ERA - Enhanced Retrieval of Aerosol properties: reference and NRT algorithm prototype for 3MI mission

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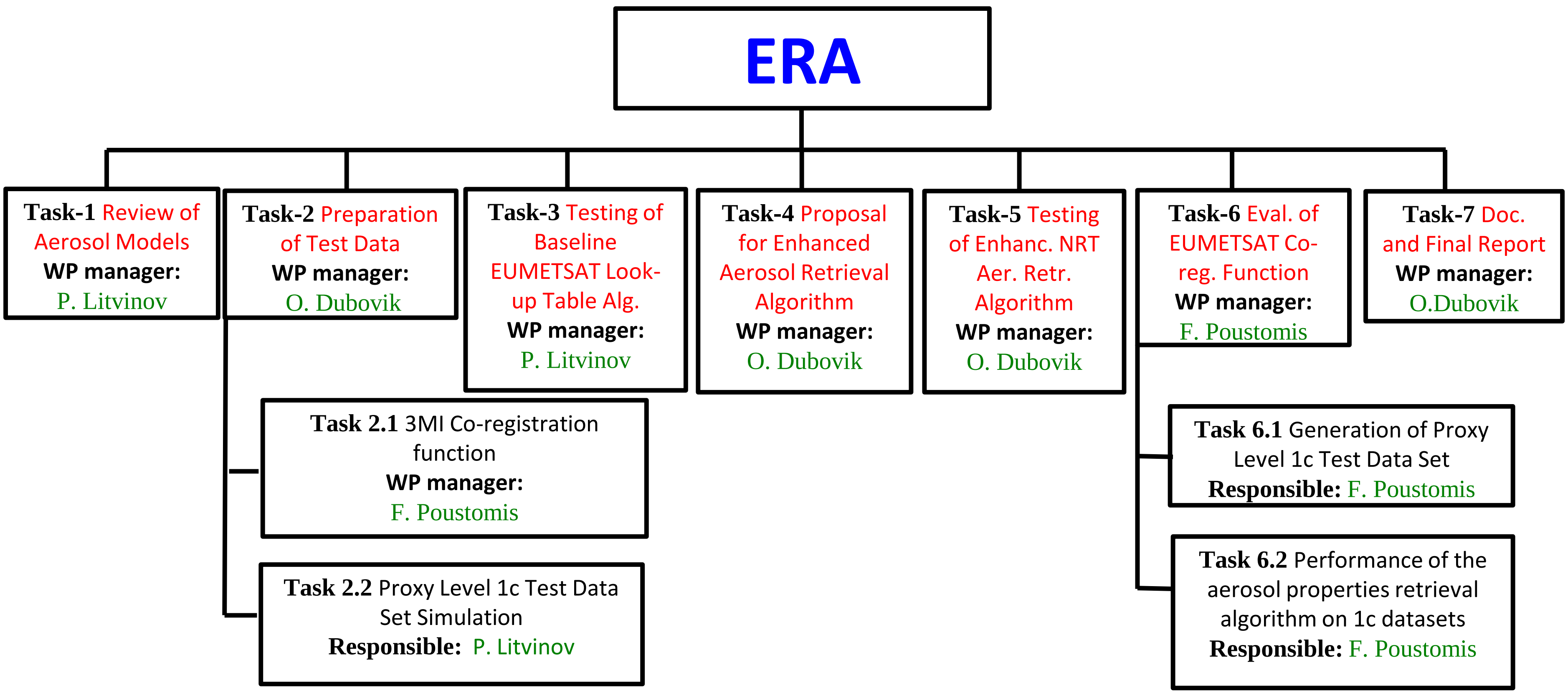

ERA
Task-1 Review of Aerosol Models
WP manager: P. Litvinov
Task-2 Preparation of Test Data
WP manager: O. Dubovik
Task-3 Testing of Baseline EUMETSAT Look-up Table Alg.
WP manager: P. Litvinov
Task-4 Proposal for Enhanced Aerosol Retrieval Algorithm
WP manager: O. Dubovik
Task-5 Testing of Enhanc. NRT Aer. Retr. Algorithm
WP manager: O. Dubovik
Task-6 Eval. of EUMETSAT Co-reg. Function
WP manager: F. Poustomis
Task-7 Doc. and Final Report
WP manager: O.Dubovik
Task 2.1 3MI Co-registration function
WP manager: F. Poustomis
Task 2.2 Proxy Level 1c Test Data Set Simulation
Responsible: P. Litvinov
Task 6.1 Generation of Proxy Level 1c Test Data Set
Responsible: F. Poustomis
Task 6.2 Performance of the aerosol properties retrieval algorithm on 1c datasets
Responsible: F. Poustomis

TASK-1: Review of Aerosol Models (WP-1)

WP manager: Dr. P. Litvinov

Start month: 0	**End month**: 1
Inputs: · LUT base algorithm. · Description of the algorithm and used aerosol models. · LOA software and calibration tools.	**Outputs**: · The summary of aerosol models analysis results. · Recommendations on aerosol models updates.

Actions:

- ➢ Review of completeness and physical basis of the EUMETSAT 3MI aerosol models.
- ➢ The summary of analysis results and recommendations on aerosol models updates will be provided.

Aerosol models for EUMETSAT 3MI model evaluation:

- Aerosol model for look up table retrieval from PARASOL instrument (Deuzé et al., 2000; Herman at al., 2005).
- Aerosol CCI (Climate Change Initiative) model (De Leeuw, et al., 2015; Holzer-Poppet al., 2013).
- Climatological aerosol models from AERONET (Dubovik et al., 2002).

Questions:

- EUMETSAT input? Format, etc.

