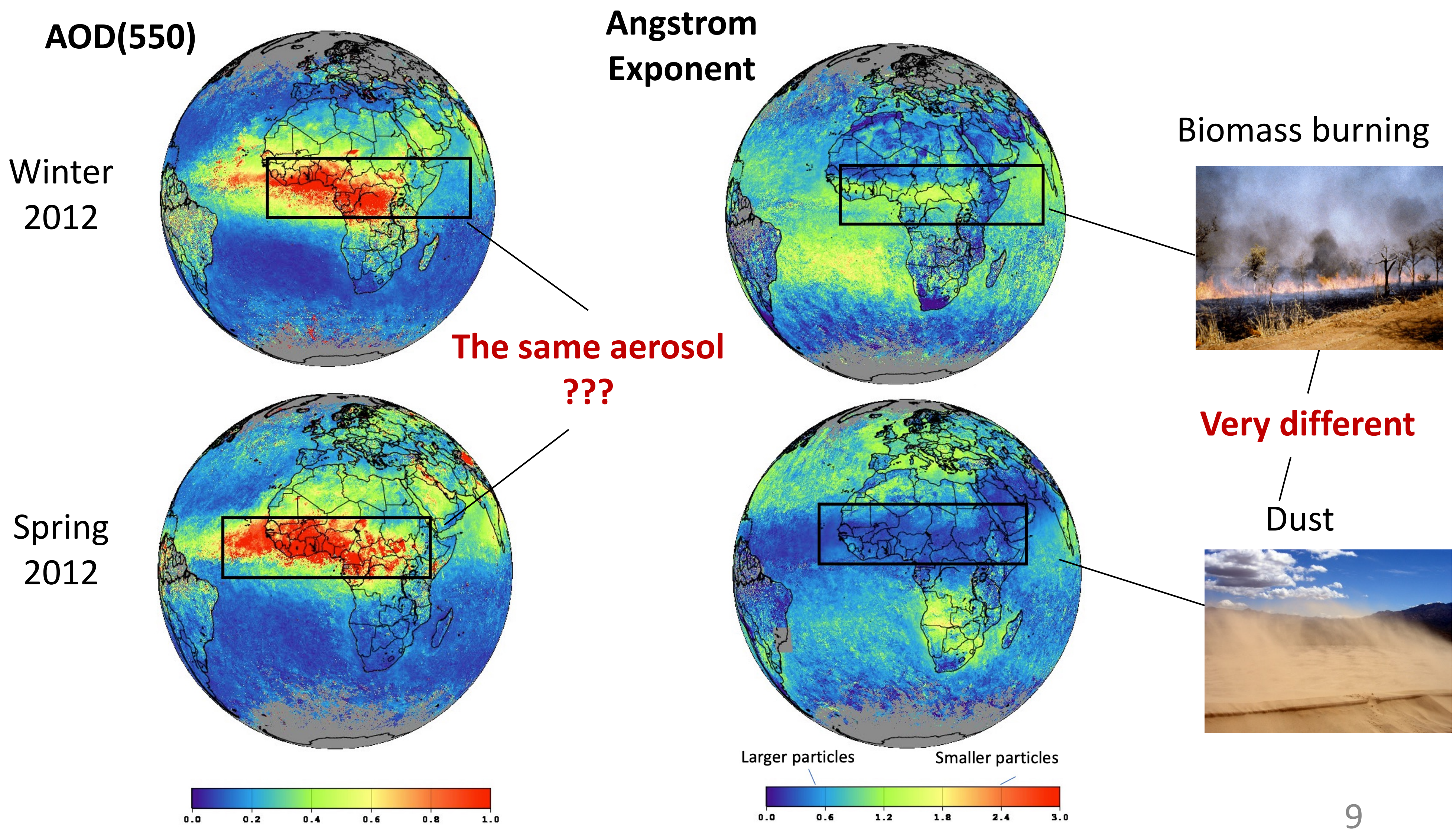
~

POLDER/ GRASP



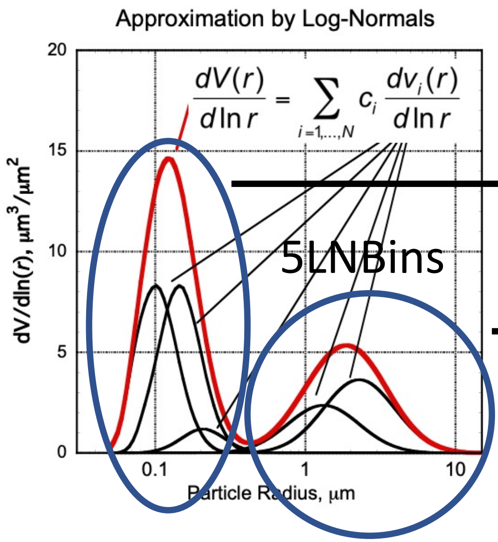
→ **MODIS**



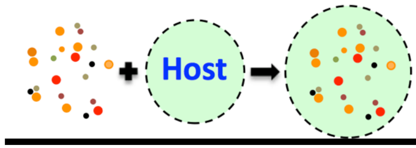

AOD(550)
Angstrom Exponent
Winter 2012
Spring 2012
The same aerosol ???
Biomass burning
Very different
Dust
0.0
0.2
0.4
0.6
0.8
1.0
Larger particles
Smaller particles
0.0
0.6
1.2
1.8
2.4
3.0

Evolution: GRASP Component approach

(Li et al., 2019, 2020, 2022)



Fine mode



Maxwell Garnett

effective medium approximation

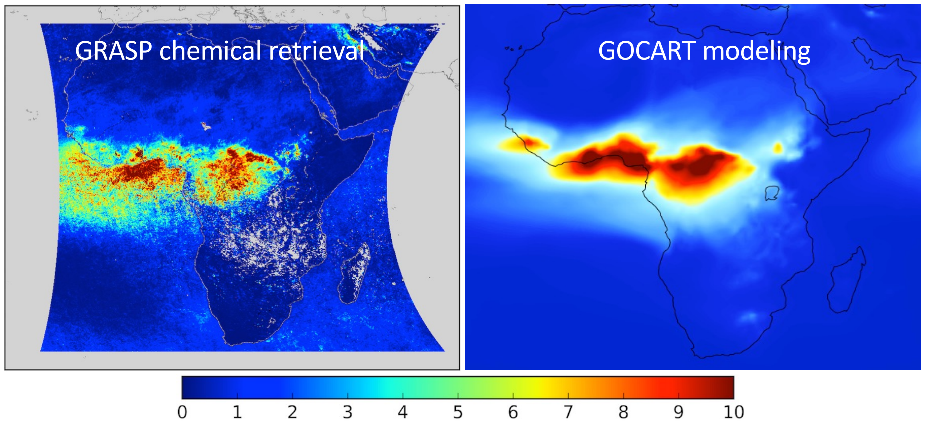
Coarse mode

Fine mode

- BC
- BrC
- Non-absorbing soluble
- Non-absorbing insoluble
- Water

Coarse mode

- Absorbing insoluble (FeOx)
- Non-absorbing insoluble (Dust)
- Non-absorbing soluble (SS, etc.)
- Water



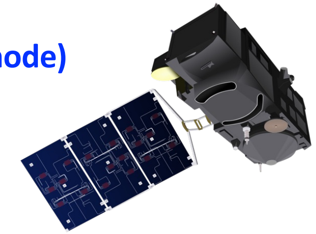
By using ***prescribed spectral refractive index*** of components, *GRASP/Component approach provides consistent and stable results for AOD as well as detailed properties*.

Sentinel-3A/OLCI

Chen et al., 2022, Rem. Sens. Environ

Ocean and Land Color Instrument (OLCI)

Onboard Sentinel-3A Single-viewing
Overpass: ~10 a.m. L.T. (descending node)
Bands: 412 – 1020 nm

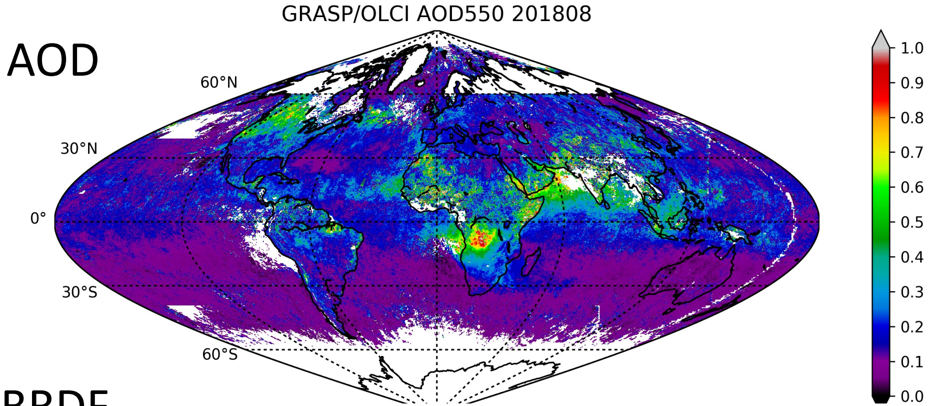


L1B RR -> Target 10km pixel aerosol and surface retrieval

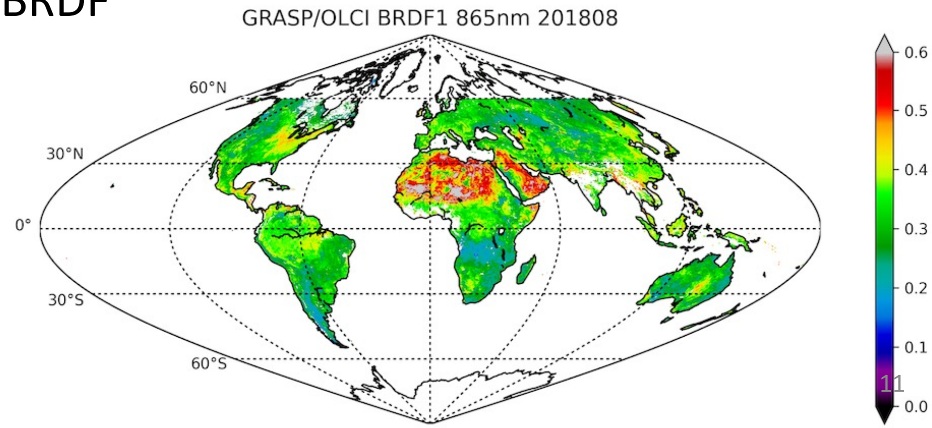
OLCI-A Band	Central Wavelength (nm)	Band Width (nm)	Radiance Bias Correction
Oa02	412.5	10	-2%
Oa03	442.5	10	-2%
Oa04	490	10	-2%
Oa05	510	10	-2%
Oa06	560	10	-2%
Oa08	665	10	-2%
Oa12	753	7.5	-2%
Oa17	865	20	-2%
Oa21	1020	40	-6%

