# GRASP versatile algorithm: utilization in polarimetric remote sensing applications

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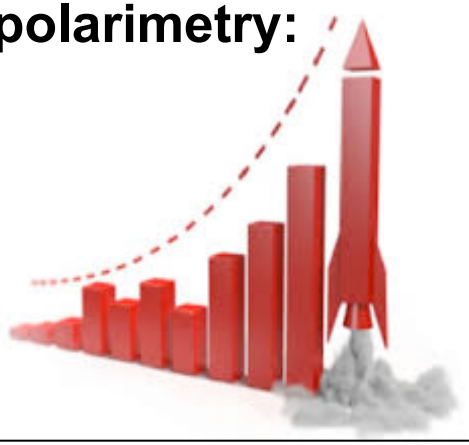
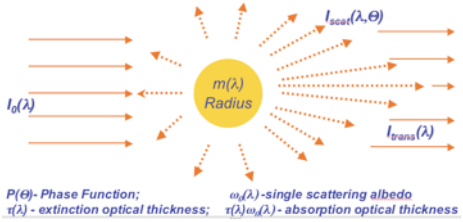
# Expectations from multi-angular polarimetry:

- Improving accuracy of base aerosol parameters (AOD)

- retrieving more aerosol information
- (absorption, aerosol type, shape, etc.);

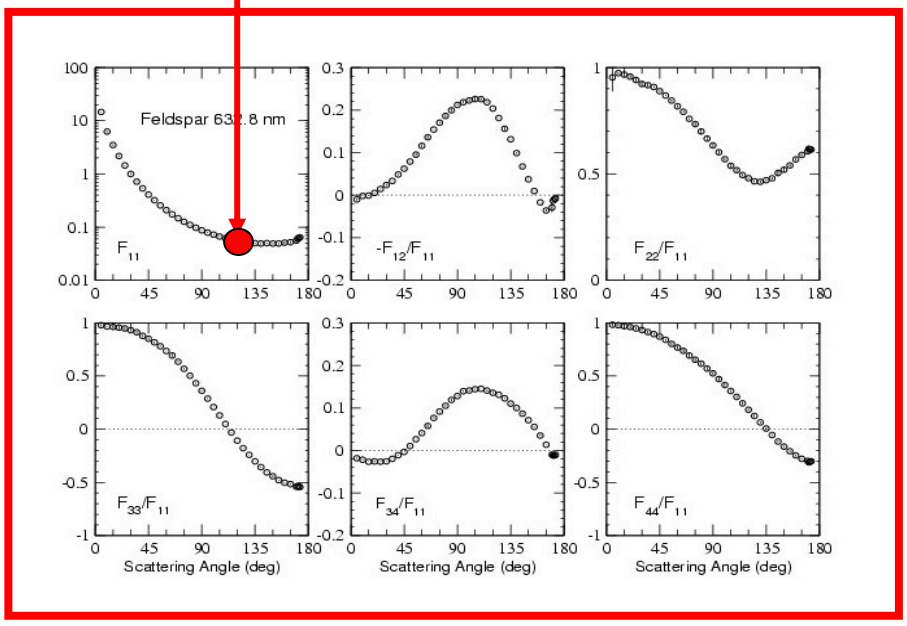


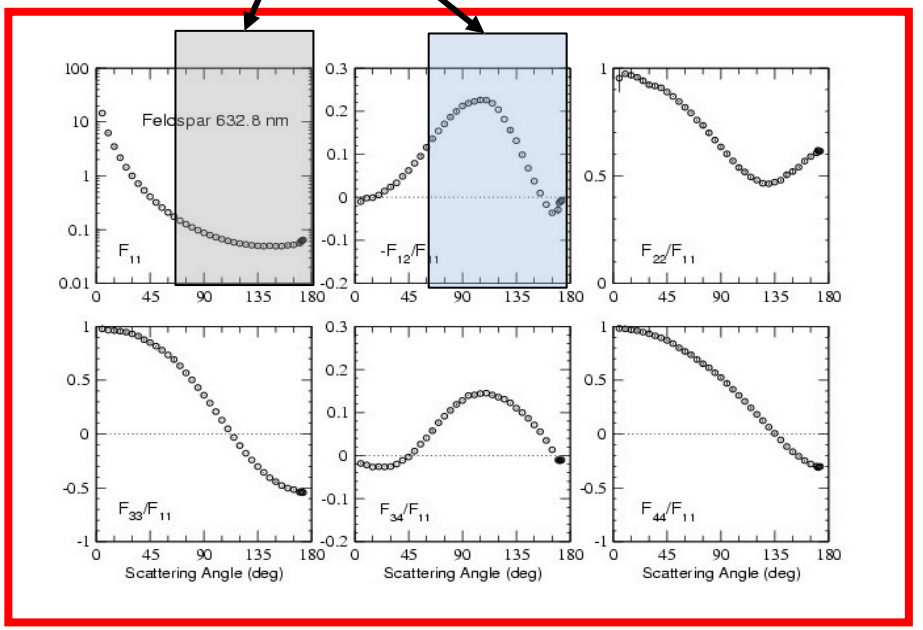
## *Single scattering*



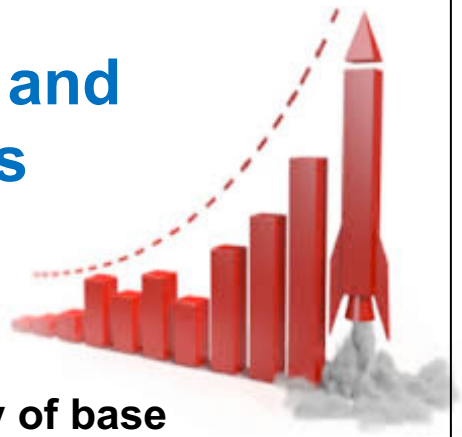

$$\begin{pmatrix} I_s \\ Q_s \\ U_s \\ V_s \end{pmatrix} \propto \begin{pmatrix} P_{11}(\Theta) & P_{12}(\Theta) & 0 & 0 \\ P_{12}(\Theta) & P_{22}(\Theta) & 0 & 0 \\ 0 & 0 & P_{33}(\Theta) & P_{34}(\Theta) \\ 0 & 0 & -P_{34}(\Theta) & P_{44}(\Theta) \end{pmatrix} \begin{pmatrix} I_i \\ Q_i \\ U_i \\ V_i \end{pmatrix}$$

Single -view radiometer (**MODIS**) << Polarimeter (**POLDER**)



## Advantages and expectations



- Improving accuracy of base aerosol parameters (AOD, Angstrom, …)
- retrieving more aerosol information (absorption, aerosol type, shape, height etc.);
- Simultaneous aerosol-cloud-surface retrieval, etc.

## Potential challenges :

- **Complex algorithms capable to retrieve many new parameters are needed**
- **Computational time is an issue;**
- **Additional uncertainties:**
  - radiometric and polarimetric calibration
  - co-registration errors (multi-angular);
  - higher sensitivity to forward model assumptions ( on vertical variability, particle shape, inhomogeneity, surface BPDF, etc.)

## advantages vs challenges ???

# GRASP: Generalized Retrieval of Aerosol and Surface Properties

S5P

POLDER, *3MI*

lidar

AERONET

MERIS

Sentinel-2

Sentinel-3

Sentinel-4

laboratory

single scattering

**GRASP**

**open source**

PROFILES of AEROSOL

$h_{max}$

$h_{min}$

$v_c(h)$

$v_f(h)$

$V_{fine,coarse}(h)$

COLUMNAR AEROSOL

fine & coarse

shape

n

k

$dV(r)/d\ln r$

$\ln r$

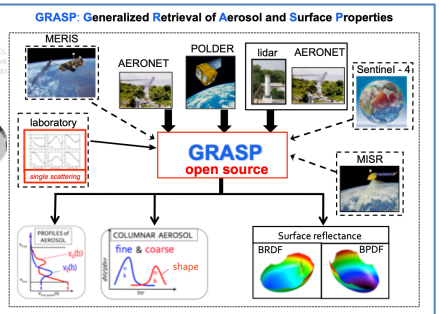
Surface reflectance

BRDF

BPDF

## PARASOL:

- radiances: *(443, 490, 560, 670, 870, 1020 nm)*
- polarization: *(490, 670, and, 870 nm)*
- up to 16 viewing directions

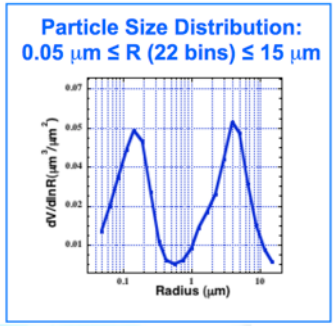


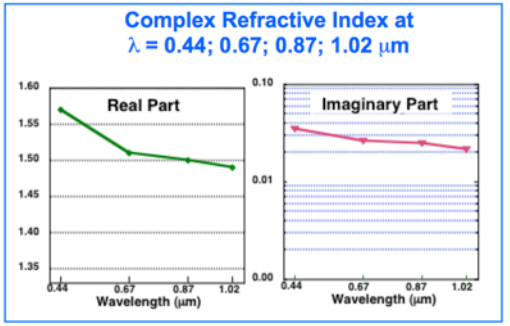

**PARASOL/GRASP** ↓ 144 measurements

**Detailed retrieval in « HP » and « optimized » approaches**

## AEROSOL:

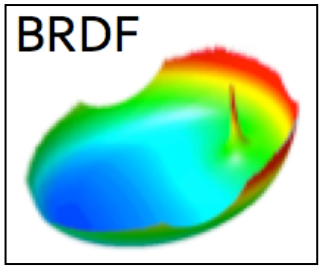
- size distribution (5 or more bins)
- spectral index of refraction (8 λ)
- sphericity fraction;
- aerosol height