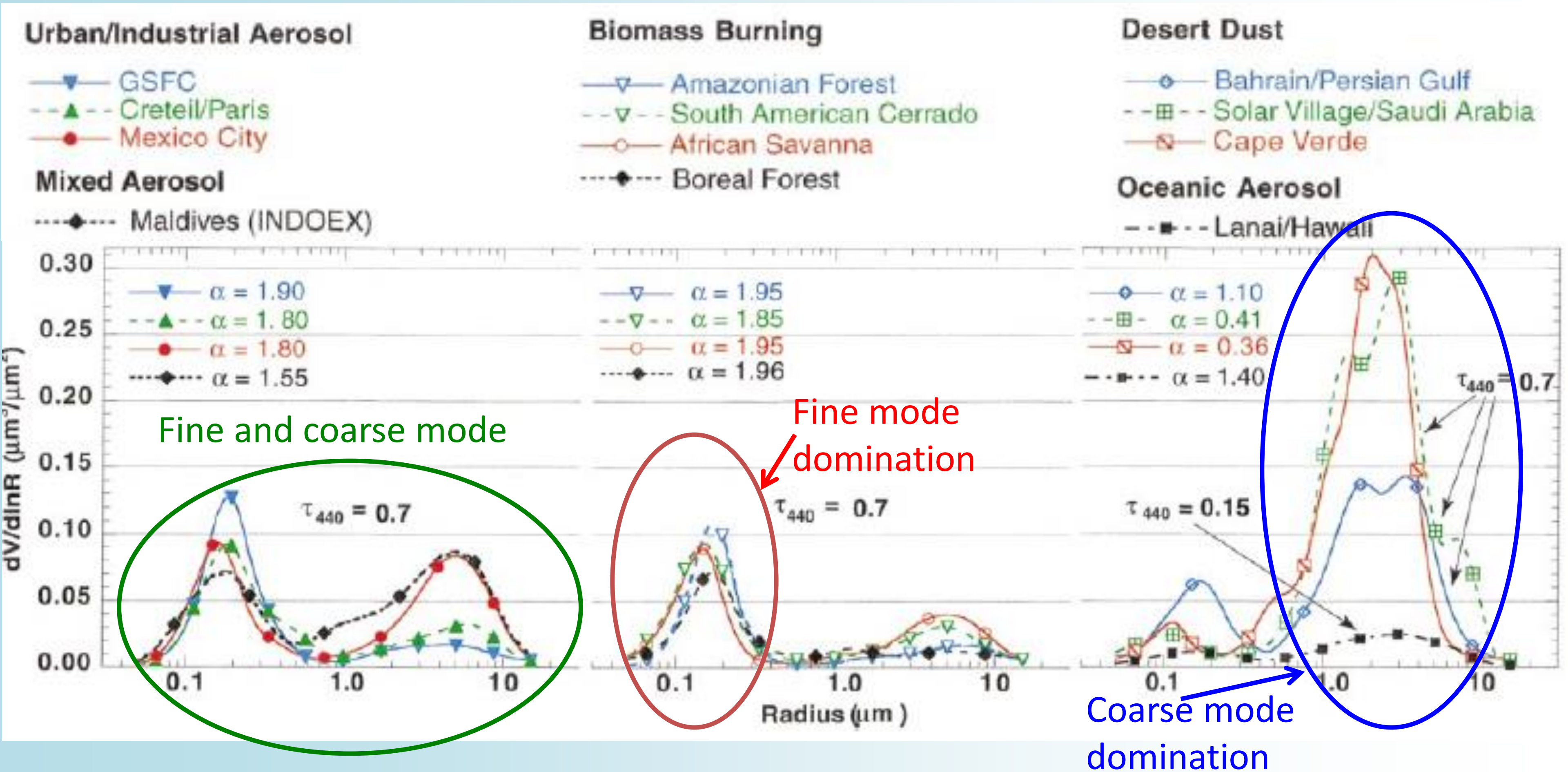
GRASP NOVELTIS

EUMETSAT 3MI Aerosol model

Fine mode	Coarse mode
Spectral dependent *m is* defined in 12 3MI spectral channels. Re(*m*): 1.418 (410 nm) - 1.321 (2130 nm) Im(*m*): 0.0023 (410 nm) – 0.007 (1650 nm) –0.0037 (2130 nm) Size distribution $<r>$ = 0.0804; s = 0.43	**1. Continental clean** Re(*m*): 1.42 (410 nm) – 1.45 (1650) – 1.4 (2130 nm); Im(*m*) = 0.001. $<r>$ = 0.34; s = 0.72. **2. Continental pollution** Re(*m*): 1.42 (410 nm) – 1.45 (1650) – 1.4 (2130 nm); Im(*m*) = 0.01. $<r>$ = 0.918; s = 0.63. **3. Oceanic** Re(*m*): 1.36 (410 nm) – 1.307 (2130 nm); Im(*m*): 0 (410) - 0.001 (2130 nm). $<r>$ = 0.547; s = 0.72. **4. Smoke** Re(*m*): 1.53 (410 nm) – 1.585 (865 nm)- 1.4(2130 nm); Im(*m*) = 0.01 . $<r>$ = 0.46; s = 0.81. **5. Dust** Re(*m*) = 1.56. Im(*m*) = 0.003 – 0.001 . $<r>$ = 0.788; s = 0.6. **6. Volcanic** Re(*m*): 1.5 - 1.46. Im(*m*) = 0.008. $<r>$ = 0.59; s = 0.56.

Fine and coarse aerosol mixing

AERONET based aerosol climatology (O. Dubovik et al., 2002)



Fine and coarse modes can be presented for any aerosol type!

Smoke/biomass burning aerosol

Currently available:

Fine Mode:

Re(m):

1.418 (410 nm) - 1.321 (2130 nm)

Im(m):

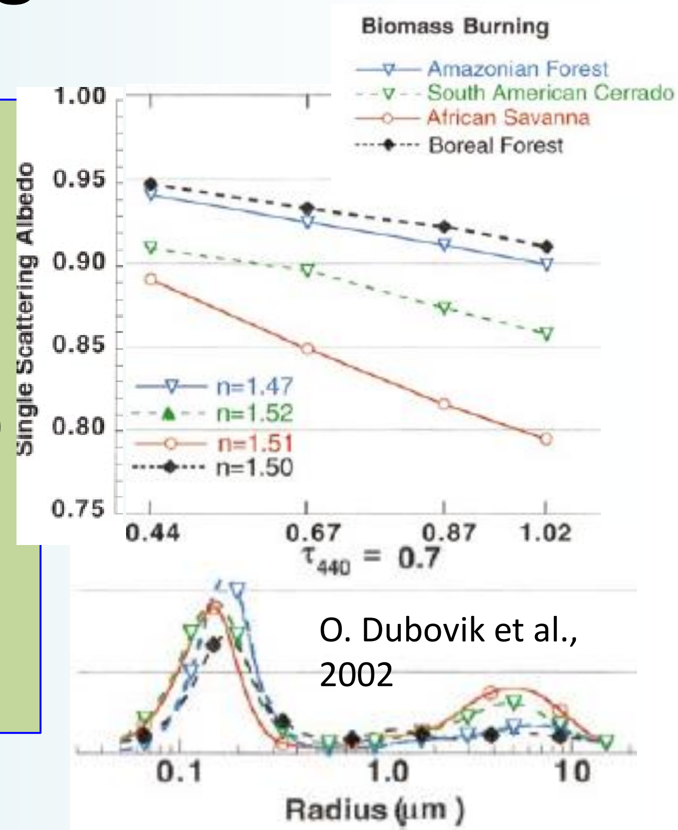
0.0023 (410 nm) – 0.007 (1650 nm) –0.0037 (2130 nm)

Coarse mode:

Re(m): 1.53 (410 nm) – 1.585 (865 nm)- 1.4(2130 nm);

Im(m) = 0.01 .

$< r >$ = 0.46; s = 0.81.



O. Dubovik et al., 2002

Possible restrictions:

For smoke/biomass burning the fine mode dominates over the coarse one.

Smoke fine mode is not described properly!

Recommended modification:

- Neglect coarse mode of smoke aerosol but add the fine mode with the same complex refractive index as for coarse mode currently.

Recommended modifications in aerosol type

Aerosol type	Fine	Coarse
Continental clean	Available	Available
Continental polluted	Can be the same as Fine smoke mode	Available
Oceanic	Can not be covered by the existent fine mode	Available
Smoke	Can not be covered by the existent fine mode	Available (Can be neglected)
Dust	Can be neglected	Available
Volcanic	Can be neglected	Available (It is recommended to modify)

Resume on aerosol model review

- Fine modes:
  1. Continental clean (should be added or current fine mode can be used)
  2. Oceanic (should be added)
  3. Smoke (should be added)
- Coarse modes:
  1. Continental clean (Ok)
  2. Continental pollution (Ok)
  3. Oceanic (Ok)
  4. Dust (Ok)
  5. Volcanic (add non-sphericity)
  6. Smoke (can be neglected)

15 aerosol mixed types in total

Project results/accomplishments:

Task-1: Set of aerosol models for LUT algorithms was reviewed corrected;

Task-2: Preparation of Test Data (WP-2)

WP manager: Dr. O. Dubovik

Start month: 1	**End month**: 3
Inputs: · Level 1b Test Synthetic Data Set. · Description of Test Data Set. · PARASOL/GRASP aerosol and surface products.	**Outputs**: · Level 1c Test Synthetic Data Set over 3MI orbits. · Level 1c Test Proxy Data Set over 3MI orbits. · Level 1c Test Proxy 3MI Data Set over selected AERONET sites.

Actions on WP-2:

- **Task 2.1. Development of co-registration function for 3MI (Responsible: NOVETIS)**
- Simulated Level 1c Test Data Set will be provided by applying NOVELTIS co-registration algorithms to EUMETSAT provided Level 1b Test Data Set ;
- **Task 2.2. Simulated Level 1c Test Data Set (GRASP.SAS)**

Questions:

- EUMETSAT input? 3MI data – 1b, format, description, etc.

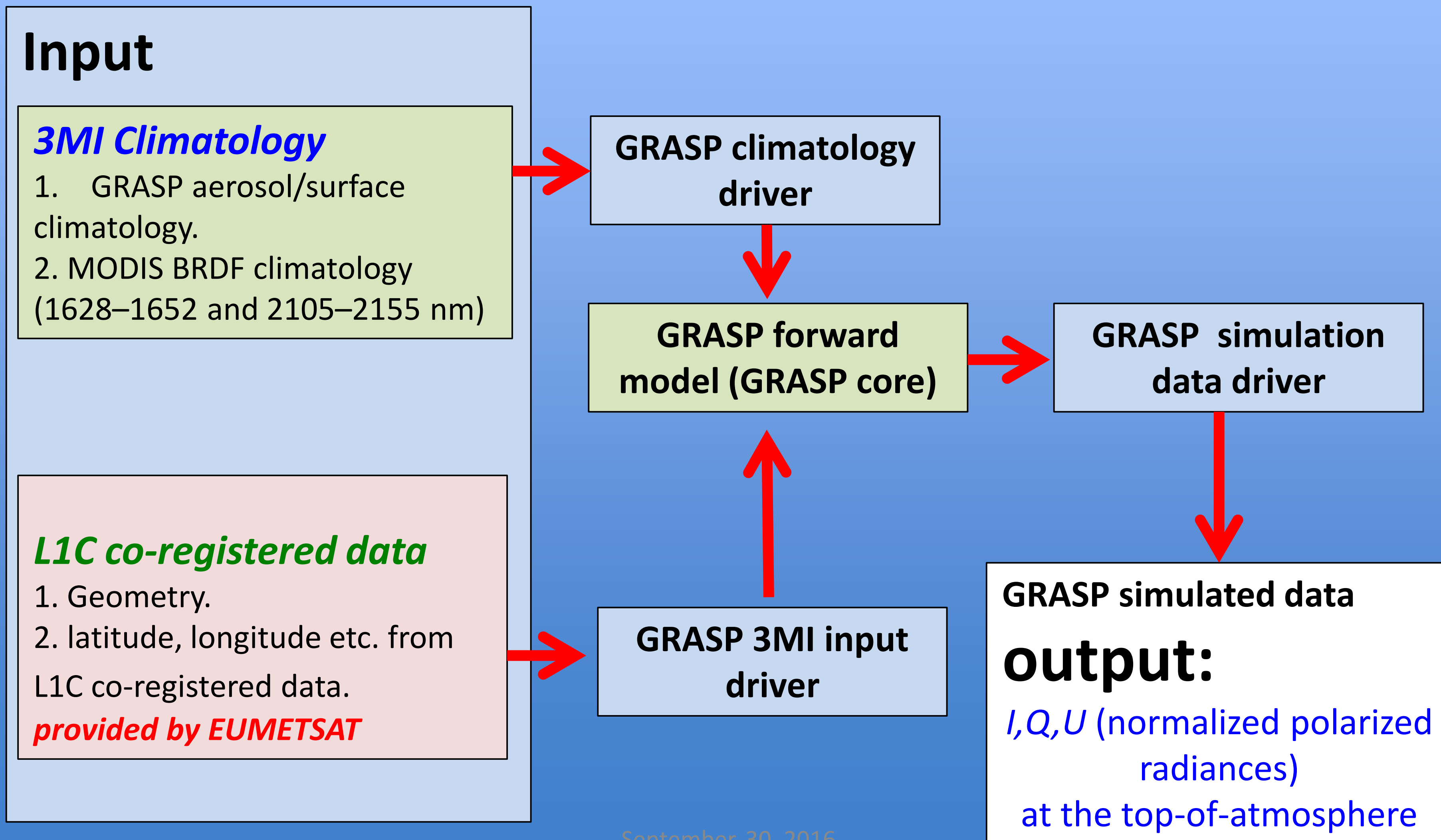
General approach

- **NOVELTIS approach: registration based on acquisitions content:**
  - Identification of the L1C overlap area
  - Generation of a multi-band raster for each acquisition
  - Relative registration with the central acquisition (see next slide)
  - Conversion of the pixel coordinates of the overlap from the 3MI L1C fixed grid to the central raster grid
  - Bilinear interpolation of the co-registered rasters
- **EUMETSAT approach: registration based on the 3MI focal plane model equations and on the knowledge of the satellite state vector at the acquisition times**