OLCI/GRASP – product. (2018-2019)

AOD



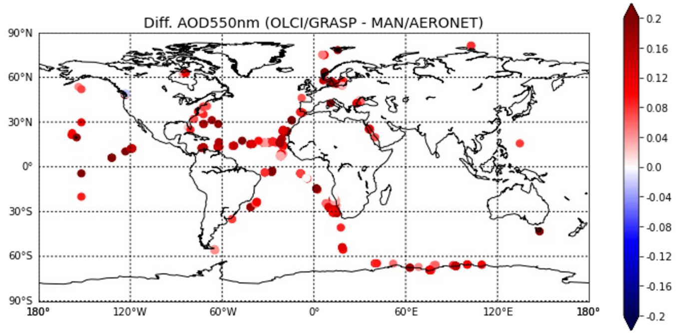
BRDF



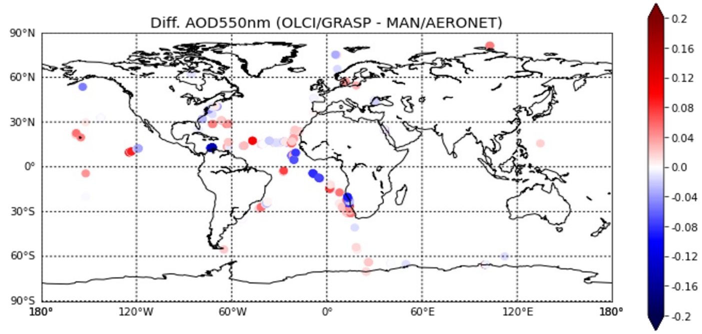
✓ *AOD retrieval over ocean*

1 yr validation with **MAN**/AERONET

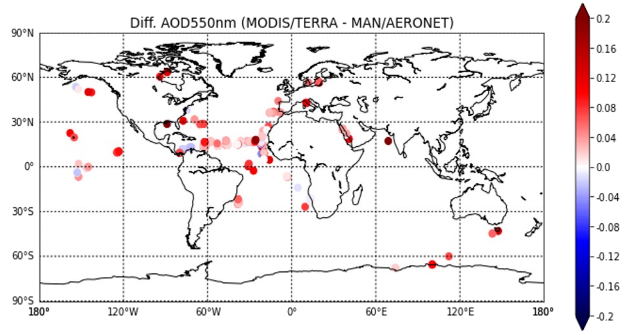
OLCI/GRASP (Initial) - MAN



OLCI/GRASP (Optimized) - MAN



MODIS/TERRA - MAN

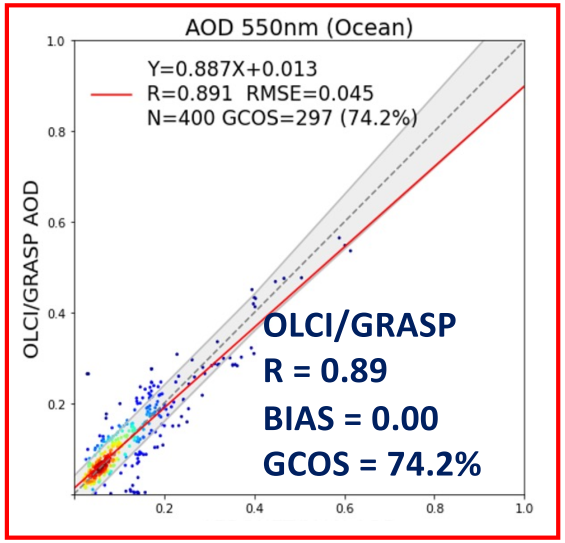


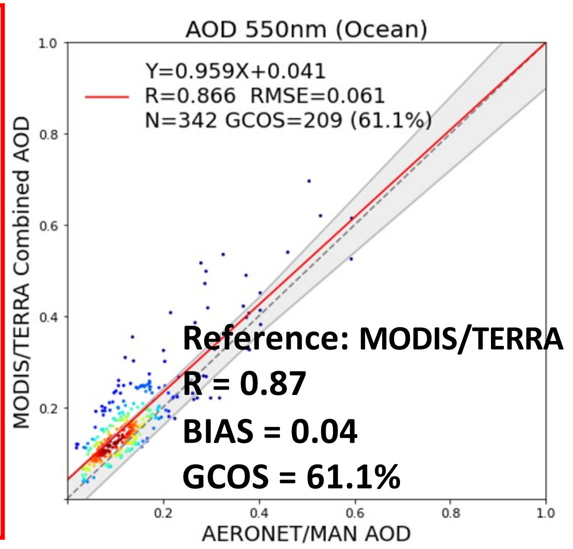
Observed improvements:

a. Clear evolution from Initial to Optimized OLCI/GRASP retrieval over ocean

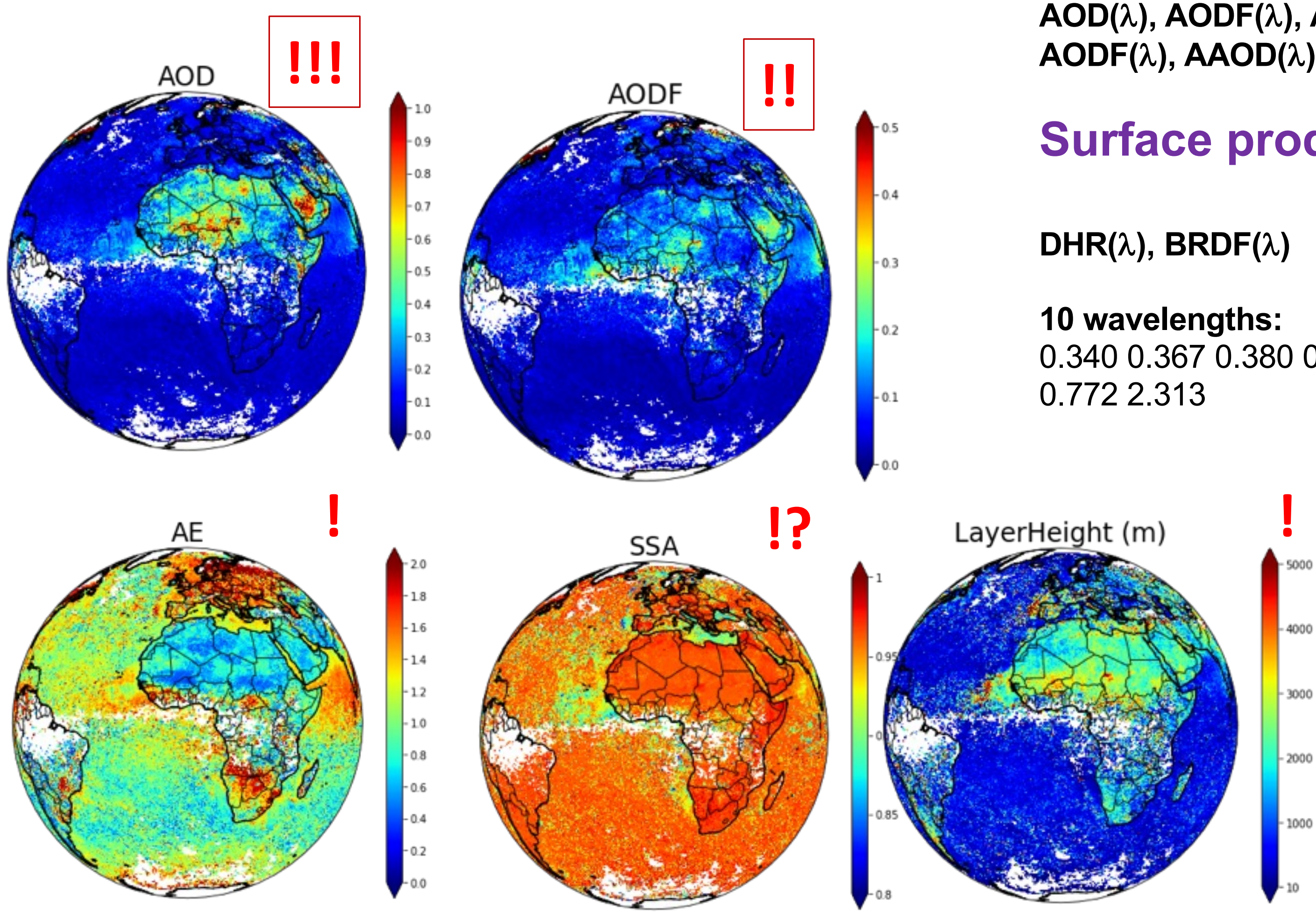
b. The AOD BIAS decrease from +0.11 to +0.01 with AERONET coastal sites and ~0.00 with MAN deep ocean measurements.

c. Comparable quality of AOD product with MODIS/TERRA. The OLCI/GRASP bias is even smaller than MODIS/TERRA over ocean.