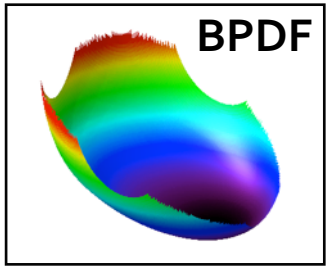



## SURFACE:

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



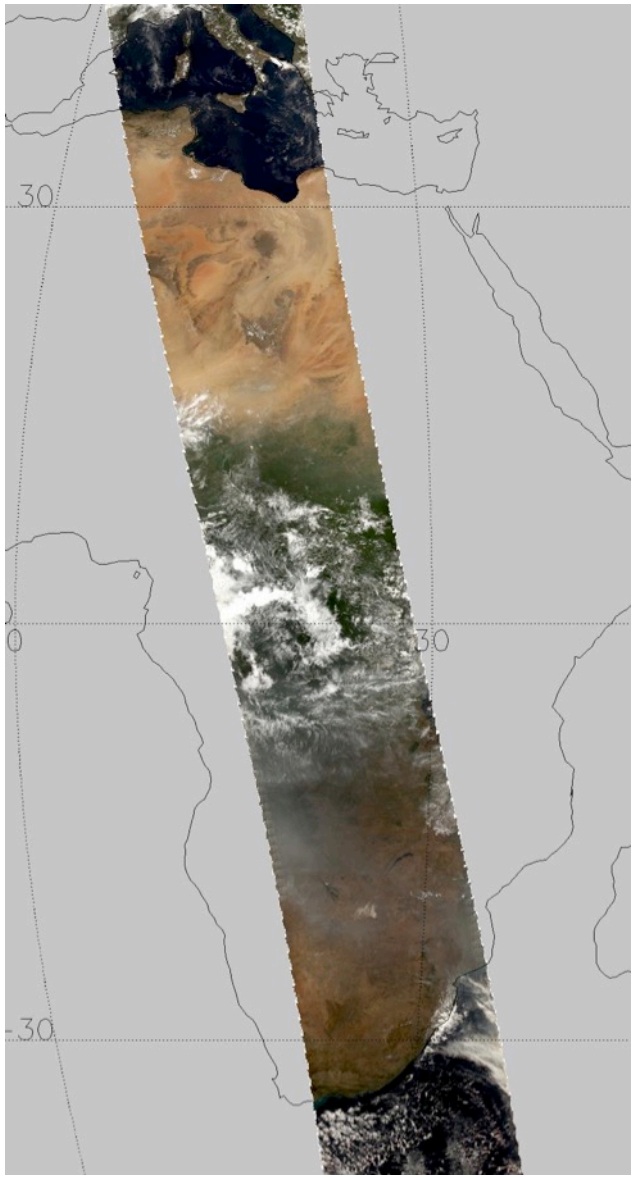

43 = (5 (SD) +12 (ref. ind.) + 1 (nonsp.) + 18 (BRDF) +6 (BPDF) + 1 (height)

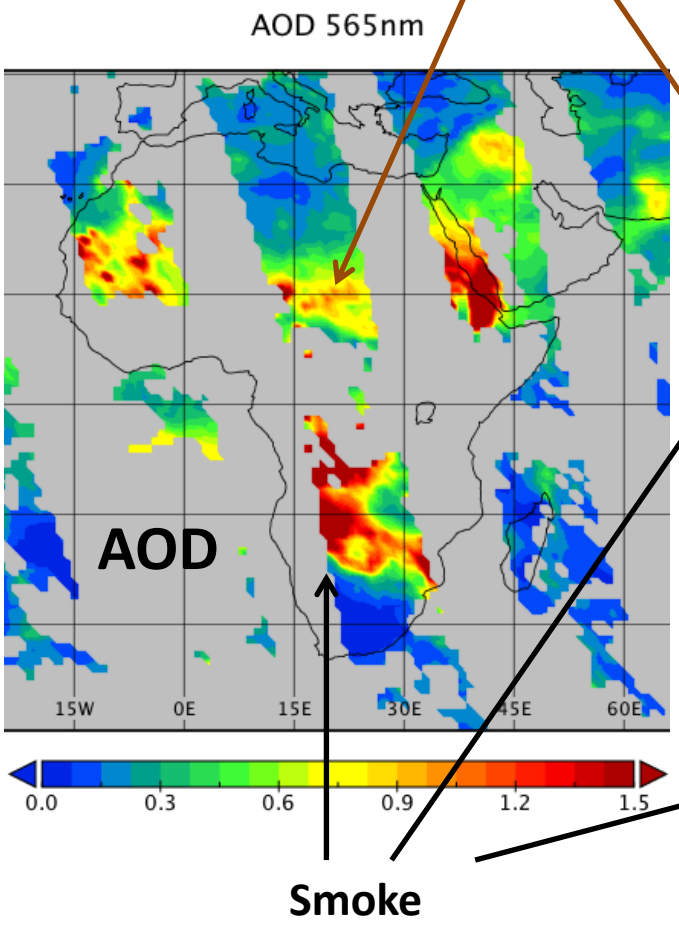
**More aerosol information can be retrieved !!!**