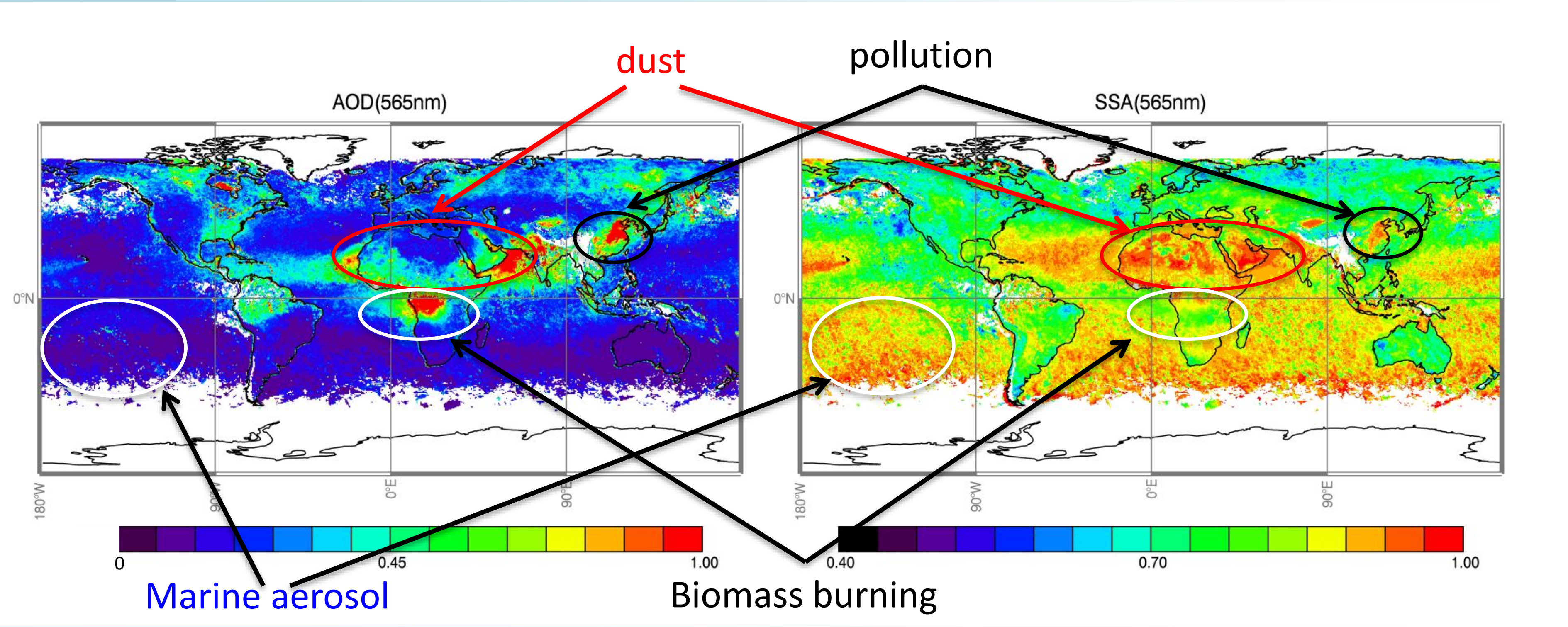
Co-registration technique

- **Extraction of interest points in the base image**
  - **Forstner operator** (search for special textures, edges…)
  - **In the raster band representing the first polarization** (I)
- **Find corresponding points in the warp image**
  - **In the raster band representing the first polarization** (I)
  - **Matching score: normalized mutual information**
- **Filtering of control points** (keep only the more reliable)
- **Geometric transformation**
  - **Based on the selected control points**
  - **For all the raster bands** (all polarisations, real angles and ancillary data)
  - **Polynomial transformation**

GRASP data flow for 3MI top-of-atmosphere simulations



GRASP/PARASOL climatology. Summer, 2008.



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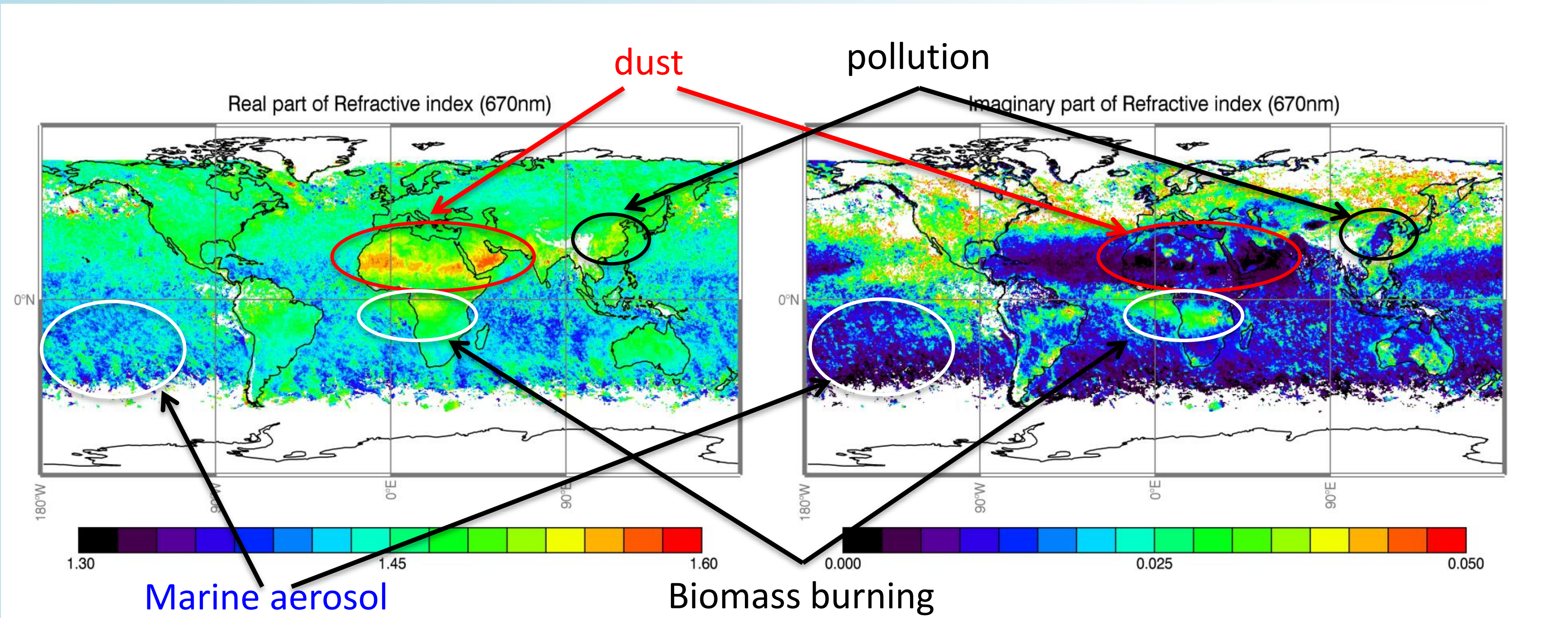
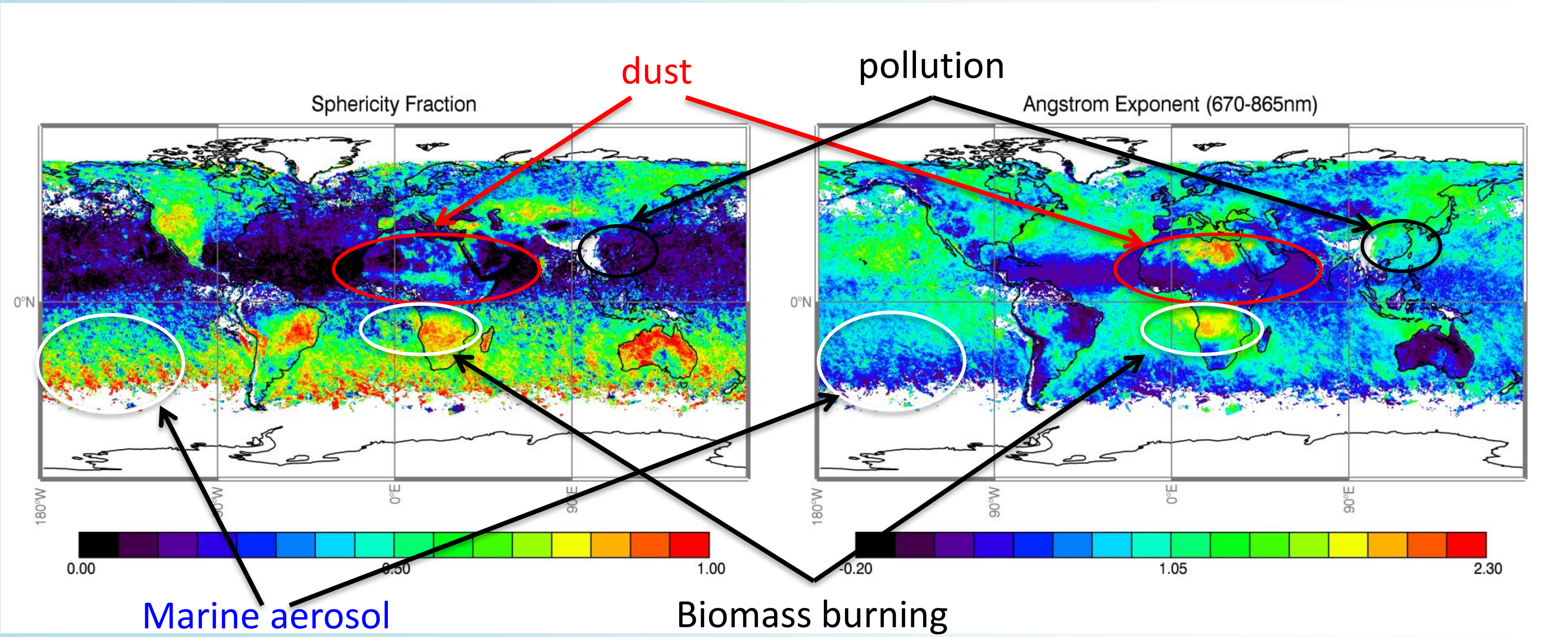