TROPOMI/GRASP (2019-2020, …)



Aerosol products:

AOD(λ), AODF(λ), AODC(λ), SSA(λ), AODF(λ), AAOD(λ), AE, Aerosol Height

Surface products:

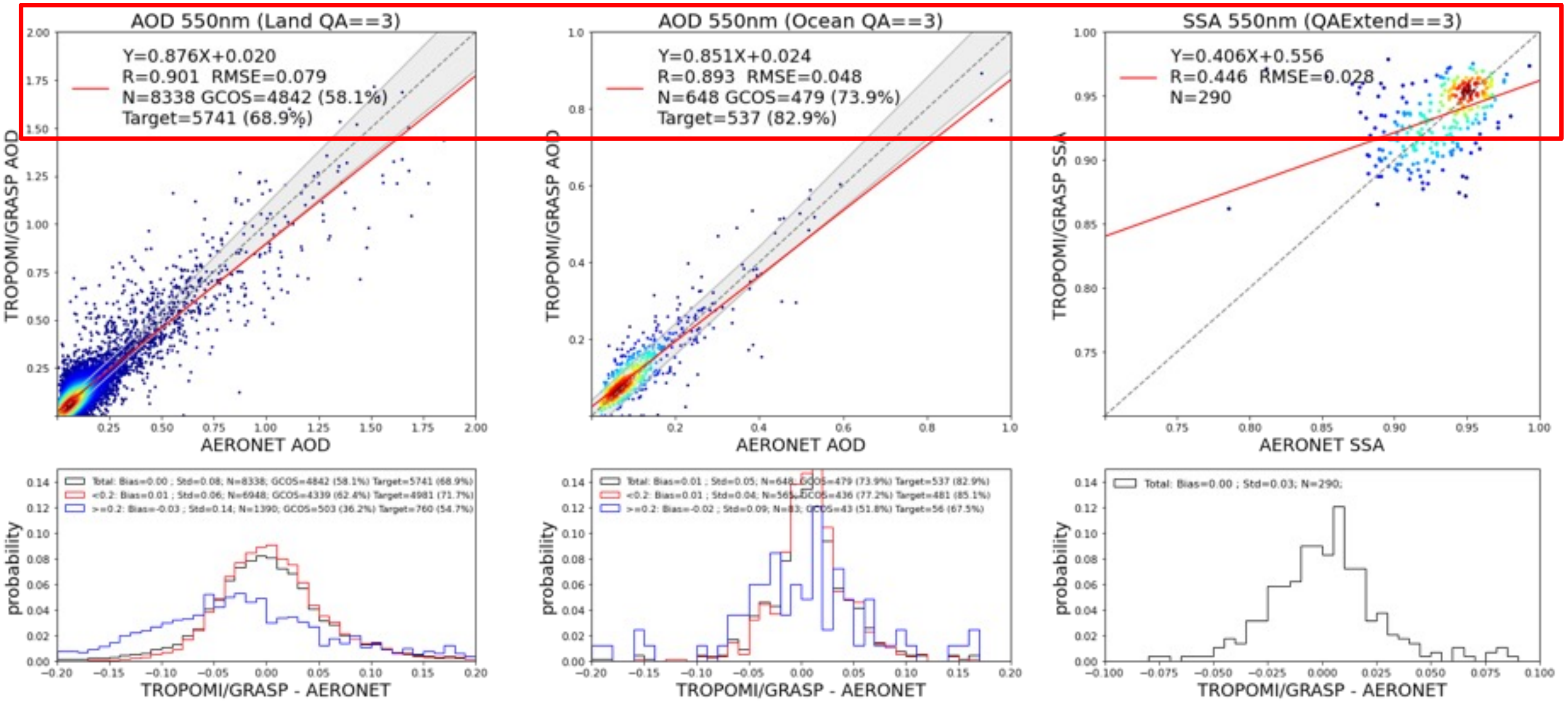
DHR(λ), BRDF(λ)

10 wavelengths:
0.340 0.367 0.380 0.416, 0.440 0.494 0.670 0.747 0.772 2.313

Litvinov et al., 2024
Chen et al., 2024

GRASP

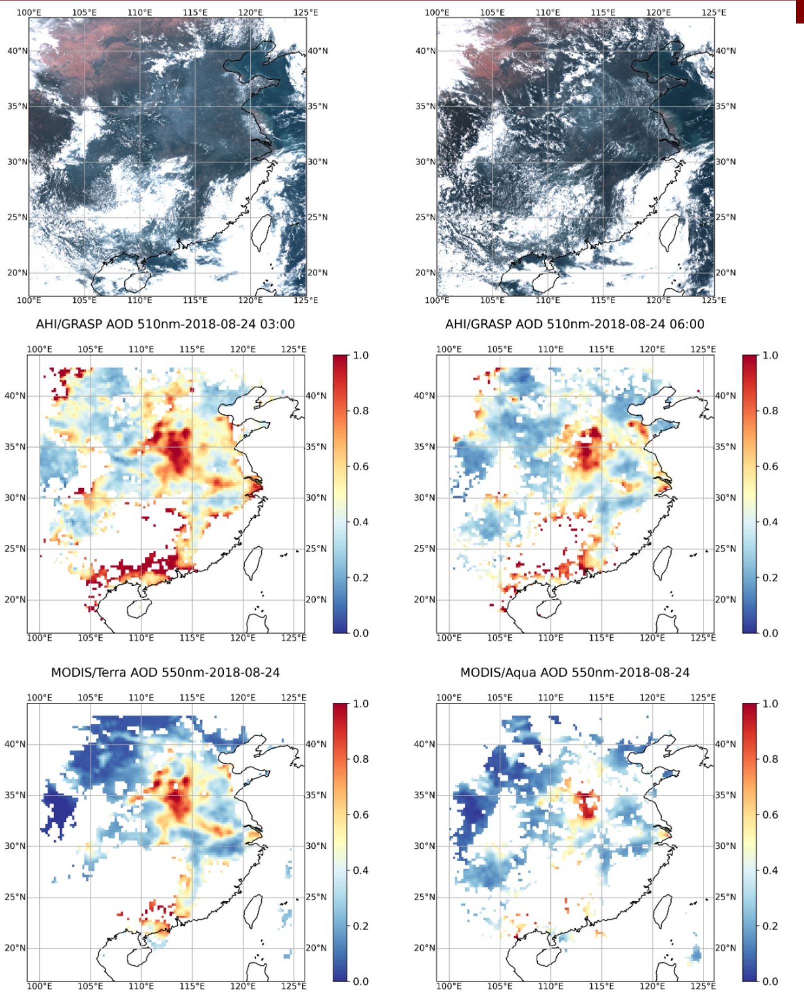
S-5P/GRASP aerosol product validation

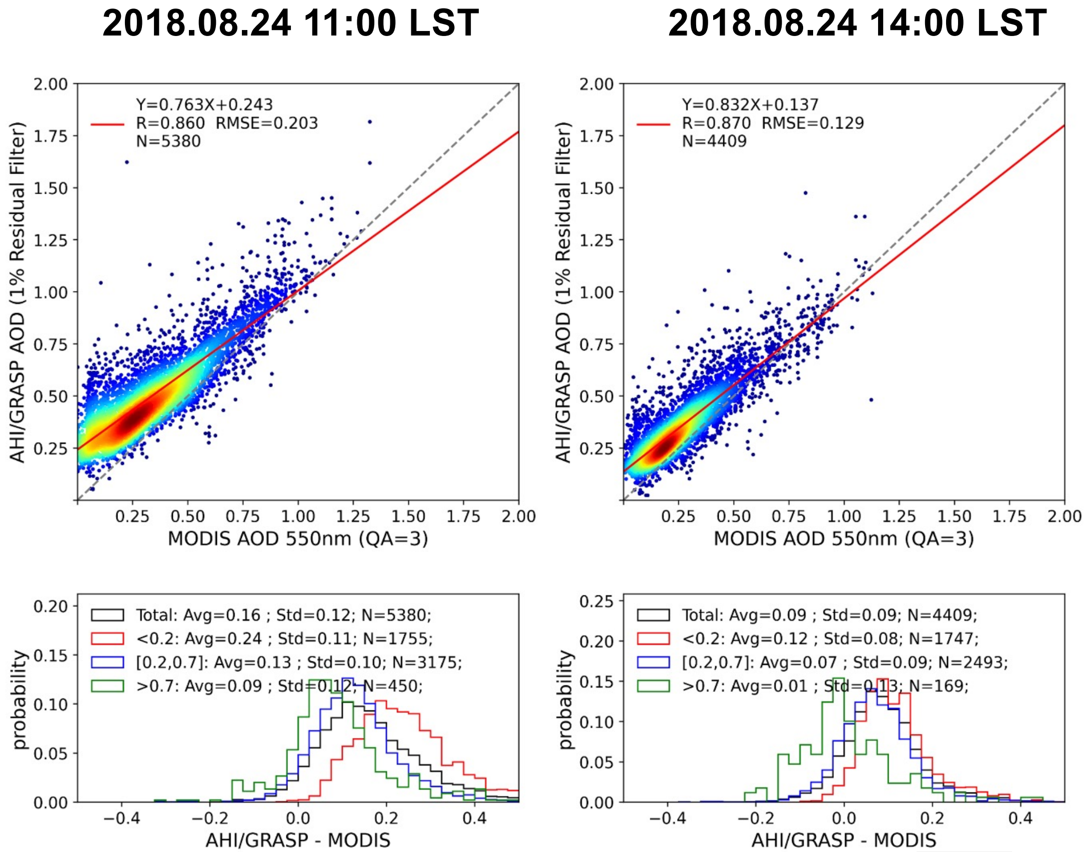


S-5P/GRASP products show to:

- be of comparable accuracy of those of MODIS;
- provide Some information about SSA and aerosol height

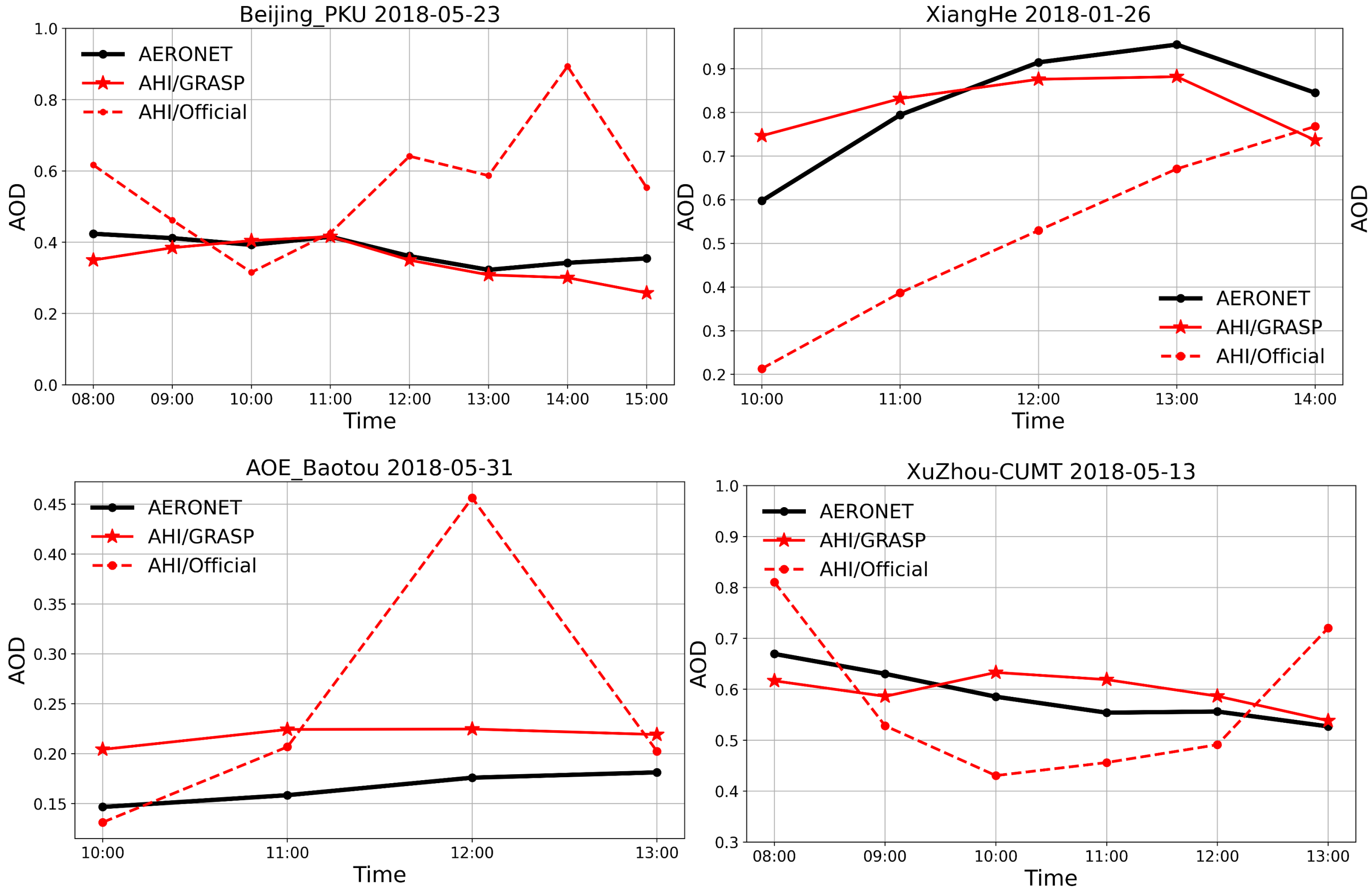
AHI/GRASP vs MODIS AOD Comparison





Data: 2018.08.24 11:00 14:00LST RGB Image; AHI/GRASP AOD; MODIS C6.1 Aqua/Terra AOD

AHI/GRASP vs AERONET Validations (AOD Diurnal Cycle)

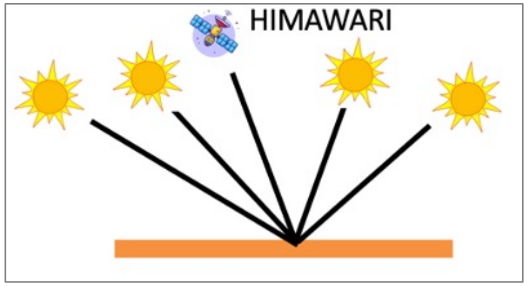


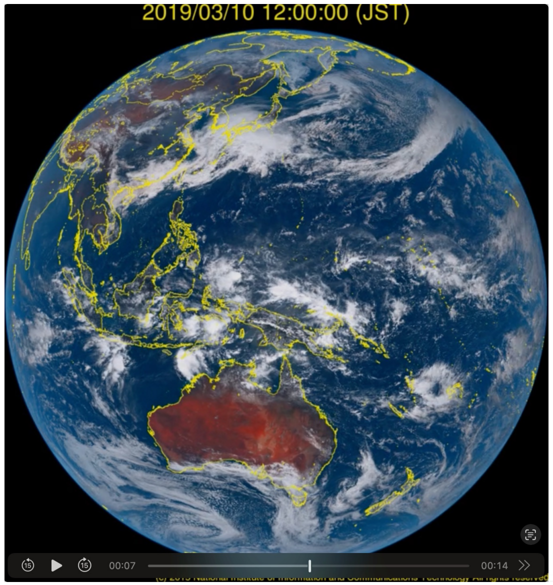
Black: AERONET AOD
Red** AHI/GRASP AOD
Red-- AHI/JAXA AOD

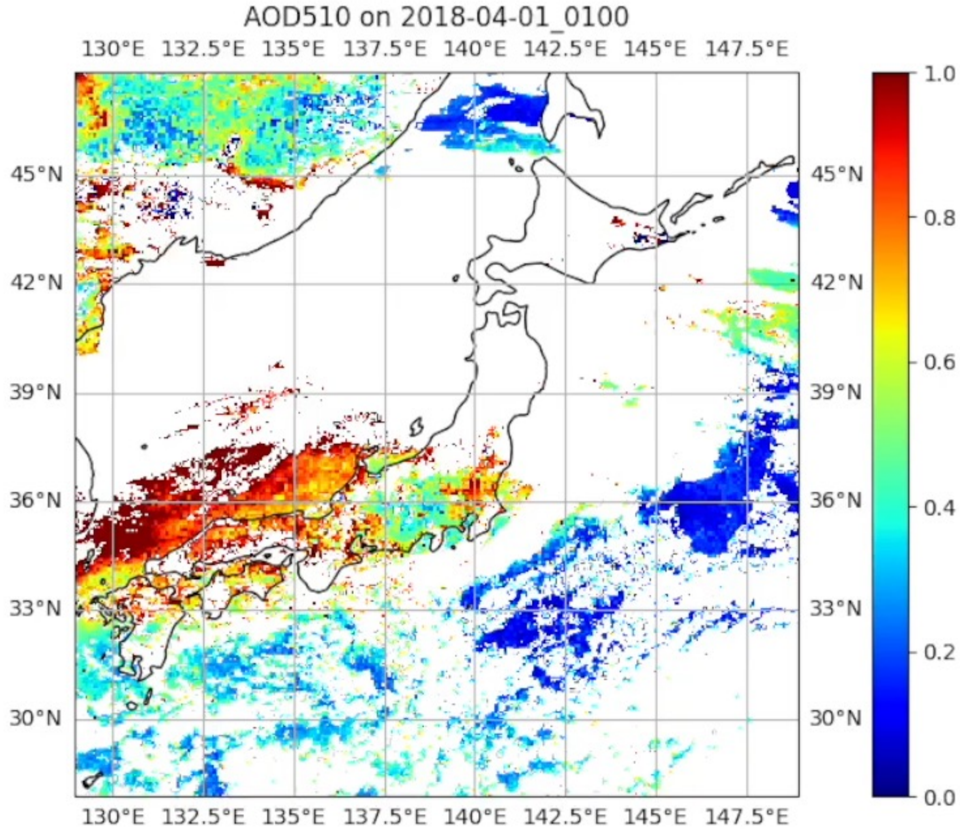
- AHI/GRASP improves AOD diurnal cycle retrieval