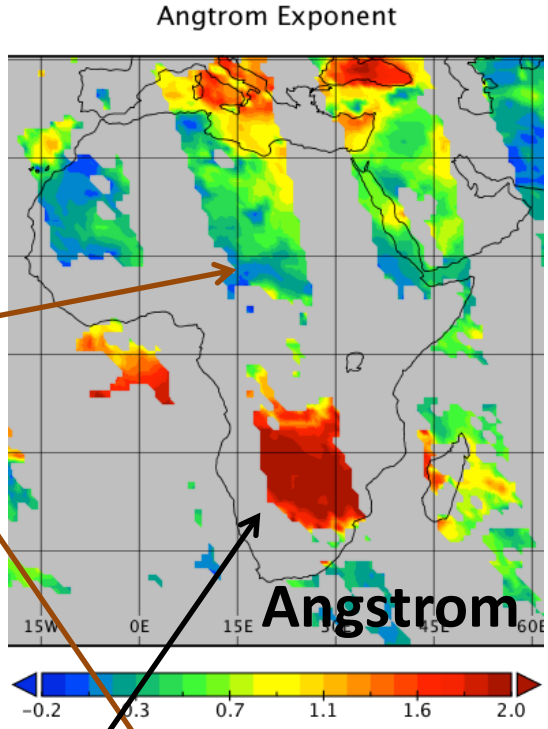
*Dubovik et al., 2011*

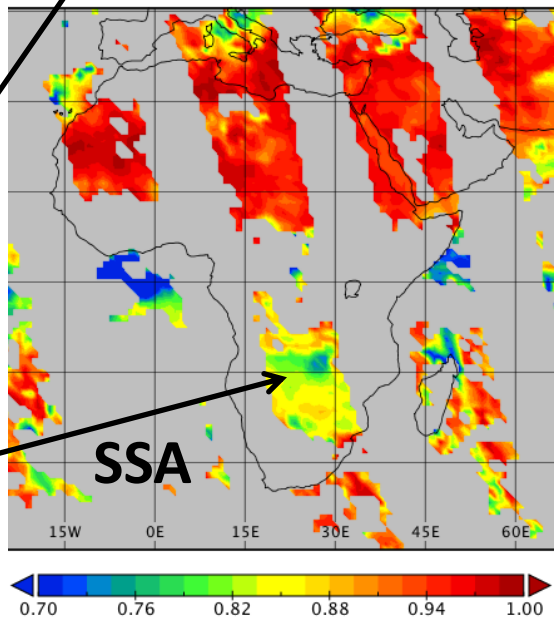
# PARASOL/GRASP

## Africa, 03.09.2008





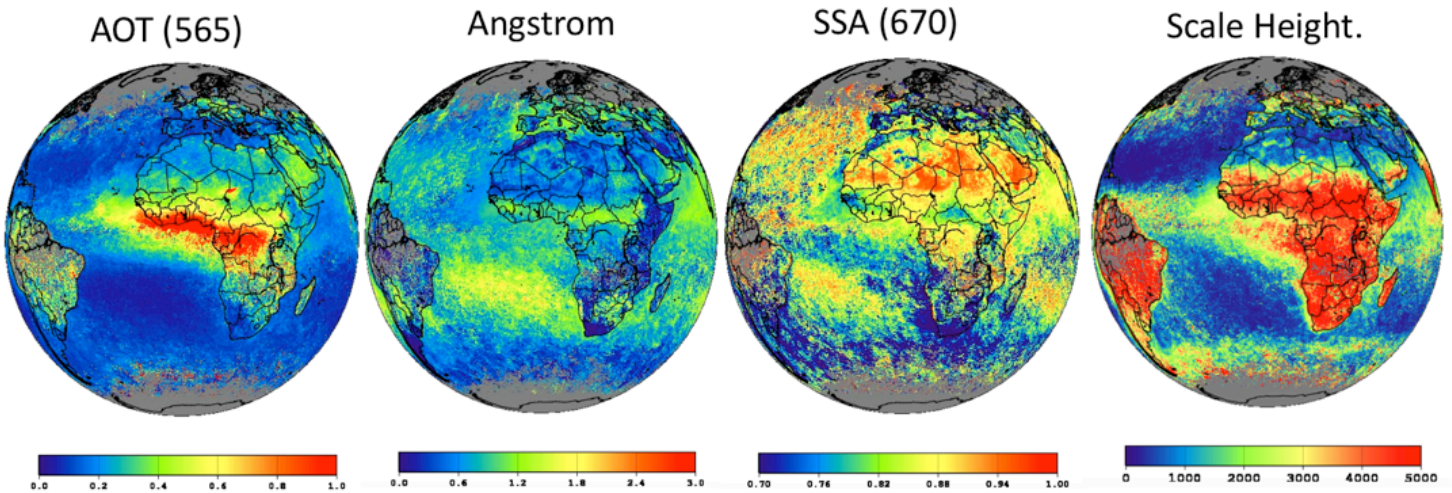

Desert dust

Smoke

# 2004-2013 POLDER/PARASOL:

**ocean and land**

**winter 2009**




**AEROSOL**: AOD spectral, AOD fine/coarse, Angstrom, **SSA**, **AAOD**, aerosol height spectral complex index of refraction, sphericity fraction.

**SURFACE** : **land**: BRDF spectral, BPDF spectral;
**ocean:** wind speed and water leaving radiances, etc.

Important features of GRASP retrieval:

- Globally the same initial guess for aerosol;
- Globally the same set of a priori constraints;
- No location specific assumptions;
- Retrieval on 6 km resolution, no averaging;
- Surface retrieved simultaneously

# Status today:

3 full PARASOL archive processings by GRASP :

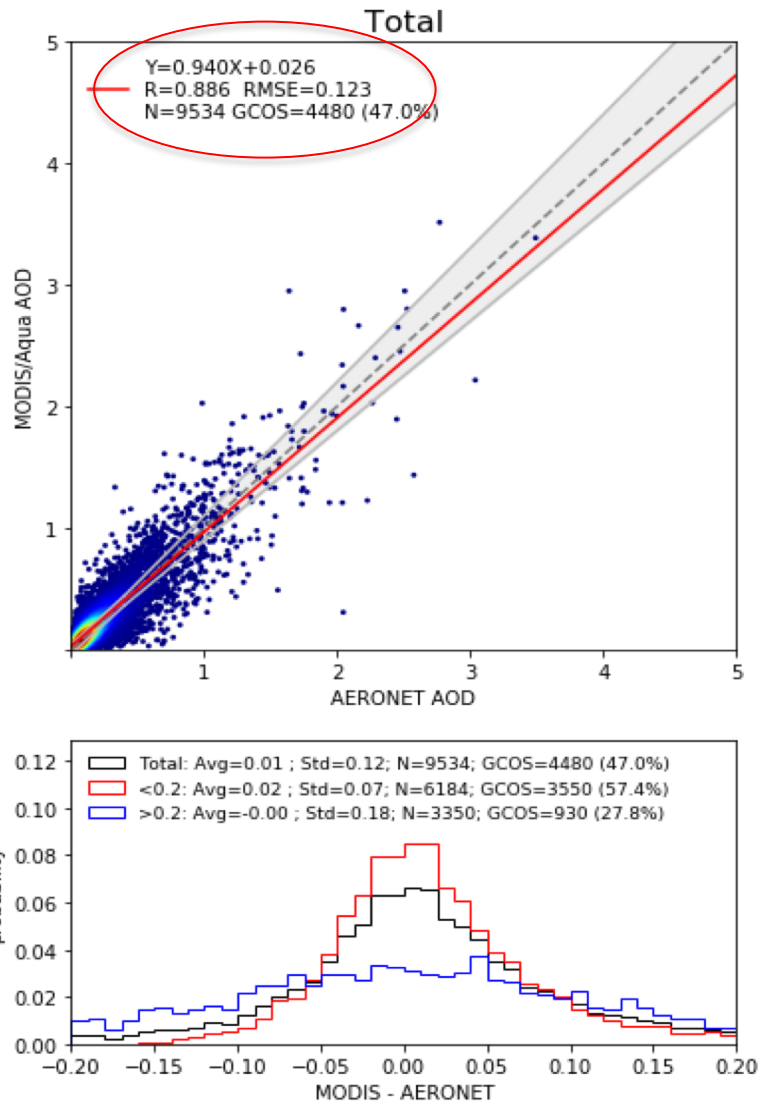
product release ://www.grasp-open.com/products, **ICARE** (to very soon):

1. **PARASOL/GRASP «optimized»** (optimized radiative transfer);
2. **PARASOL/GRASP «high-precision»** (the most accurate radiative transfer);
3. **PARASOL/GRASP «models»** (the aerosol is an external mixture of aerosol components).

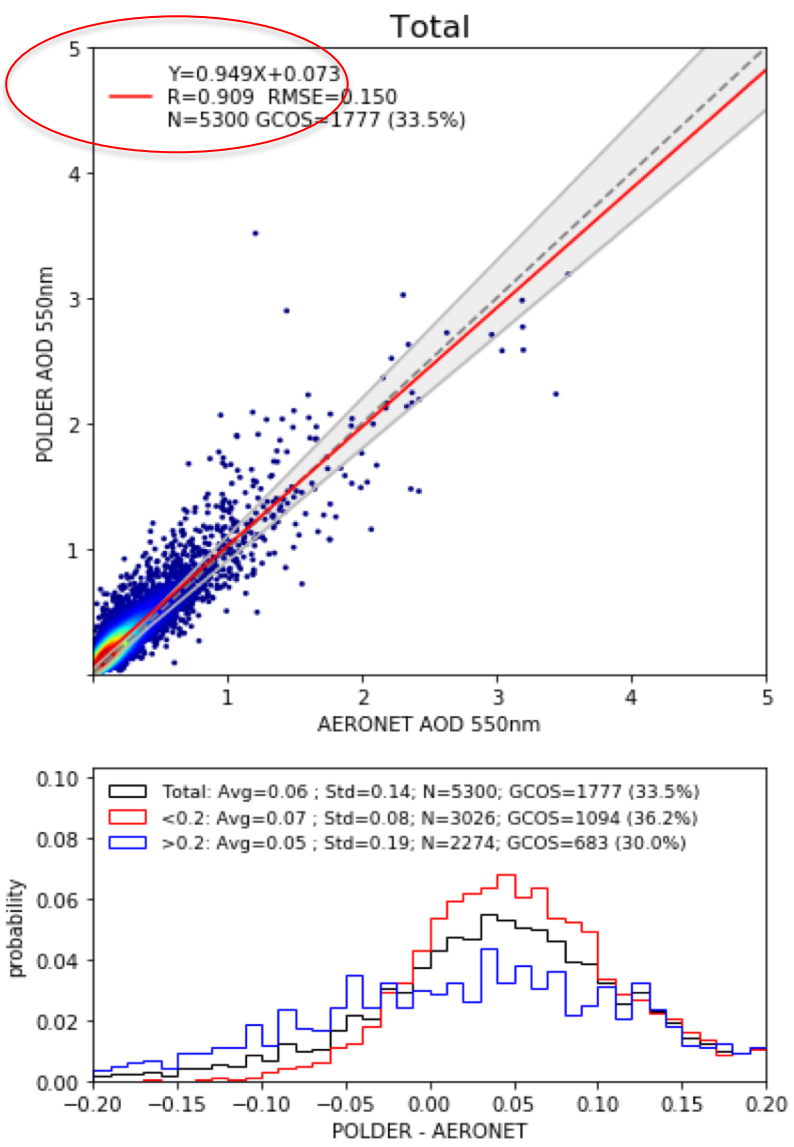
Retrieval speed is now appropriate!