GRASP/PARASOL climatology. Summer, 2008.



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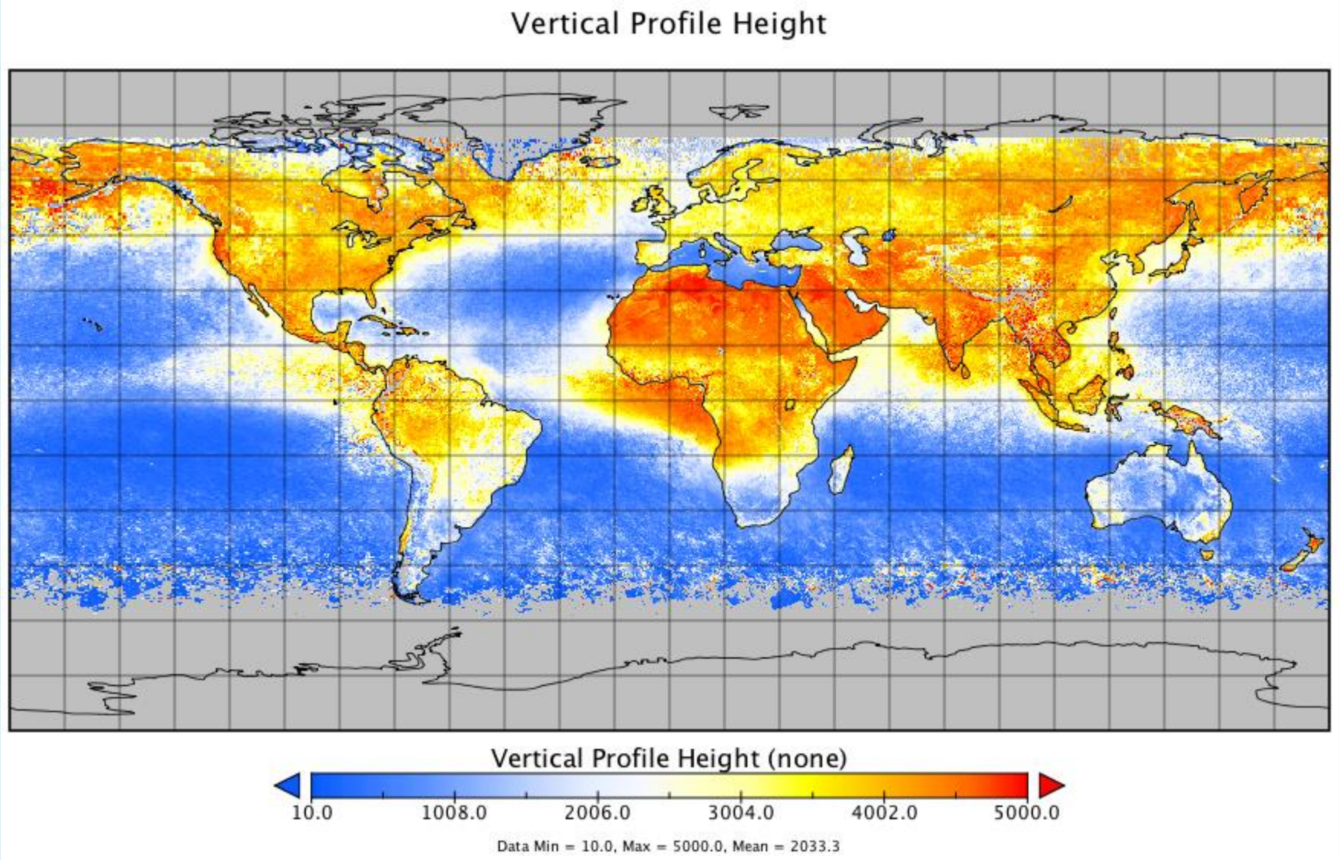
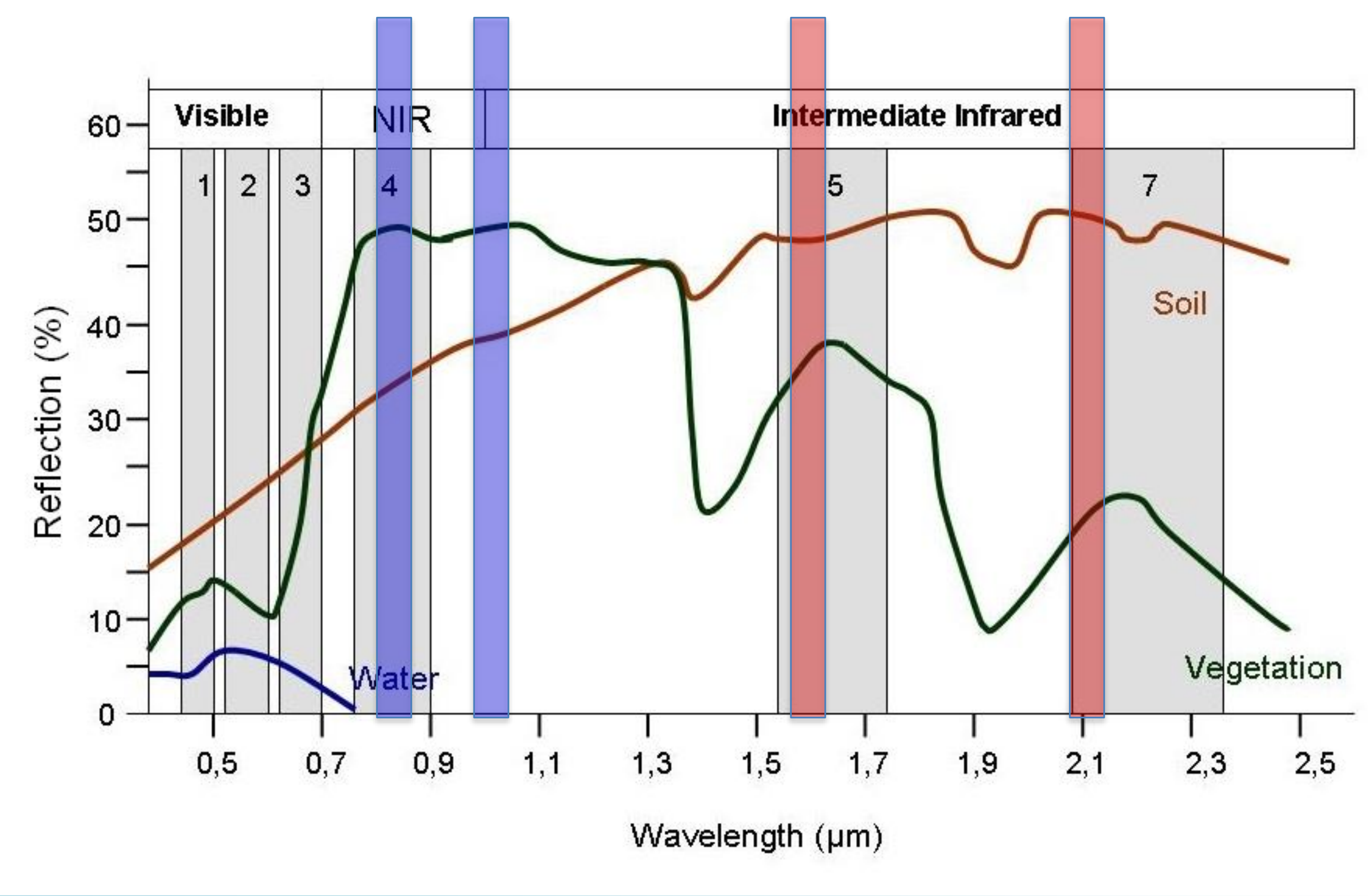


Surface BRDF climatology

PARASOL/3MI 3MI



Aerosol characteristics
Interpolation/extrapolation

PARASOL 6 aerosol channels:

443, 490, 565, 670, 865, 1020 nm

3MI 8 aerosol channels:

410, 443, 490, 555, 670, 865, 1650, 2130 nm ???

$$\ln x_1 = - a_x \ln /_1 + b$$

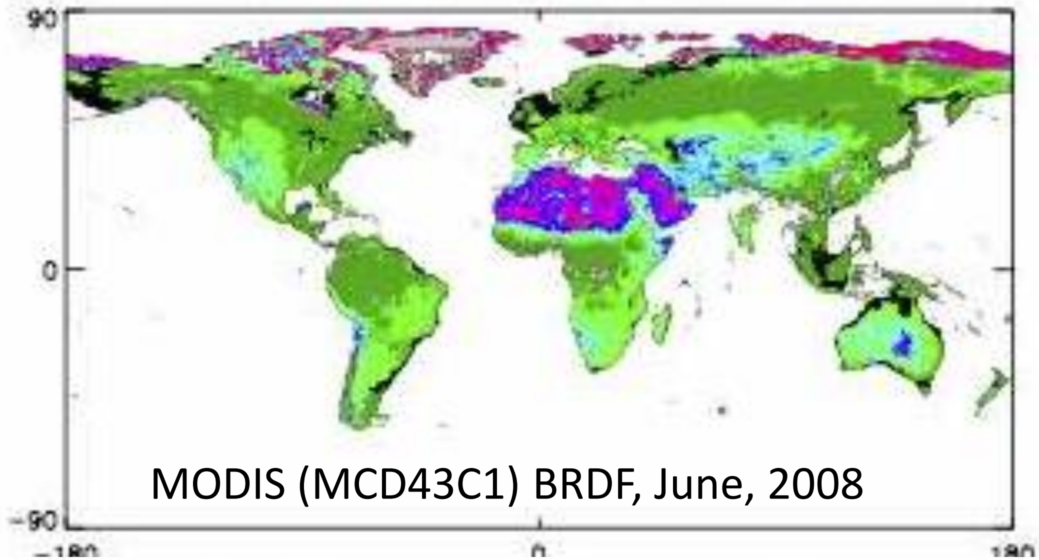
$$\ln x_2 = - a_x \ln /_2 + b$$

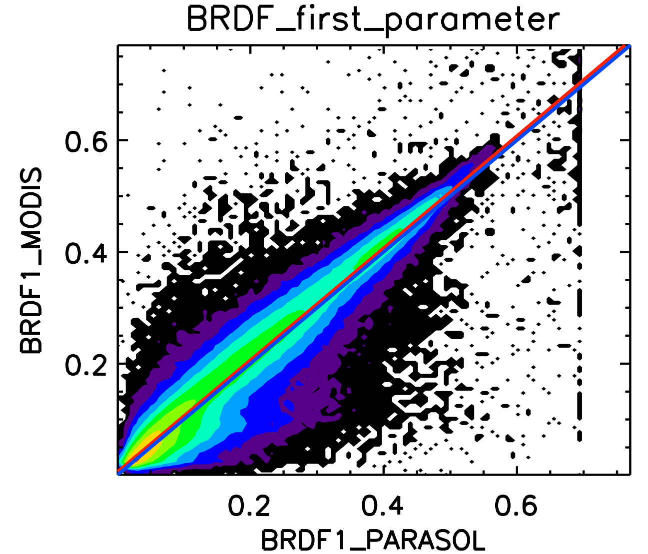
=>

$$a_x = - \frac{\ln x_2 / x_1}{\ln /_2 / /_1}$$

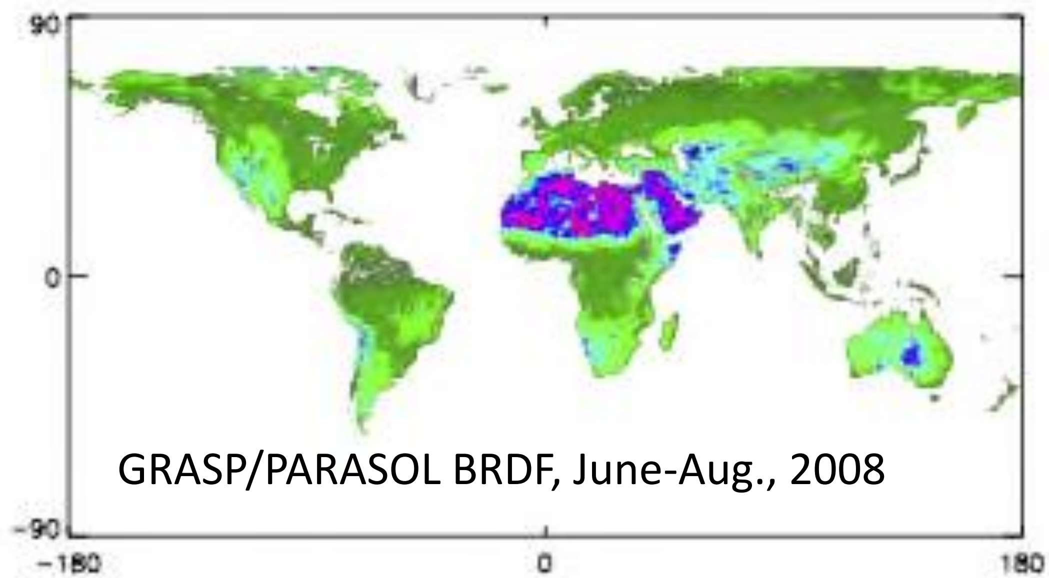
$$\frac{x}{x_1} = \left(\frac{/}{/_1} \right)^{- a_x}$$

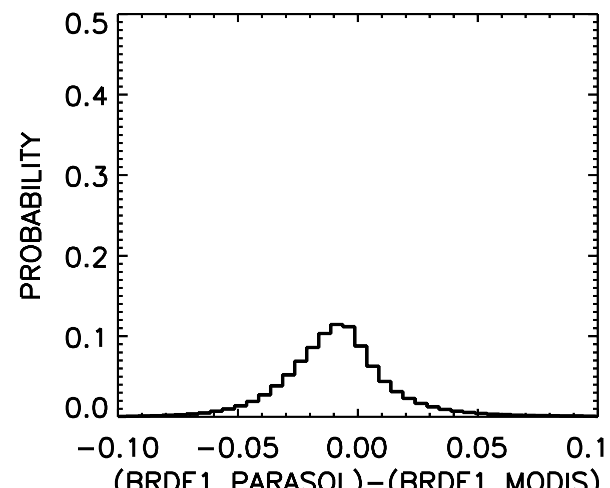
First parameter (670 nm) of Ross-Li BRDF, 2008