Data: AHI/GRASP; AHI/JAXA; AERONET

HIMAWARI/ GRASP-NN 4 times faster







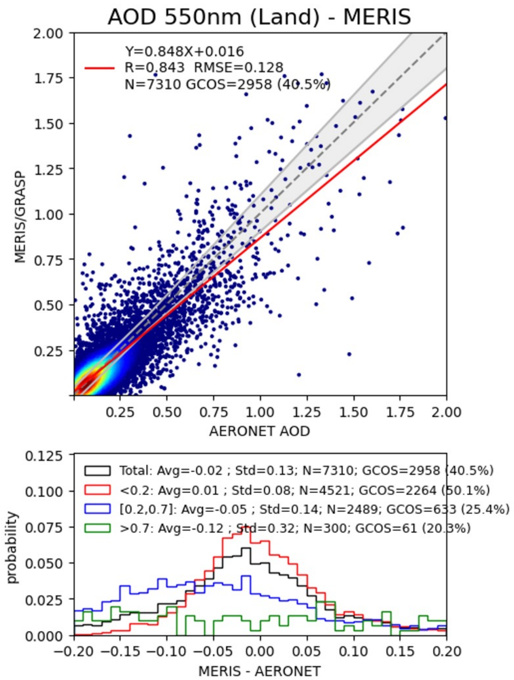
Asian dust storm

Multi-instrument synergies

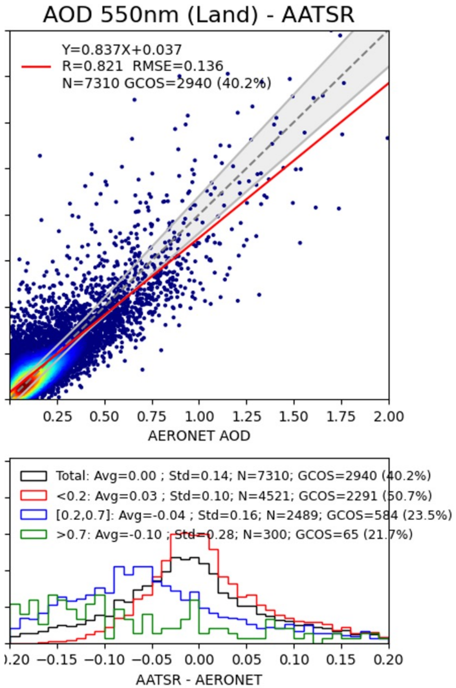
ENVISAT/GRASP (2002-2012)

AOD(550)

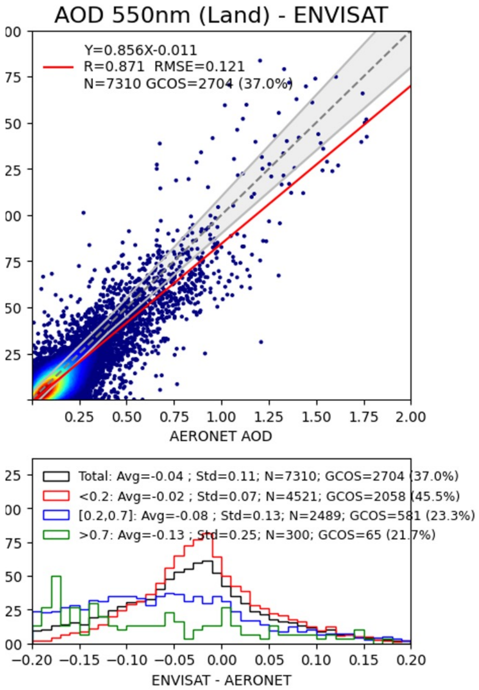
MERIS



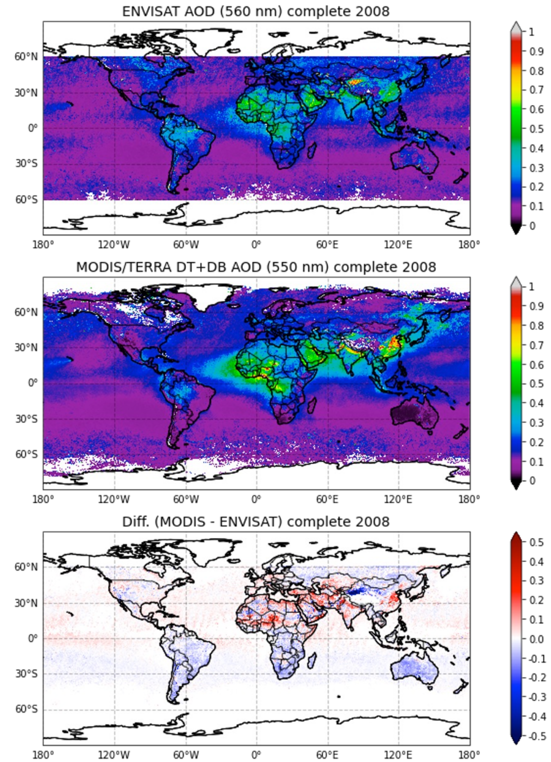
AATSR



MERIS + AATSR



ENVISAT vs MODIS

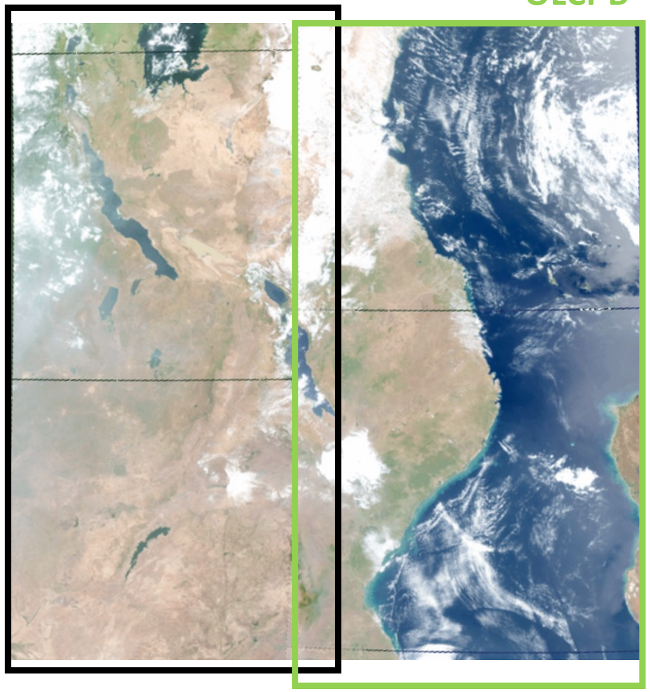


Lopatin et al, 2025 (in preparation)

Synergy of TROPOMI+ OLCI-A + OLCI-B +HIMAWARI

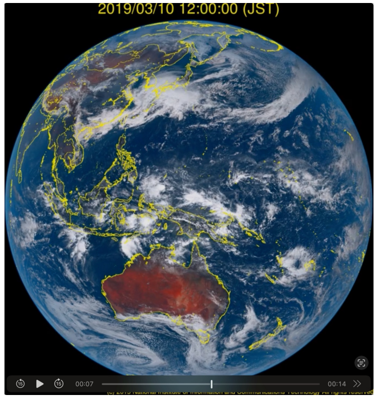
OLCI-A

OLCI-B

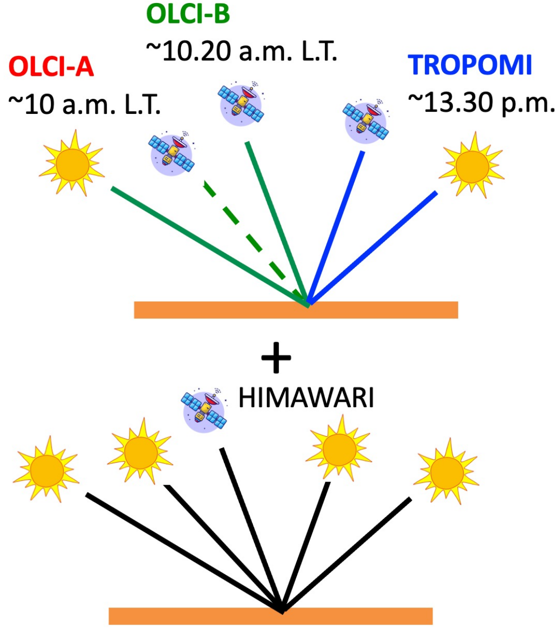


+

HIMAWARI -8



Pseudo "multi-angle", multi-temporal measurements



More exciting details in talk by Pavlo Litvinov (@ 14:30)

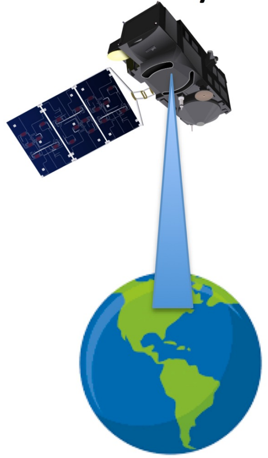
Back to Earth

Ground-based applications

GRASAT Synergetic Satellite + AERONET retrieval with GRASP

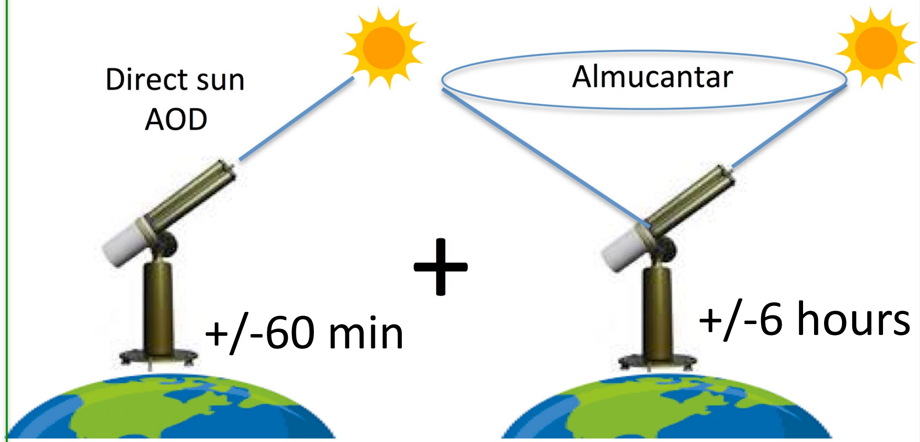
Satellite + Nearest AERONET TOD + Almucantar (or Combined Almucantar and Principal plane) measurements