# Validation, all AERONET sites (Land + Ocean), 2008

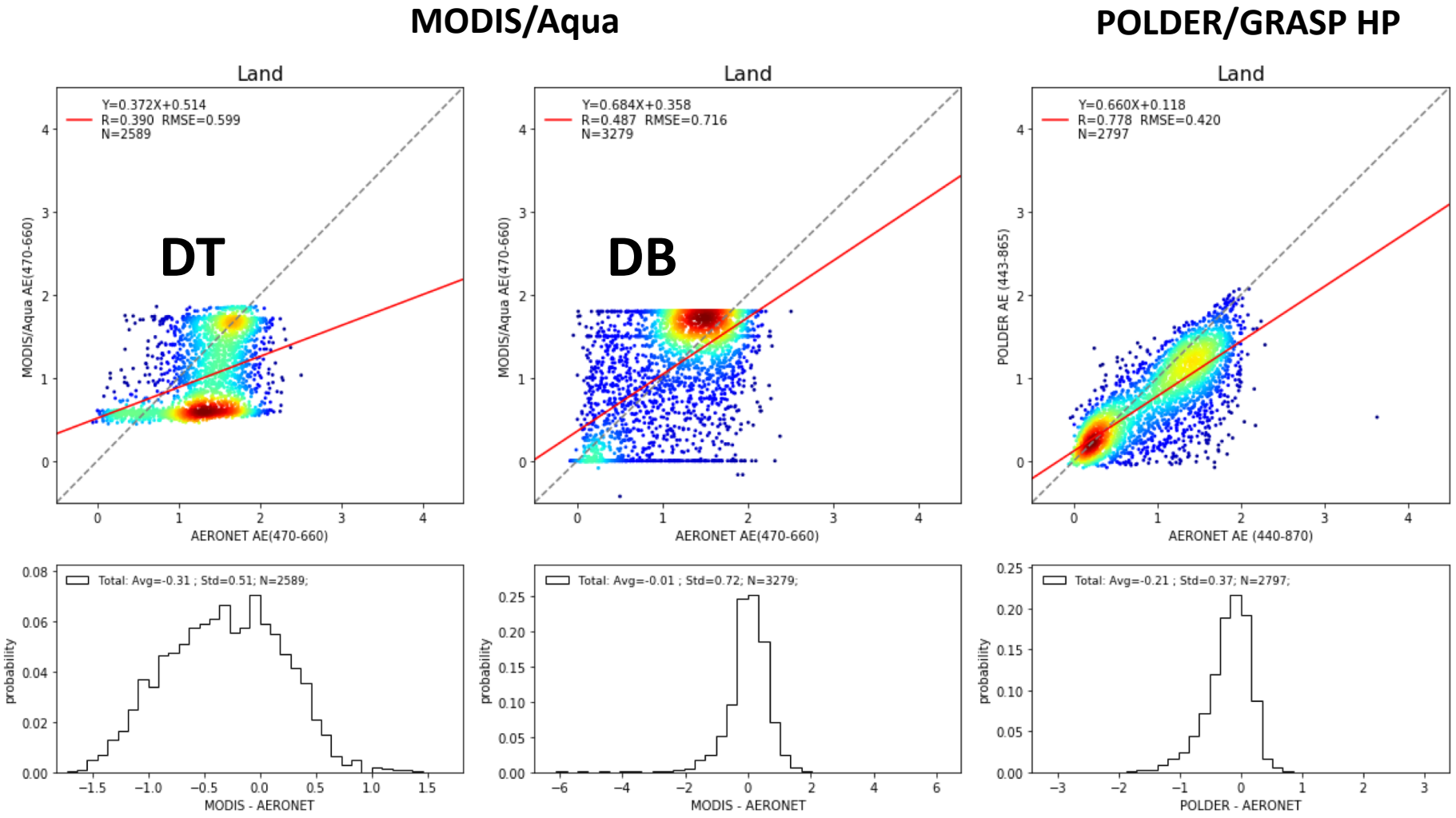
## MODIS/Aqua




## POLDER/GRASP HP



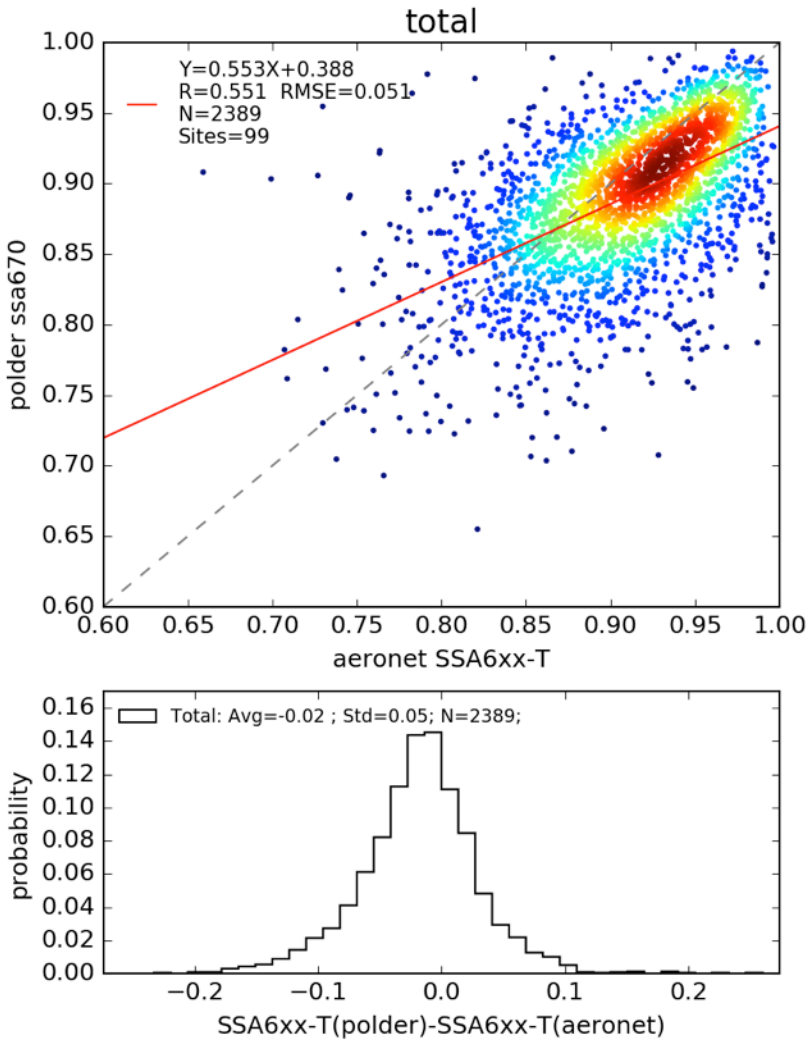
# Validation, all AERONET sites (Land + Ocean), 2008



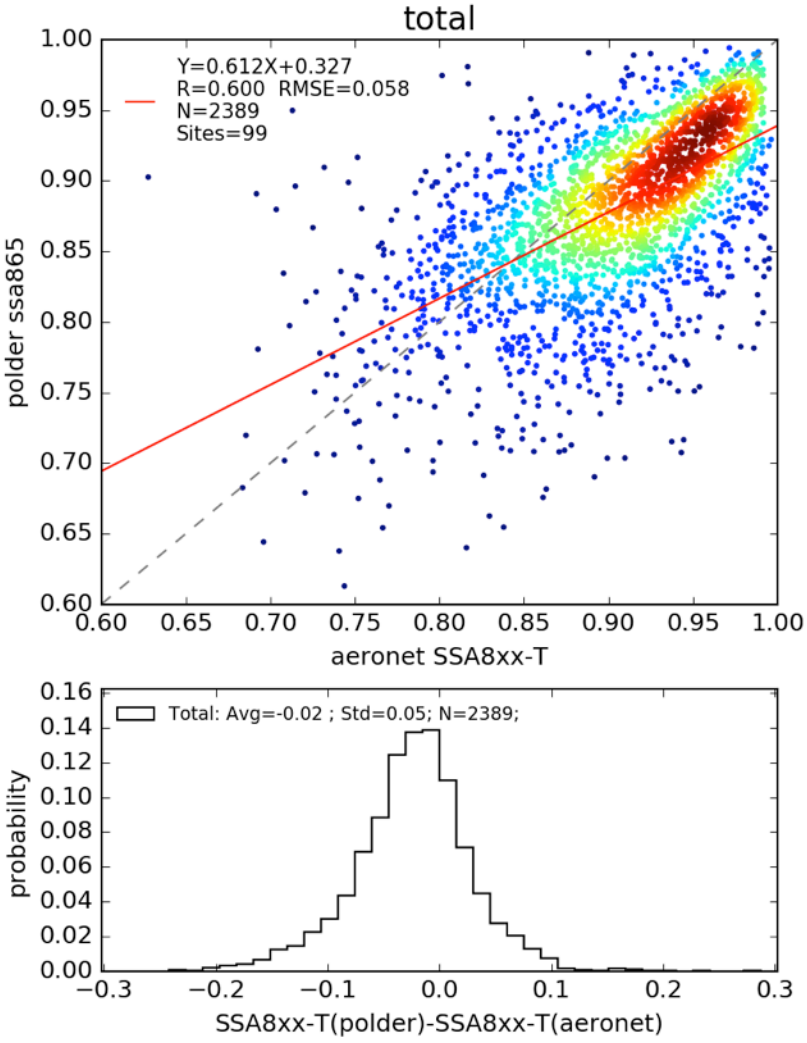
# PARASOL Validation vs AERONET 2004 - 2013