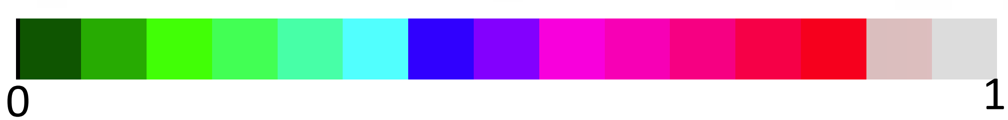


K=0.965 a= 1.00 b= 0.01 RMSE= 0.030

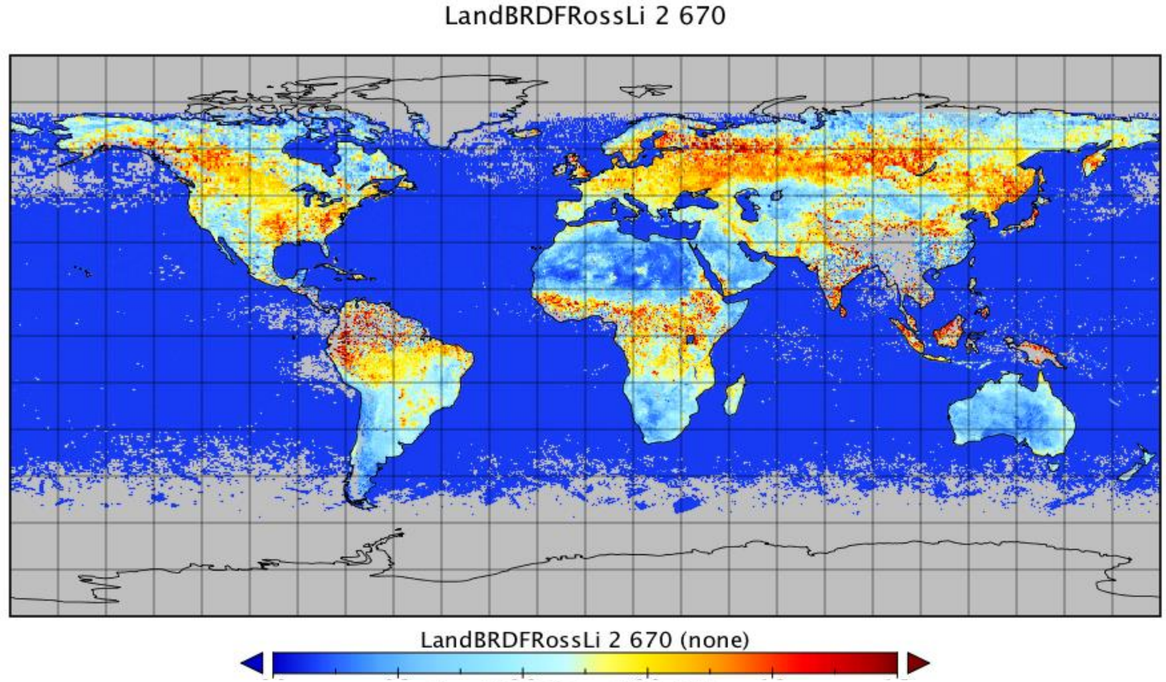




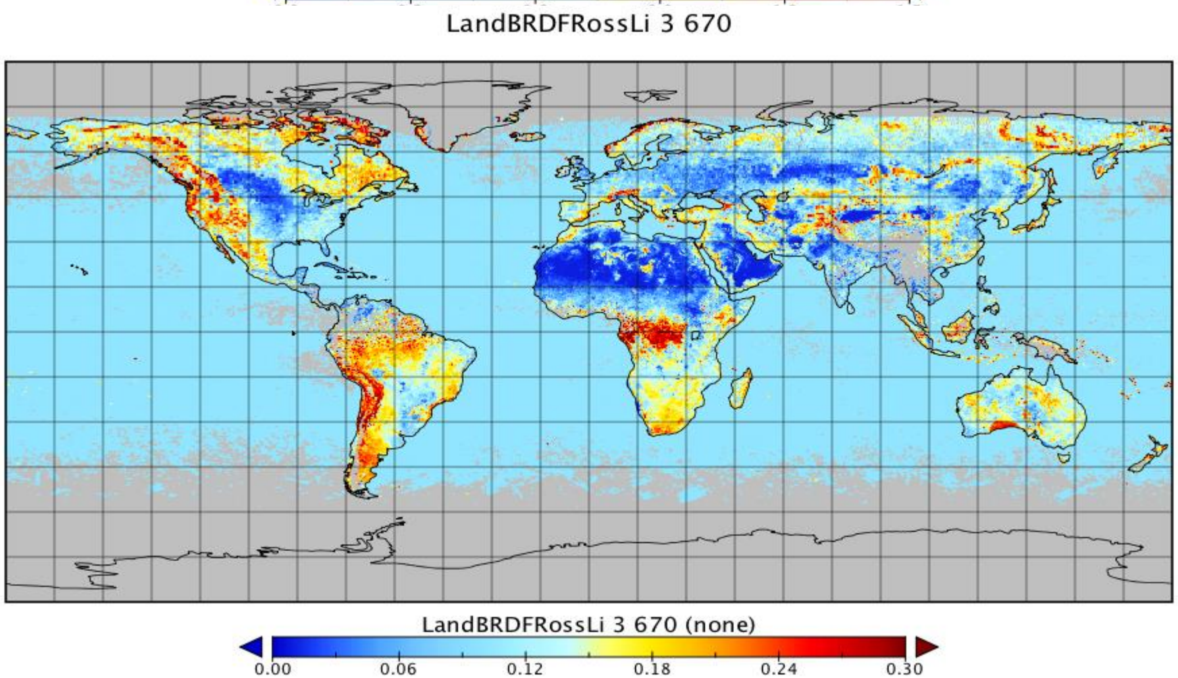
Aver. Value=−0.006 St.D.= 0.030 N=122295



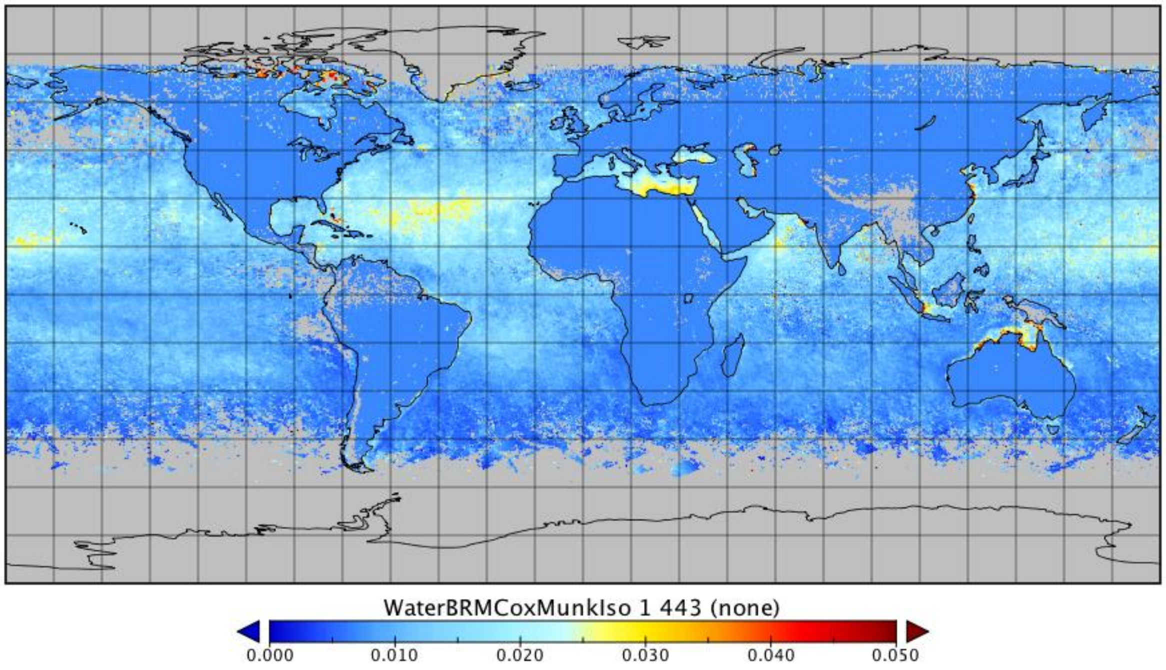
BRDF **second parameter** climatology for Summer, 2008.



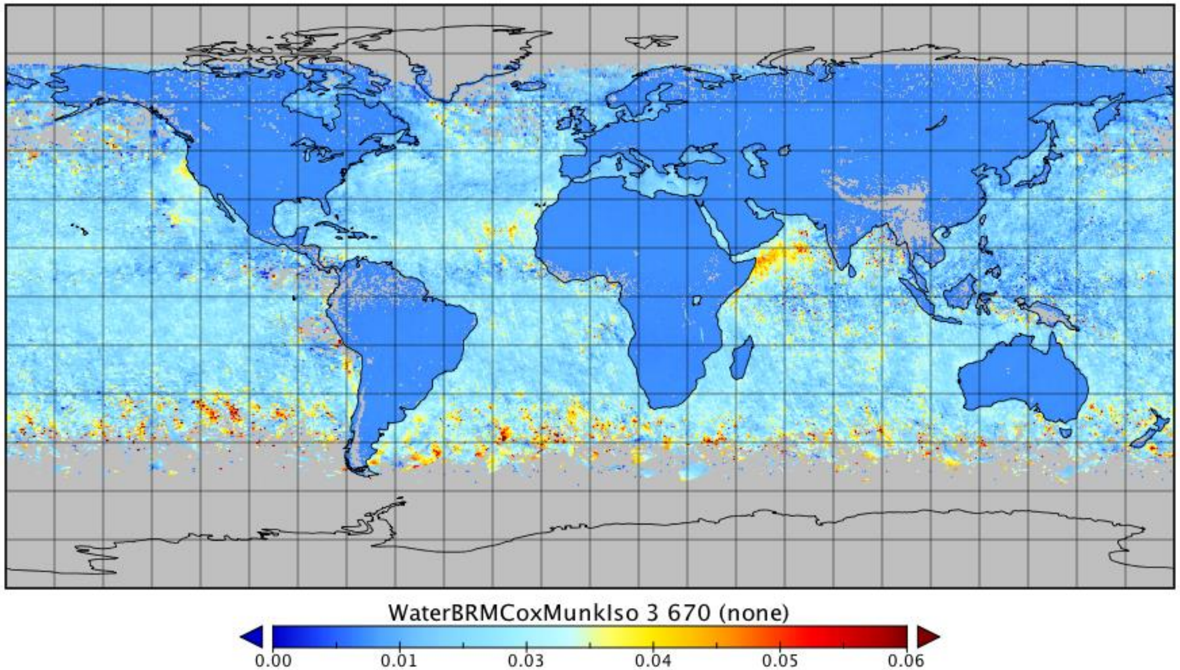
BRDF **third parameter** climatology for Summer, 2008.



climatology for
isotropic albedo of water body.
Summer, 2008.