Surface properties mainly



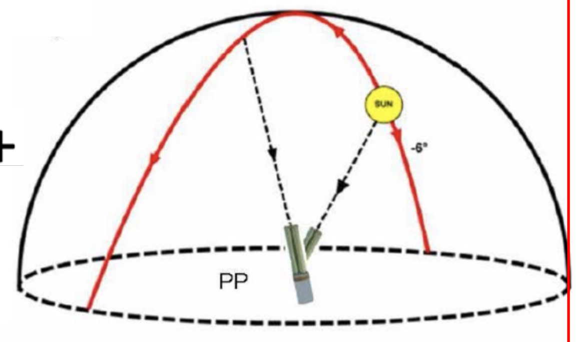
+

Aerosol properties mainly



+

Principal Plane



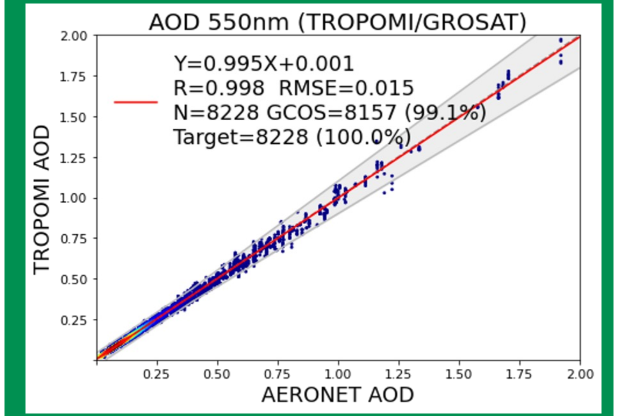
Conditions:

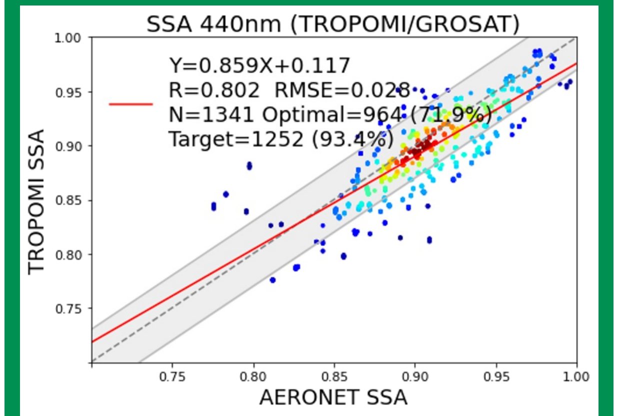
1. Reasonable fit of measurements (less than radiometric error).
2. Good correspondence of the retrieved aerosol properties with AERONET.
3. Instrument is well calibrated.

New Possibilities:

1. Validation tool for forward models of aerosol and surface
2. Surface Reference Database for surface validation
3. Instrument inter-calibration.

Synergetic satellite + AERONET retrieval: validation of aerosol models





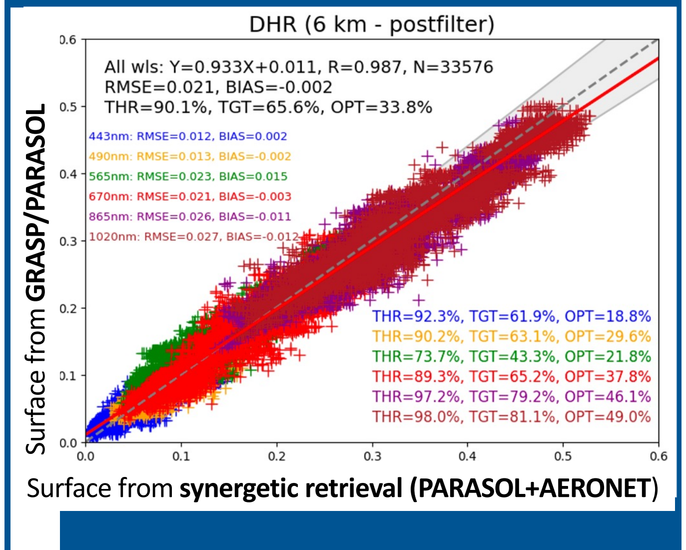
ESA GROSAT project:

Surface reference dataset Selected satellites

Satellite	Resolution	Product
S2/MSI	20 m	BRDF, albedos
S3/OLCI	700 m; 10 km	BRDF, albedos
PARASOL/ POLDER	6 km	BRDF, BPDF, albedos
S5p/ TROPOMI	0.1 deg (~10 km)	BRDF, albedos

Surface BRDF/albedos	Uncertainties
Threshold	Max (0.02 or 20%)
Target	Max (0.01 or 10%)
GCOS (Optimal)	Max (0.0025 or 5%)

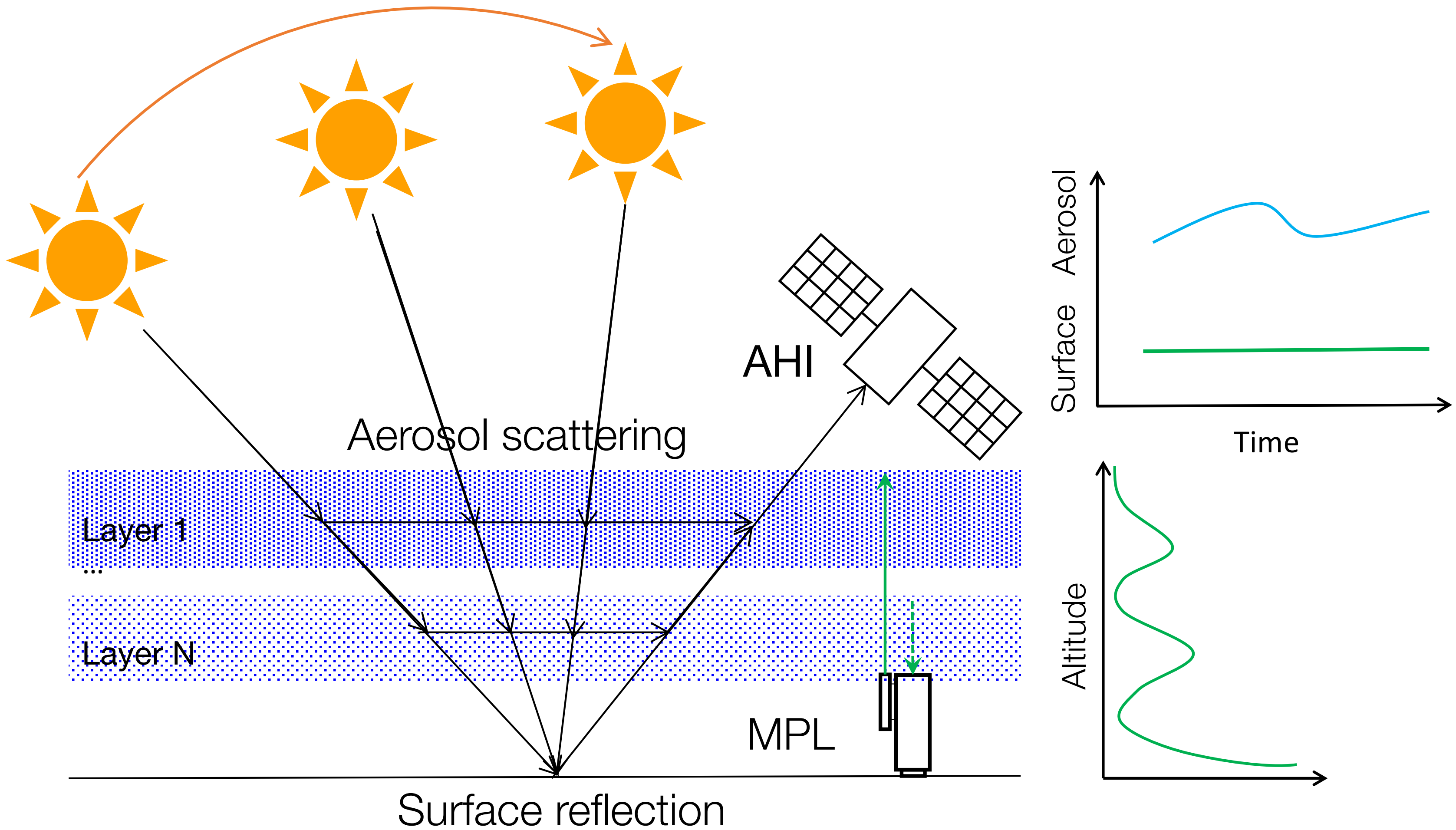
Synergetic satellite + AERONET retrieval: surface reference dataset



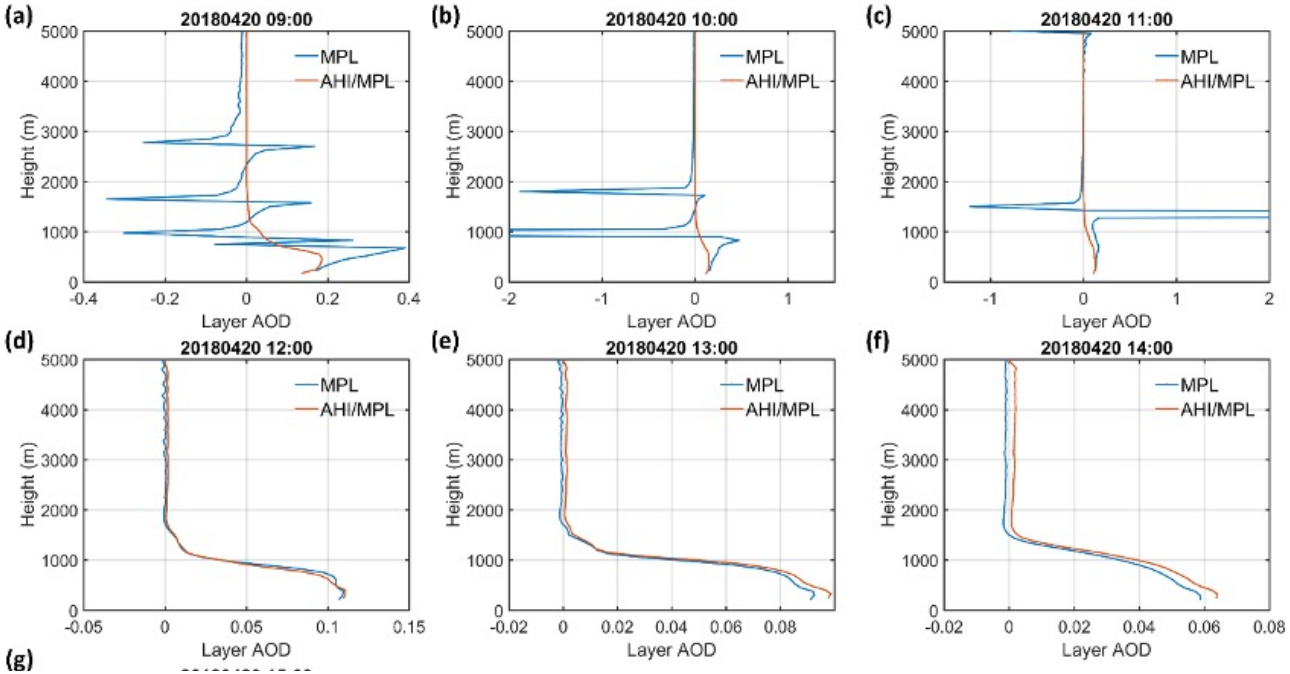
www.grasp-sas.com/projects/grosat/
eo4society.esa.int/projects/grosat