## Land + Ocean

SSA(670) R=0.55

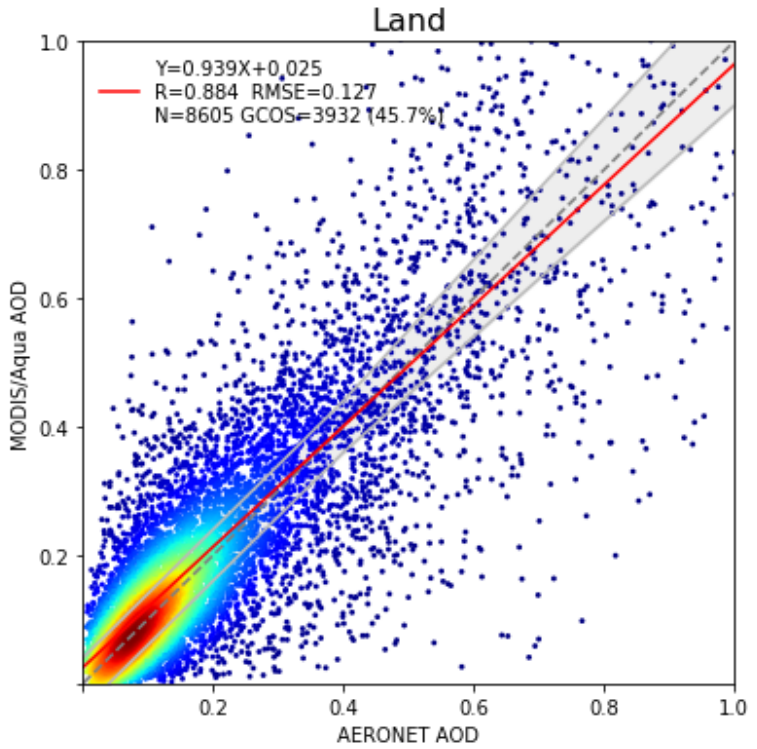


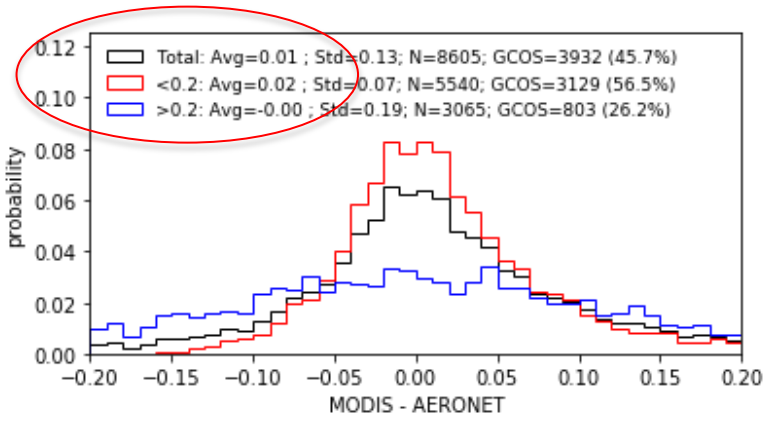

SSA(870) R=0.6



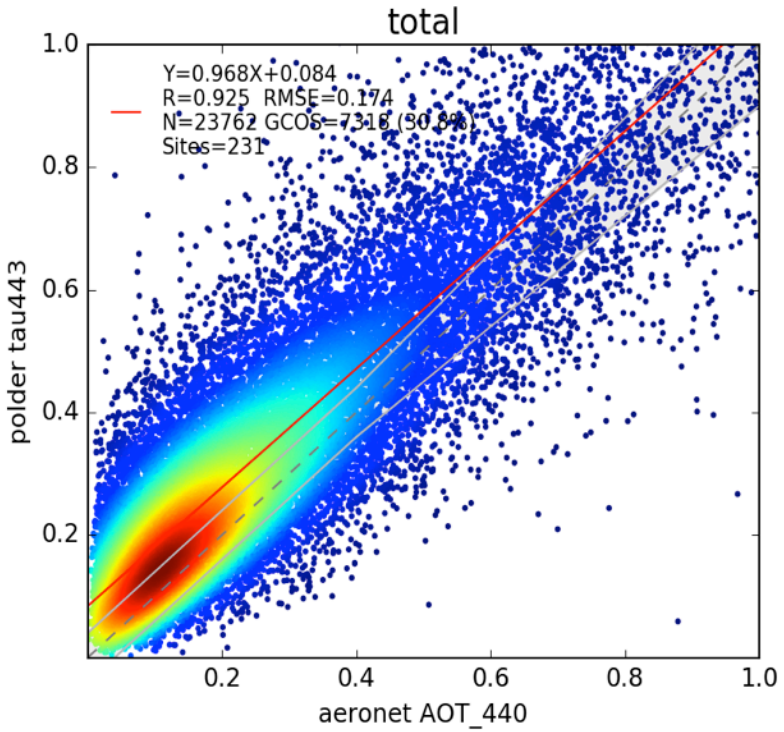
# Validation, all AERONET sites (Land + Ocean), 2008

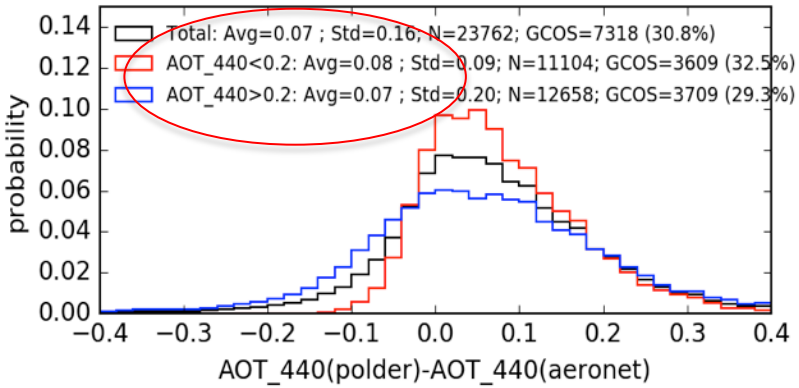
## MODIS/Aqua



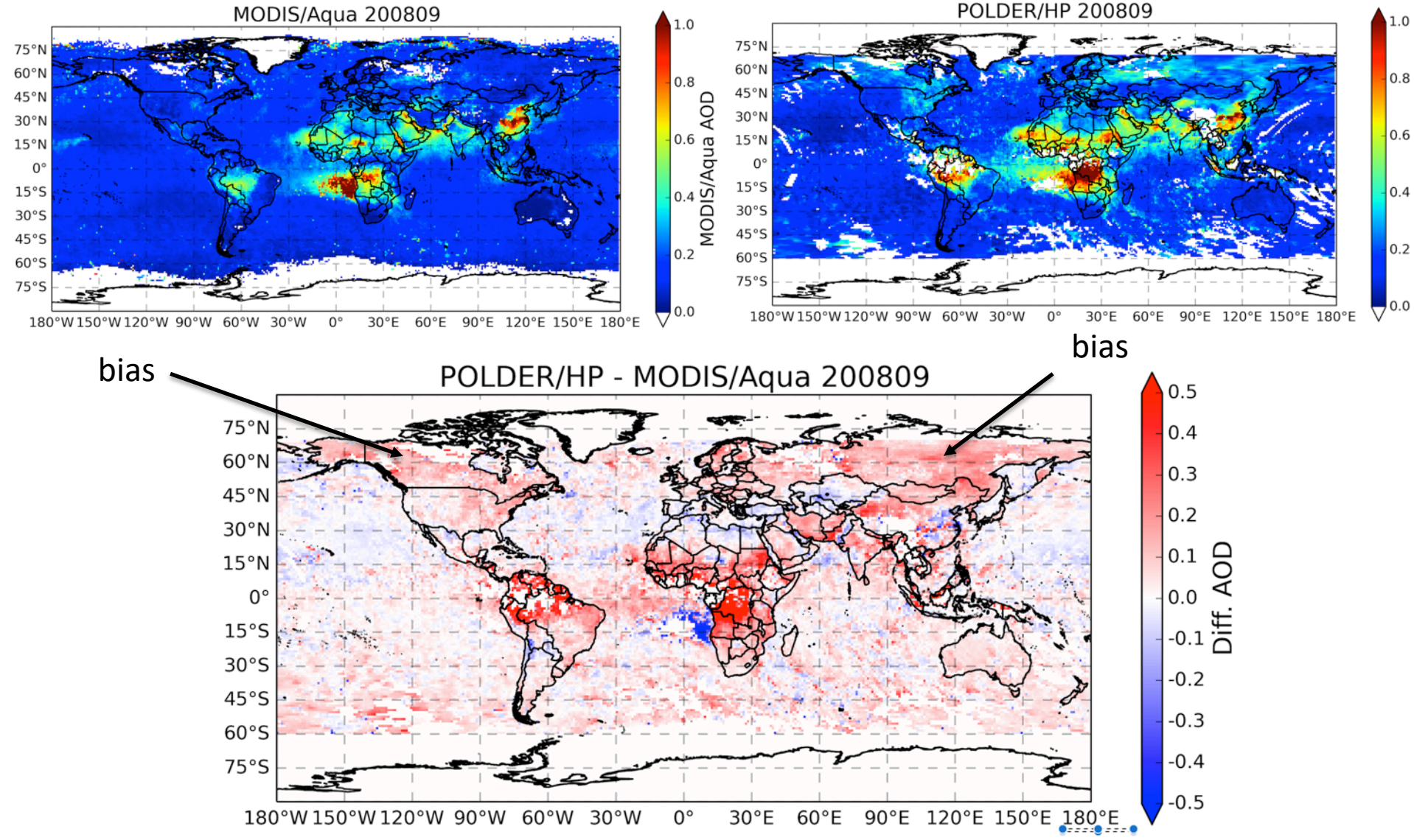




## POLDER/GRASP HP



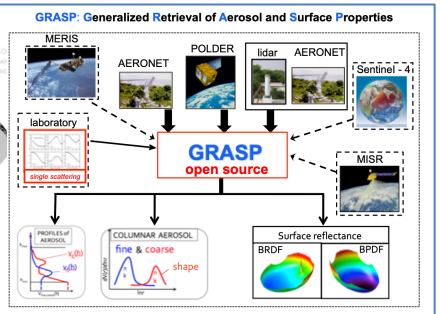



# AOD(560), September 2008



## PARASOL:

- radiances: *(443, 490, 560, 670, 870, 1020 nm)*
- polarization: *(490, 670, and, 870 nm)*
- up to 16 viewing directions