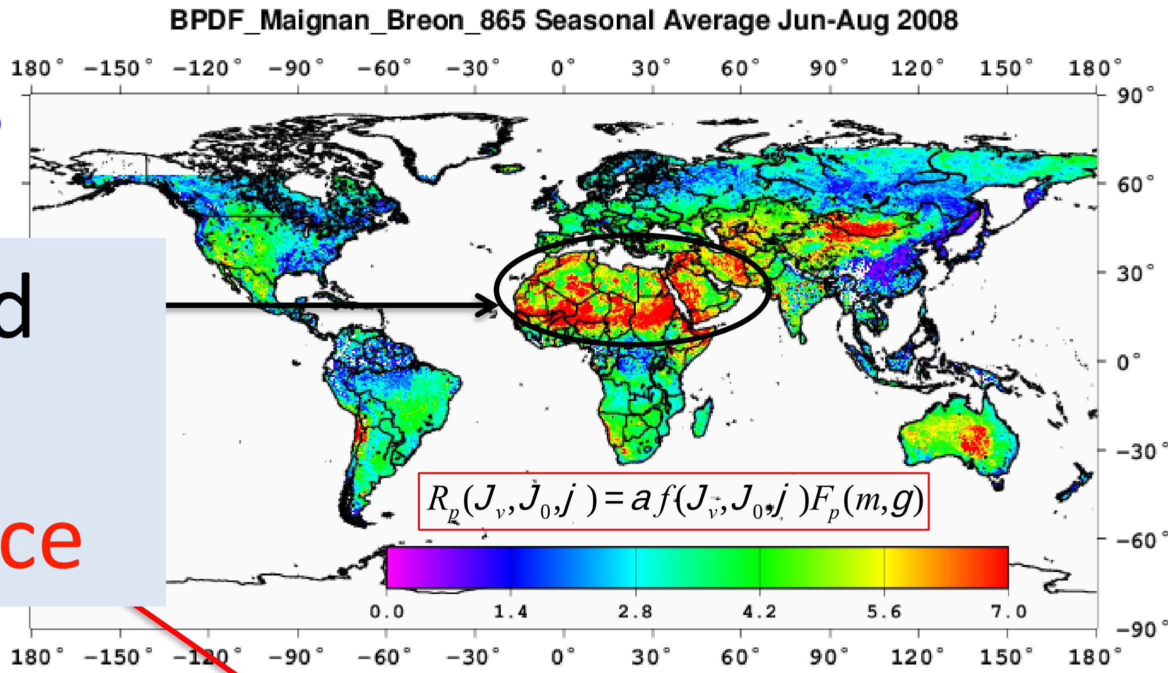


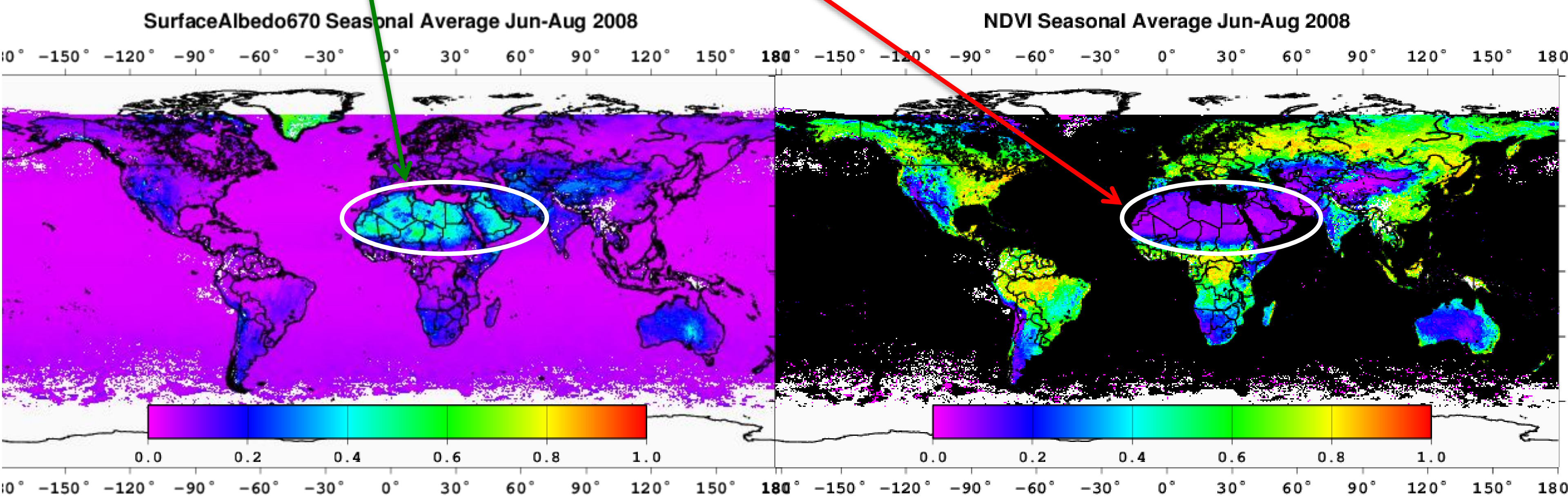
climatology for
mean square facet slope.
Summer, 2008.



Advanced surface retrieval with GRASP

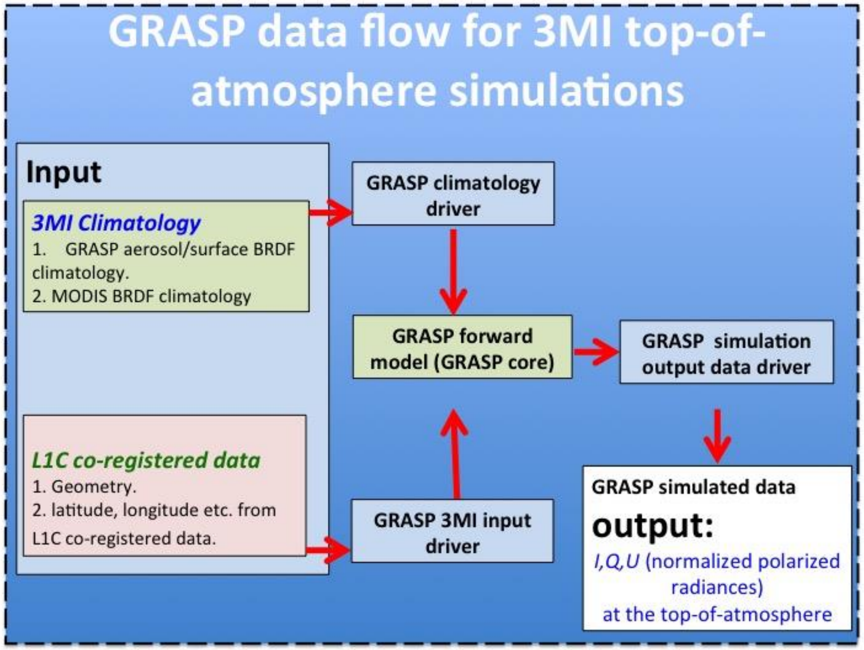
The same NDVI and DHR but different Polarized reflectance

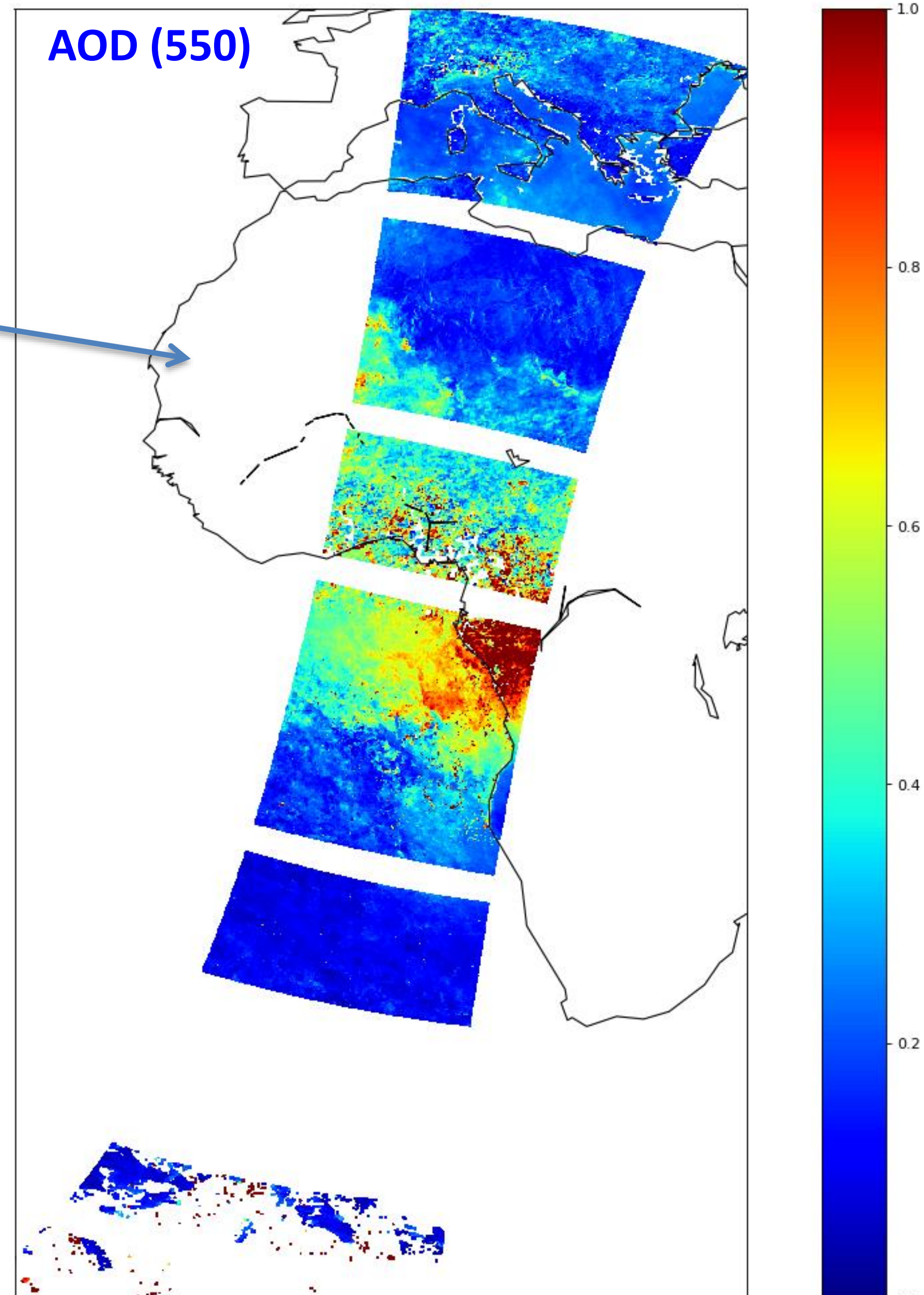




Polarized reflectance provides new information about surface type!