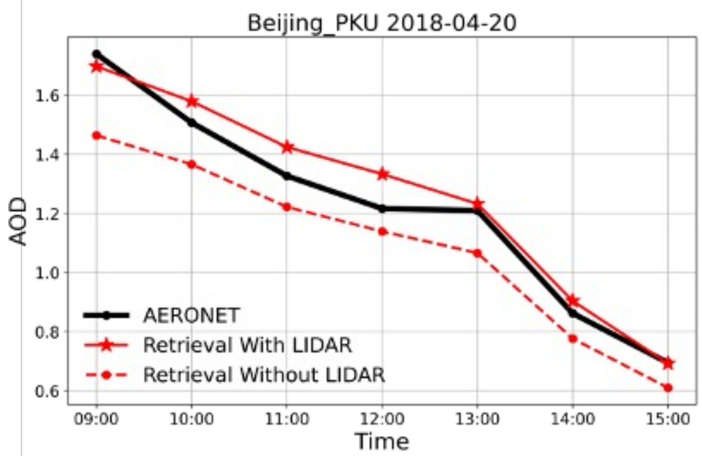
More details by Pavlo Litvinov (@ 14:30)

HIMAWARI8/AHI+MPL synergy



HIMAWARI+MPL



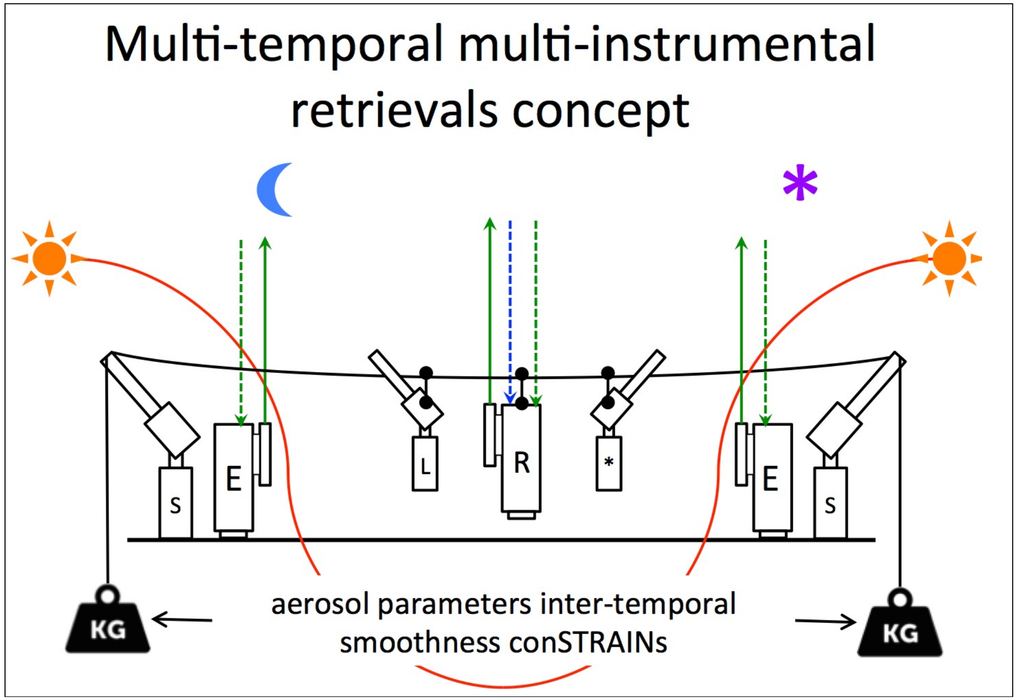


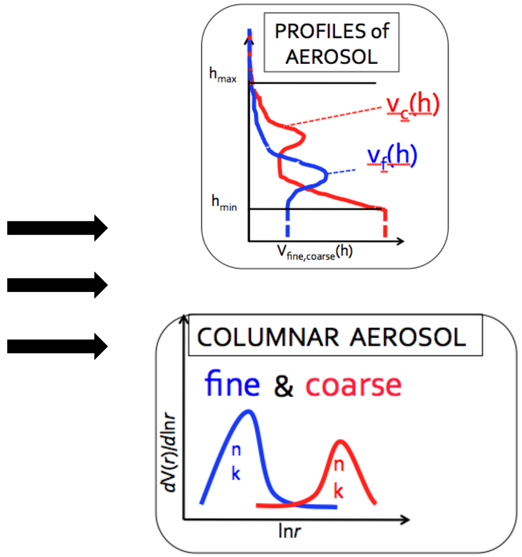
Not only space!!! Advanced processing of ground-based observations using GRASP

Lopatin et al., 2013, 2021, 2024

- combining observation during **several days**;
- combining **day and night** observations;
- combining **passive** (photometric) **and active** (lidar);
- combining **ground-based and satellite** observations;
- retrieving as many parameters as possible;

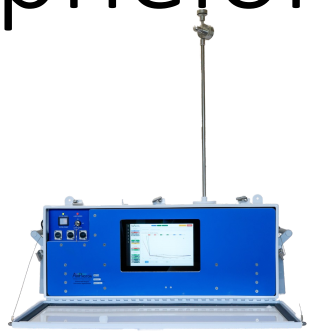
Expectations: more accurate and more complete validation data set





More details @ 12:30 by Anton Lopatin

In-Situ Nephelometers



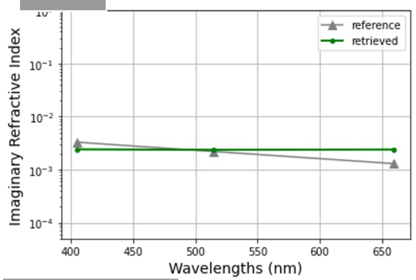
Instrument	Integrating	iMAP	Pi-Neph
Measurements	$P_{11}(\lambda,\Theta)$ @PM 1, 2.5, 4, 10	$P_{11}(\lambda,\Theta)$, $-P_{12}/P_{11}(\lambda,\Theta)$	
Angles	Forward: 7°–90° Backward: 90°–173°	5°, 10.5°, 31.8°, 63.5°, 95.3°, 116.5°, 148.2°, 169.4° (8 angles)	5° – 175°, 1° resolution (170 angles)
Wavelengths	450, 532, 660 nm	471, 529, 621 nm	405, 515, 660 nm