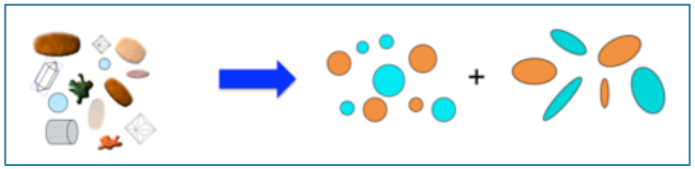



## PARASOL/GRASP ↓ 144 measurements

**Retrieval in « models » approach**

## AEROSOL:

- 5 or more concentrations
- aerosol height

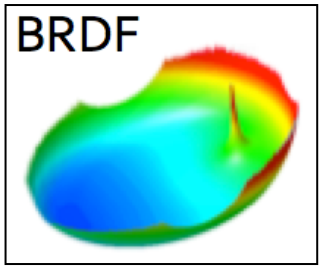


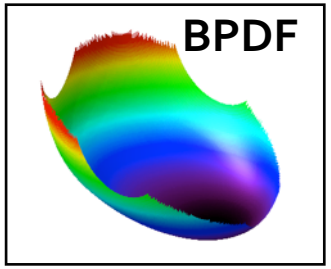
**Aerosol - external mixture of several components:**

$$\tau_{scat} = c_i \sum_{i=1}^{N} \int K^{i}_{scat}\left(\lambda; n_i; k_i; r\right) V_i\left(r\right) N_i\left(\varepsilon\right)$$