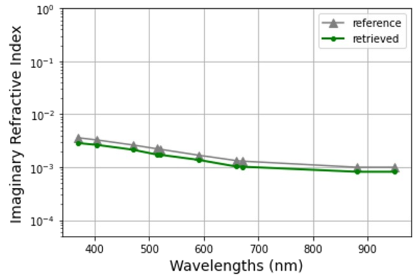
Pi-Neph

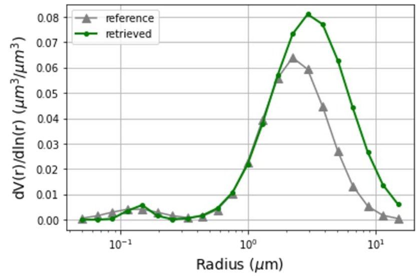
In-neph Combined with Aethalometer

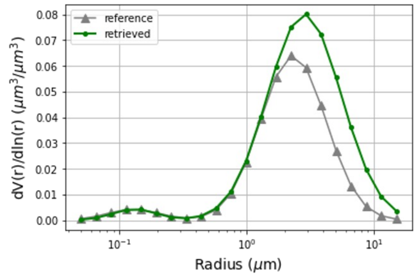
Adding Size Cut-off

Dust

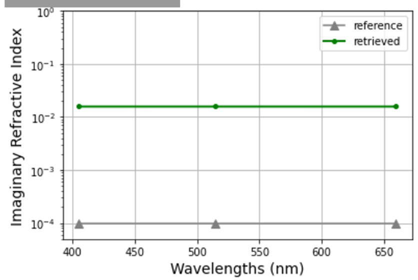


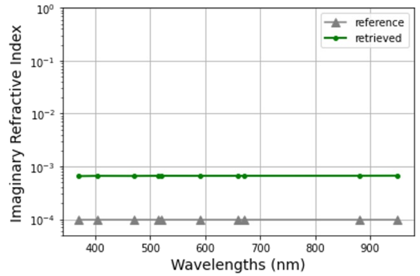


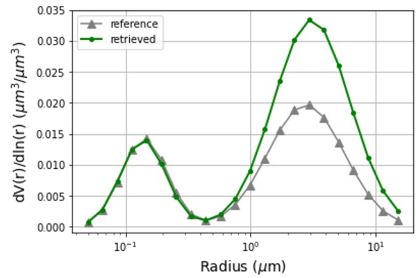


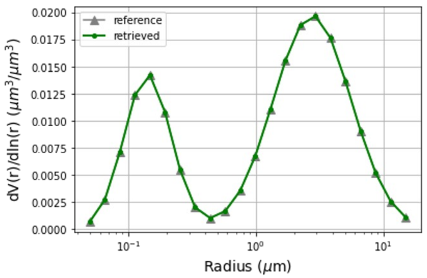


Oceanic

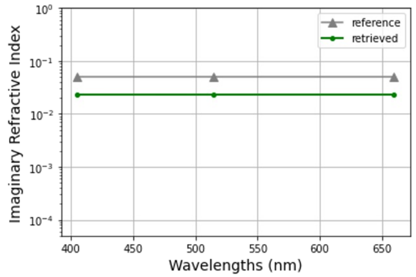


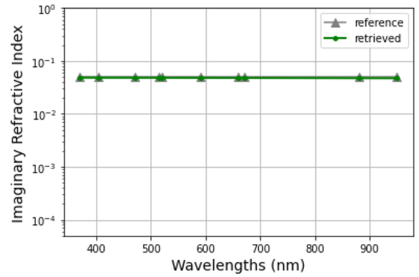






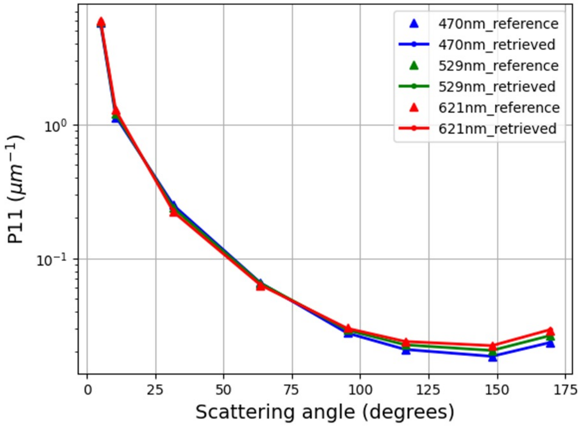
Biomass Burning

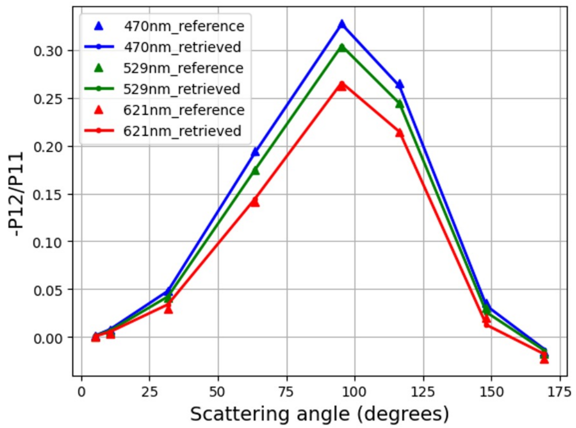




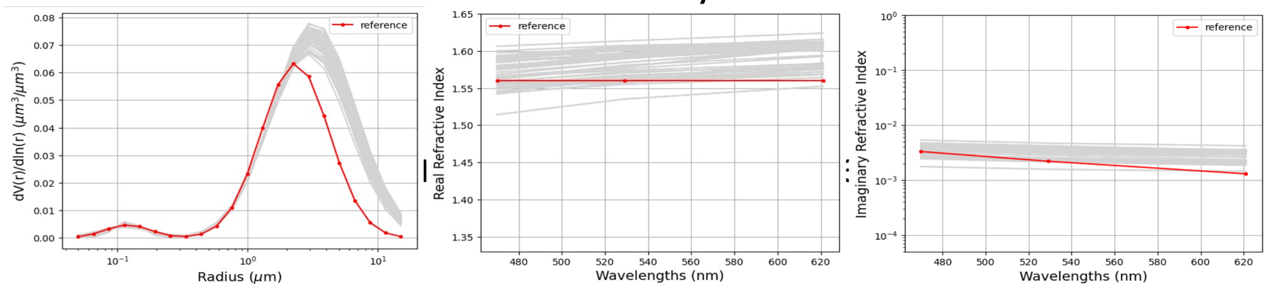
- Combining aethalometer information enhances the imaginary refractive index retrieval from integrated nephelometer significantly;
- Adding cut-off information can have some improvements for size distribution retrieval for IN-Neph;

iMAP: Dust Aerosol Example

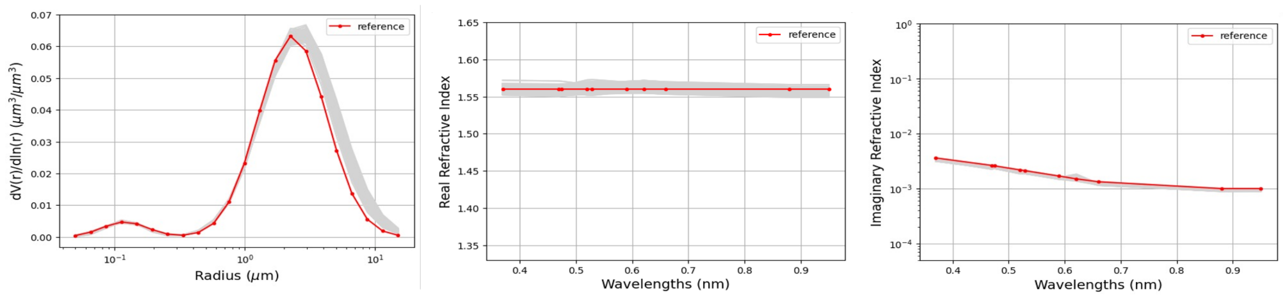




IMAP only

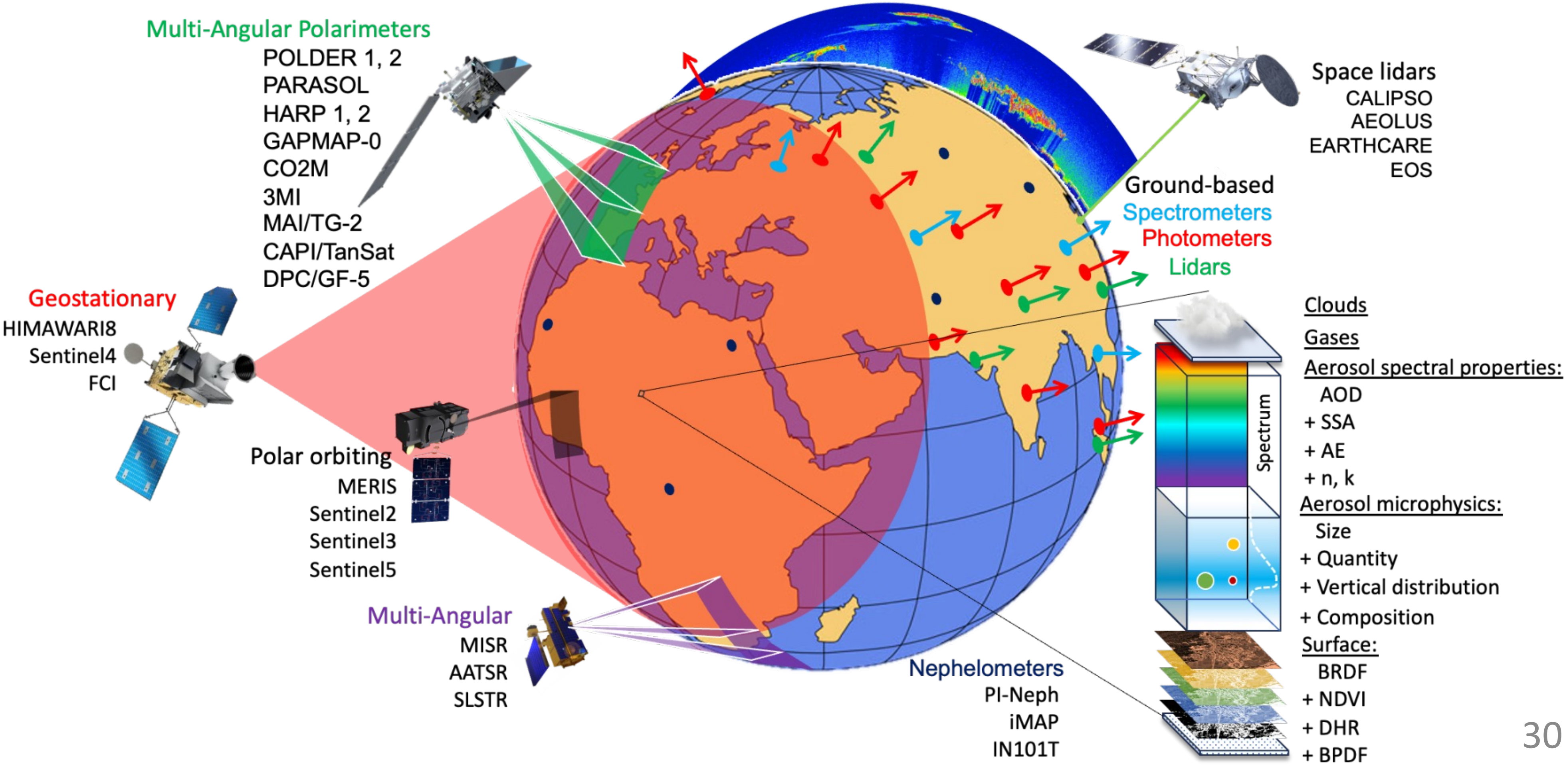


IMAP + aethalometer



- Combination with aethalometer data allows to reduce uncertainty for aerosol retrieval from IMAP data;

Future vision: AIRSENSE, PANORAMA, ECAMS, GLADIS



Amazing GRASP team