## SURFACE:

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

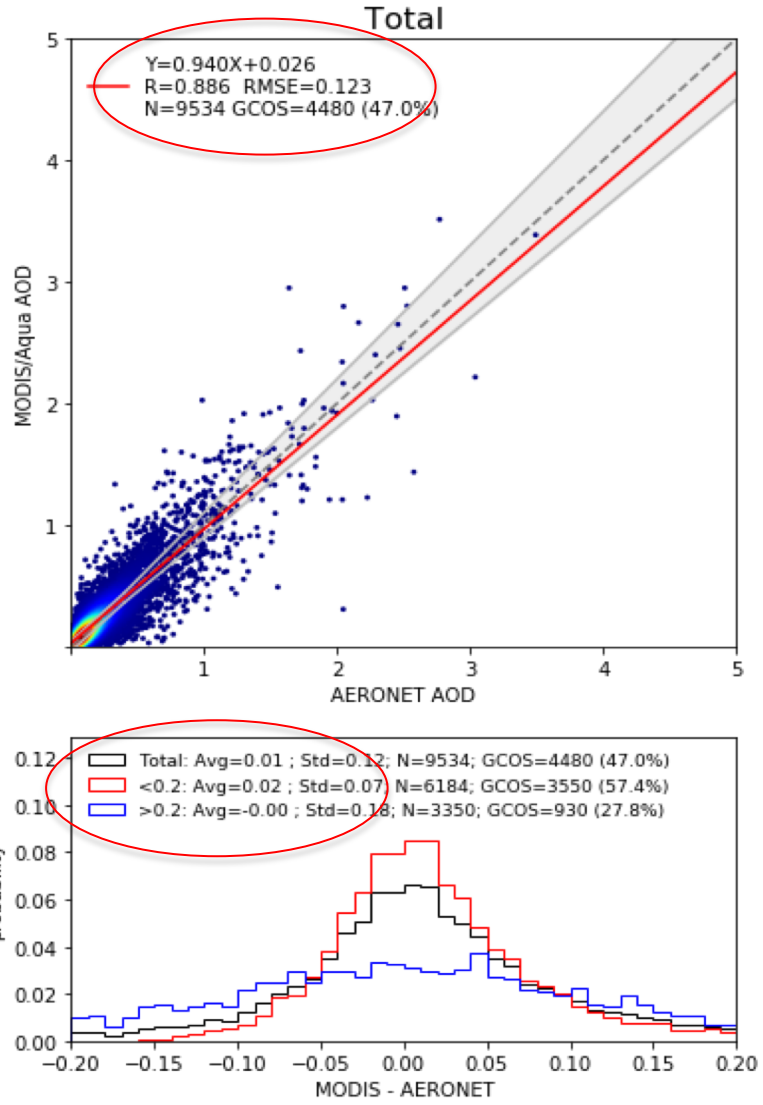


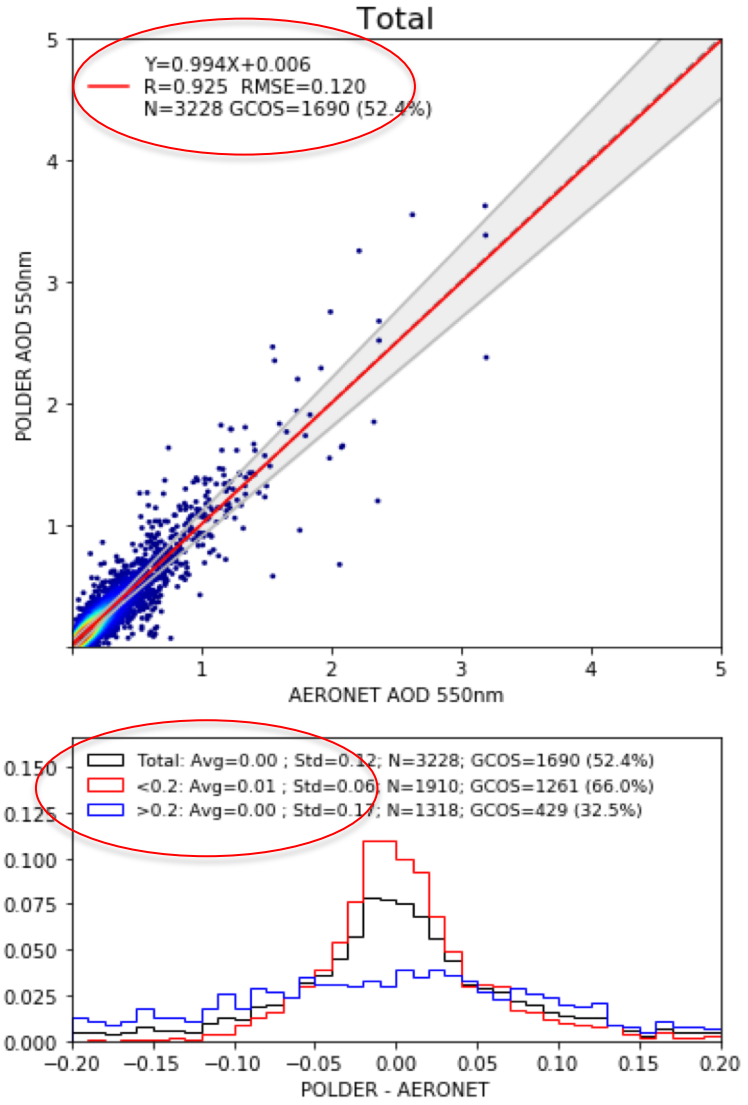

30 = (5 (concentrations) + 18 (BRDF) +6 (BPDF) + 1 (height) per pixel

# Validation, all AERONET sites (Land + Ocean), 2008

## MODIS/Aqua




## POLDER/GRASP Models



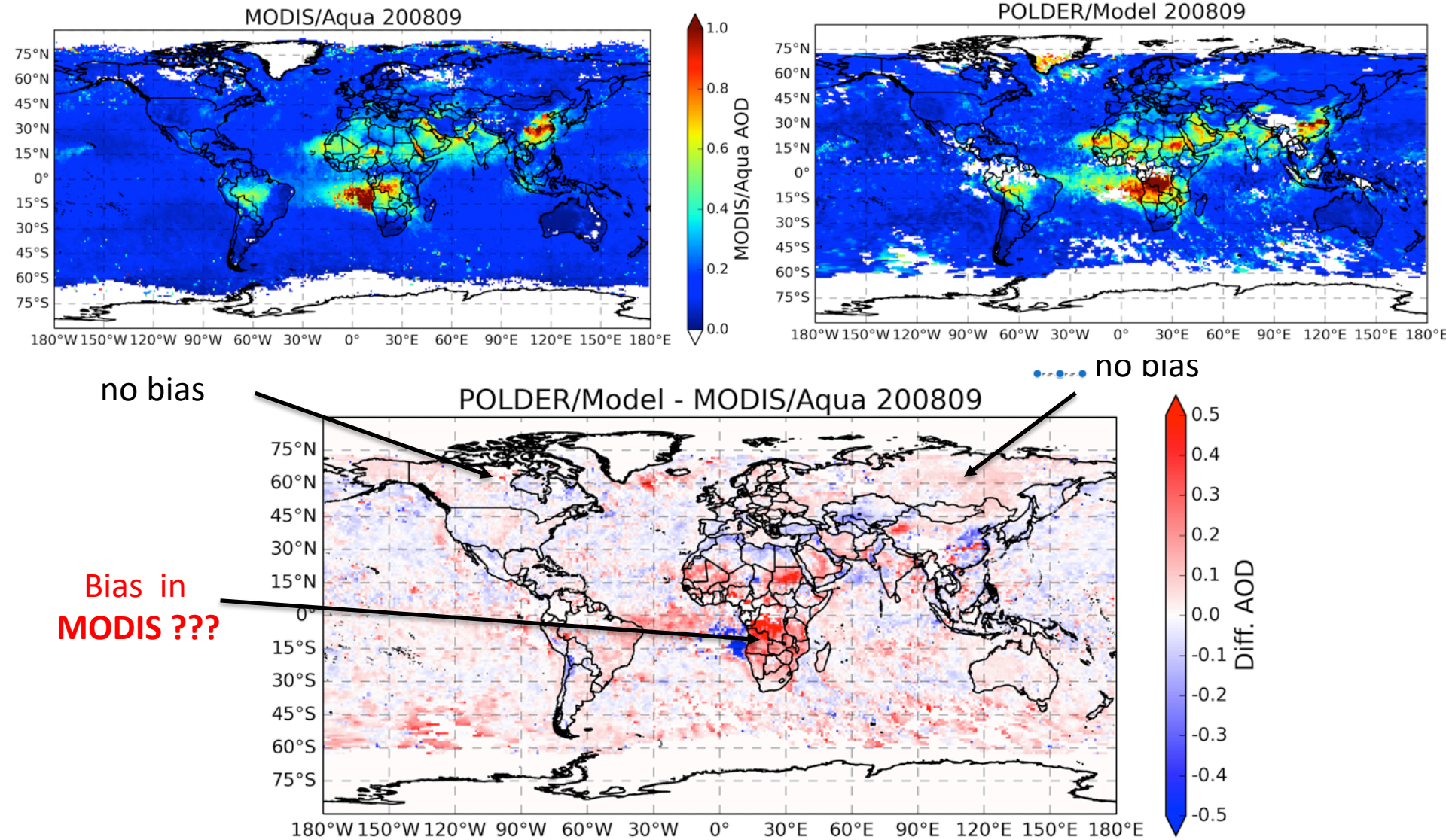
# Performance description (global 2008):

for low AOD (< 0.2),
for medium AOD (up to 0.7),
for high AOD (> 0.7), and
for the slope of regression:

**Statistics of AOD 550 nm validation with all AERONET sites in 2008**

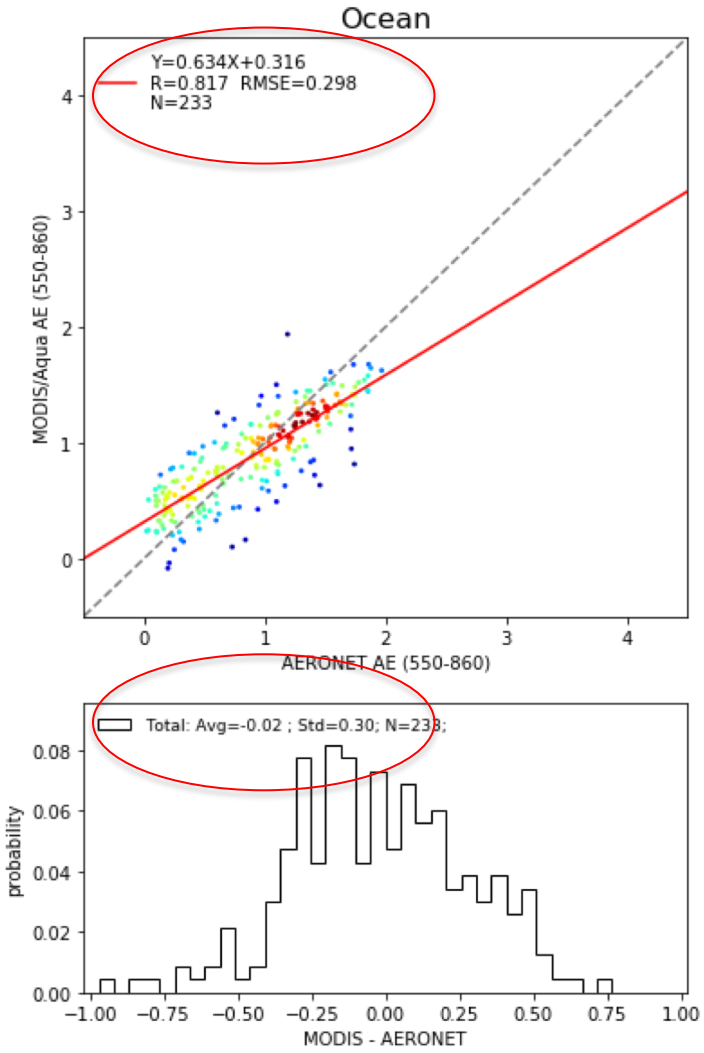
| | R | RMSE | Slope | Bias | Bias AOD<0.2 | Bias 0.2<AOD<0.7 | Bias AOD>0.7 |
|---|---|---|---|---|---|---|---|
| MODIS/Aqua | **0.886** | 0.123 | **0.940** | **0.01** | 0.02 | **0.01** | **-0.04** |
| POLDER/Optimized | **0.888** | 0.139 | 0.786 | 0.04 | **0.07** | 0.02 | **-0.13** |
| POLDER/HP | **0.909** | 0.150 | **0.949** | 0.06 | **0.07** | **0.06** | 0.03 |
| POLDER/Models | **0.925** | **0.120** | **0.994** | **0.00** | **0.01** | **0.00** | **0.02** |

# AOD(560), September 2008

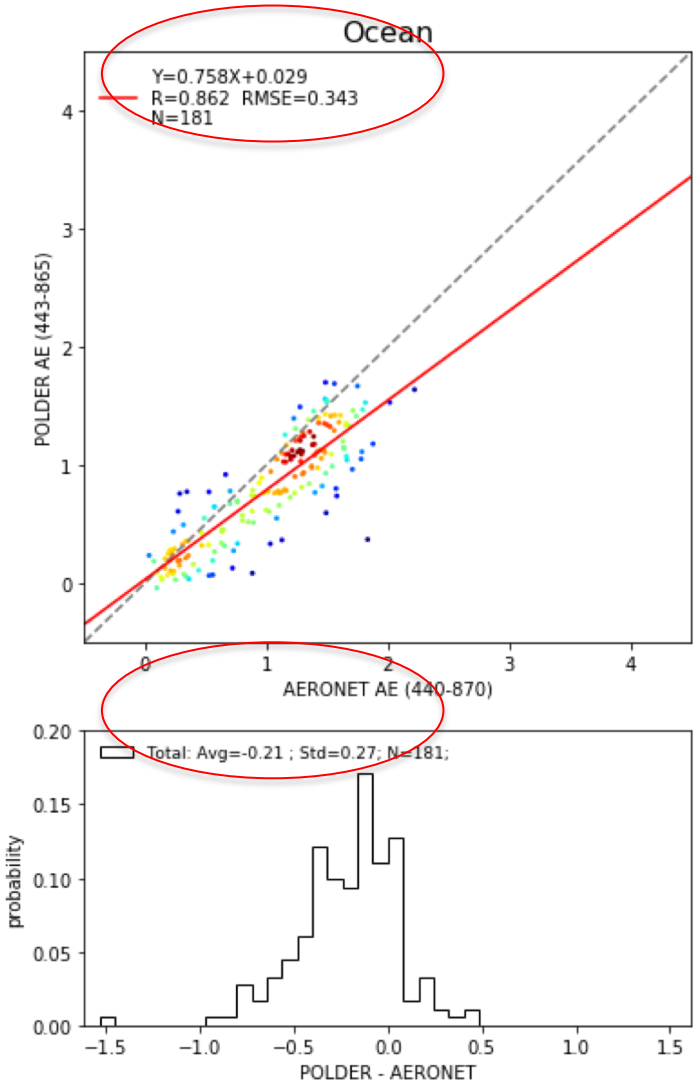


# Validation, all AERONET sites (Ocean), 2008

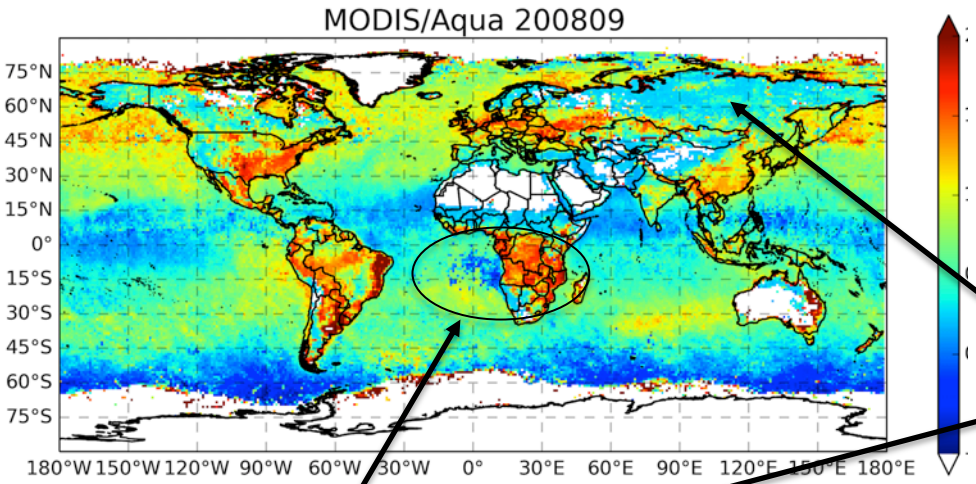
## MODIS/Aqua

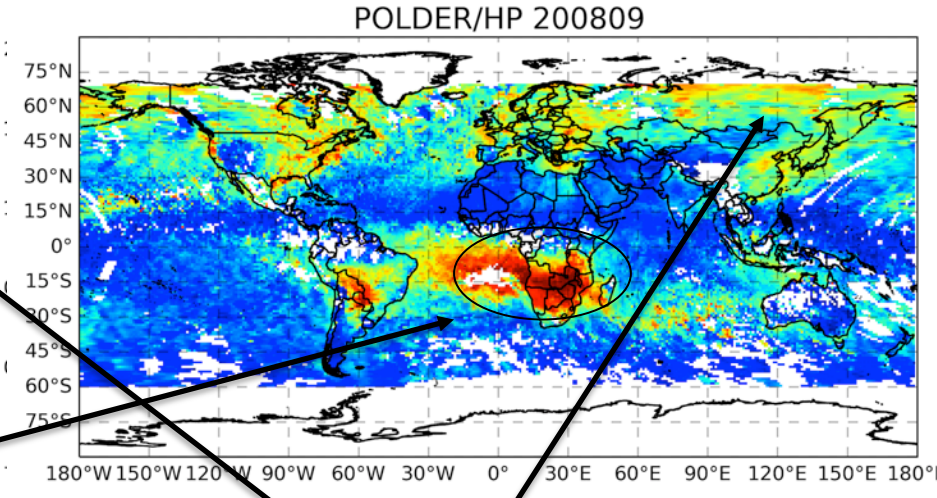



## POLDER/GRASP HP



# Angstrom, September 2008

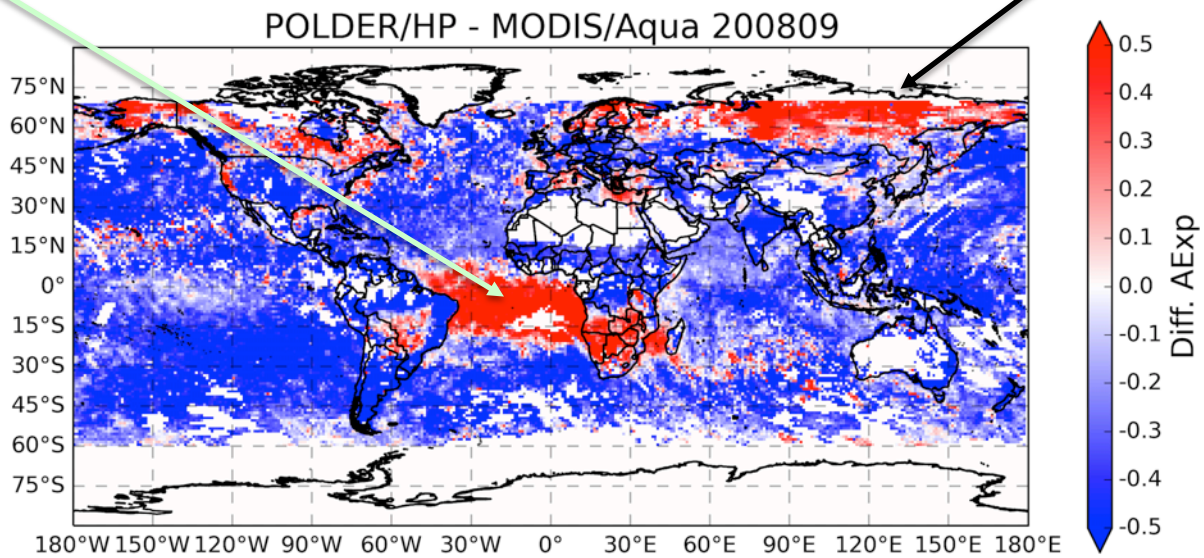


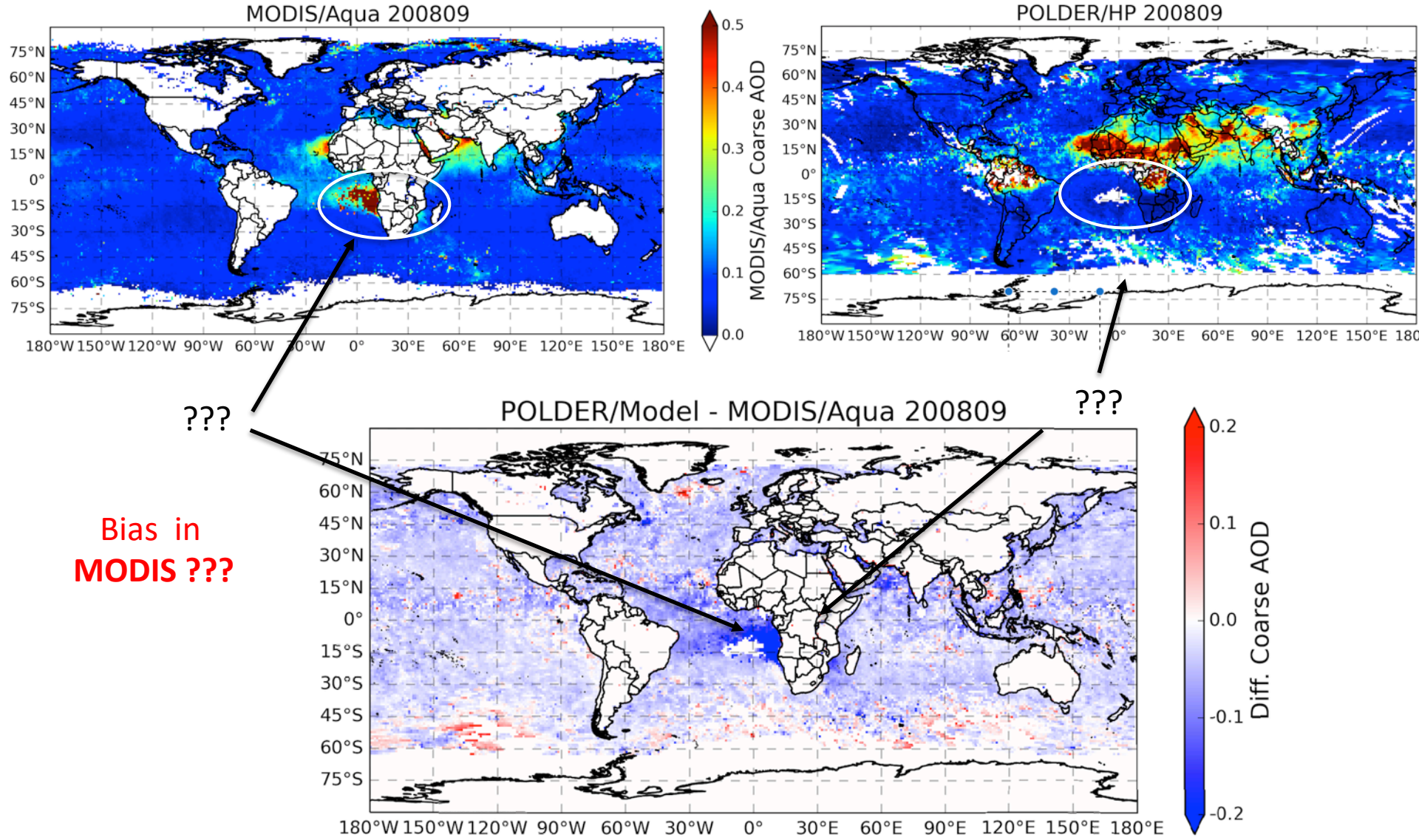

???

???

Bias in **MODIS ???**



# AOD Coarse (560) , September 2008




Bias in **MODIS ???**

# Conclusions from GRASP activities:

- Speed of polarimetry retrieval for is not a challenge,. ( > 3 PARASOL archive processings were done)


- More aerosol (absorption, aerosol type, etc.) and surface information can be retrieved as a product

- The accuracy of all parameters can be retained and increases.

- Providing reliably all parameters with high accuracy is challenging in singe approach.

- Different approaches may be needed for different parameters: - Total AOD with simpler approach, while Angstrom, Fine/Course AOD, SSA, etc. is better with more complex approach


- Analysis of existing and future (3MI, PACE, DPC, etc.) aerosol products from polarimetry are expected to bring important correction aerosol climatology and other finding

perspectives