Illustration of PARASOL/GRASP aerosol climatology for selected 3MI orbit





Project results/accomplishments:

Task-1: Set of aerosol models for LUT algorithms was reviewed corrected;

Task-2.1: Independent co-registration function was developed, and corresponding 3MI Level 1C were prepared and delivered;

Task-2.2: 3MI Level 1C proxy data based on PARASOL climatology were simulated were generated and delivered: 1 complete orbit + 3 months over selected AERONET sites.

Task-3 Testing of Baseline EUMETSAT Look-up Table Algorithm (WP-3)

WP manager: Dr. P. Litvinov

Start month: 3	**End month**: 6
Inputs: · Baseline LUT EUMETSAT algorithm; · Level 1c Test Synthetic Data Set for 3MI orbits. · Level 1c Test Proxy Data Set for 3MI orbits based on PARASOL/GRASP retrieval results. · Level 1c Test Proxy 3MI Data Set over selected AERONET sites.	**Outputs**: · Report on the results of the tests on Baseline LUT algorithm performance.

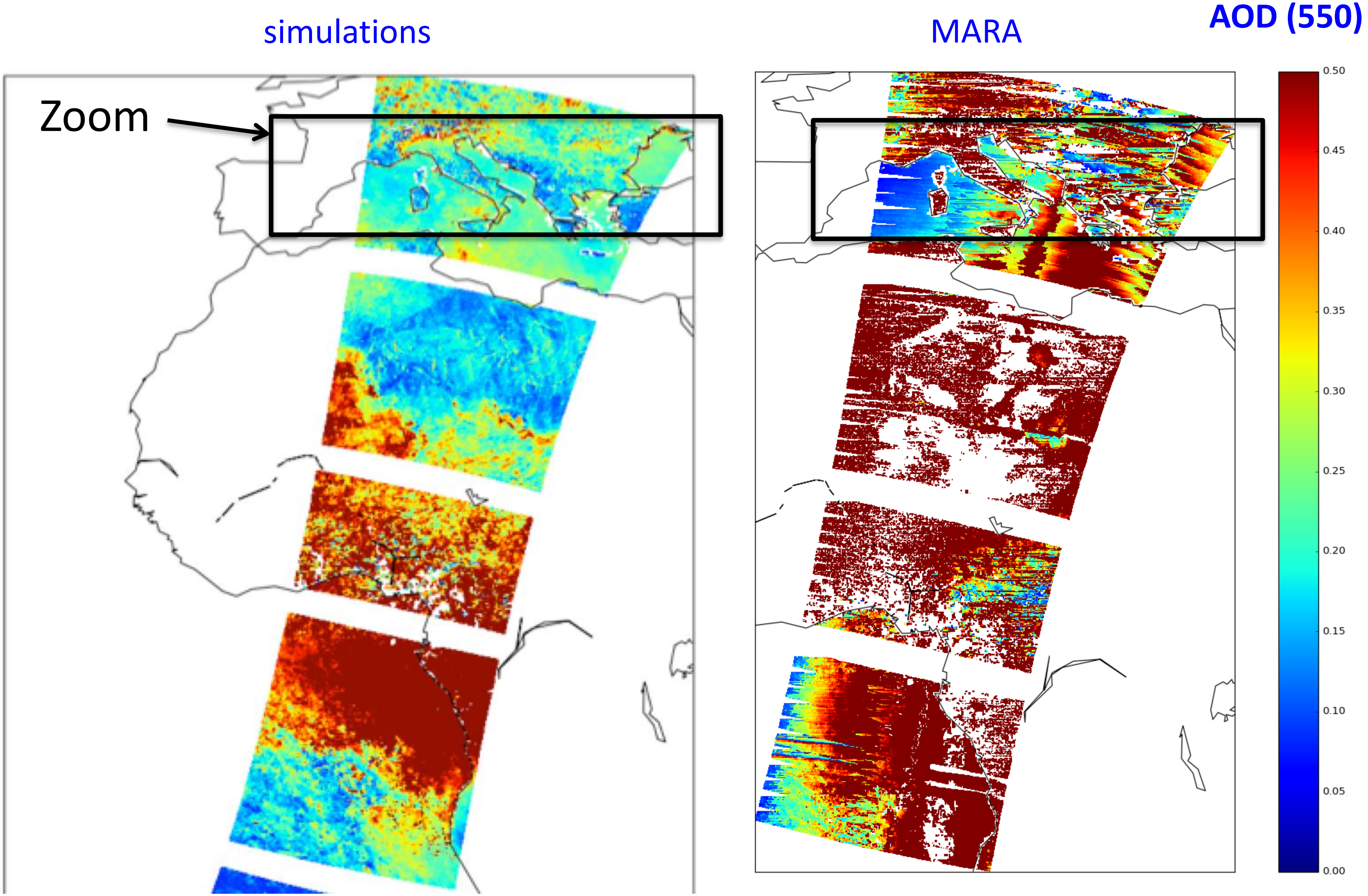
Actions:

- Evaluation of Baseline EUMETSAT Look-up Table Algorithm on the Level 1c Test Synthetic Data Set for 3MI selected orbits;
- Evaluation of Baseline EUMETSAT Look-up Table Algorithm on the Level 1c Test Proxy Data Set for 3MI orbits;
- Evaluation of Baseline EUMETSAT Look-up Table Algorithm on the Level 1c Test Proxy Data Set produced over selected AERONET sites.

Questions:

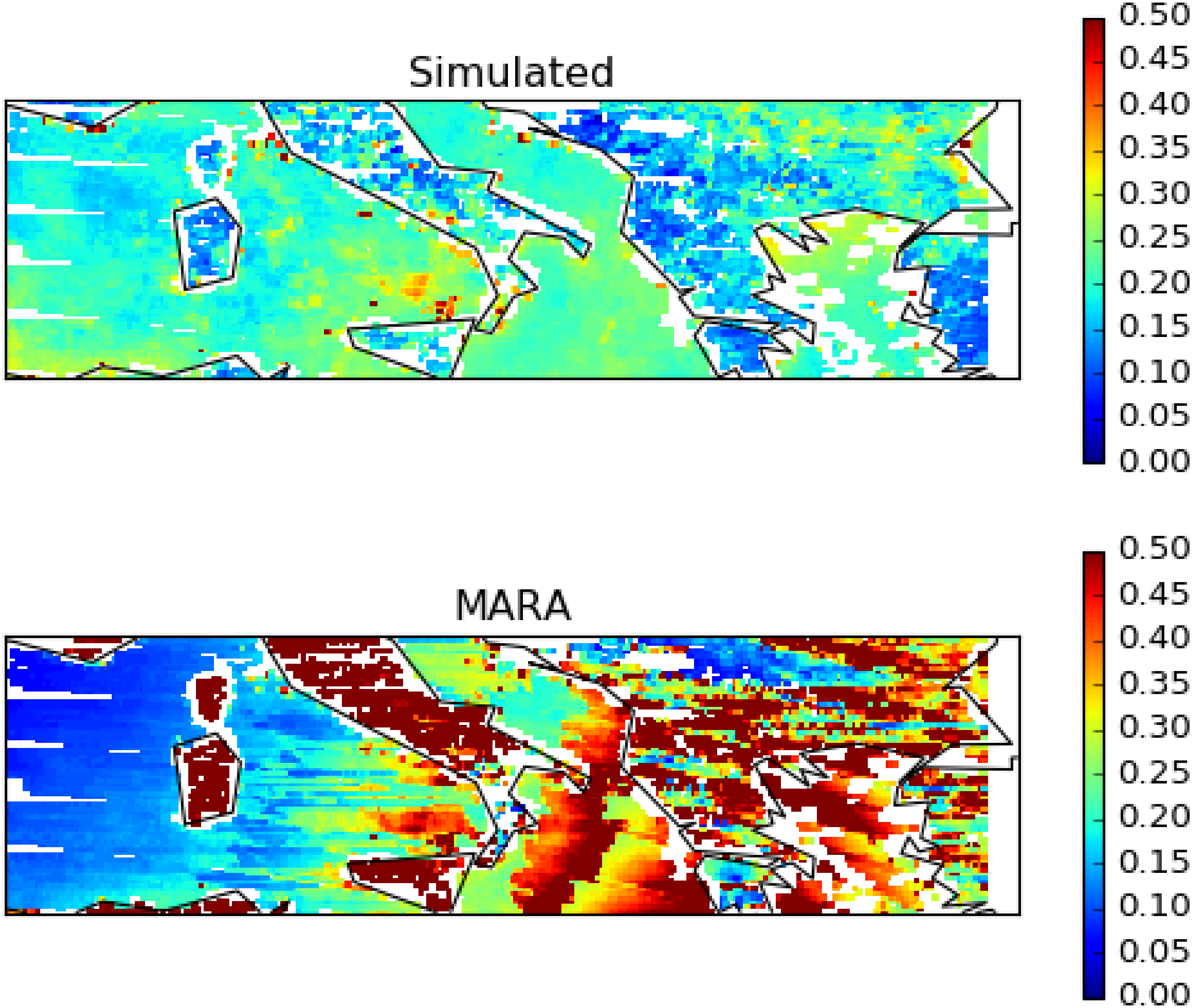
- EUMETSAT input? Algorithm, algorithm framework, format, description, etc.

Comparison "GRASP simulated AOD with retrieved by MARA



Comparison "GRASP simulated AOD" with retrieved by GRASP and MARA (for one file)

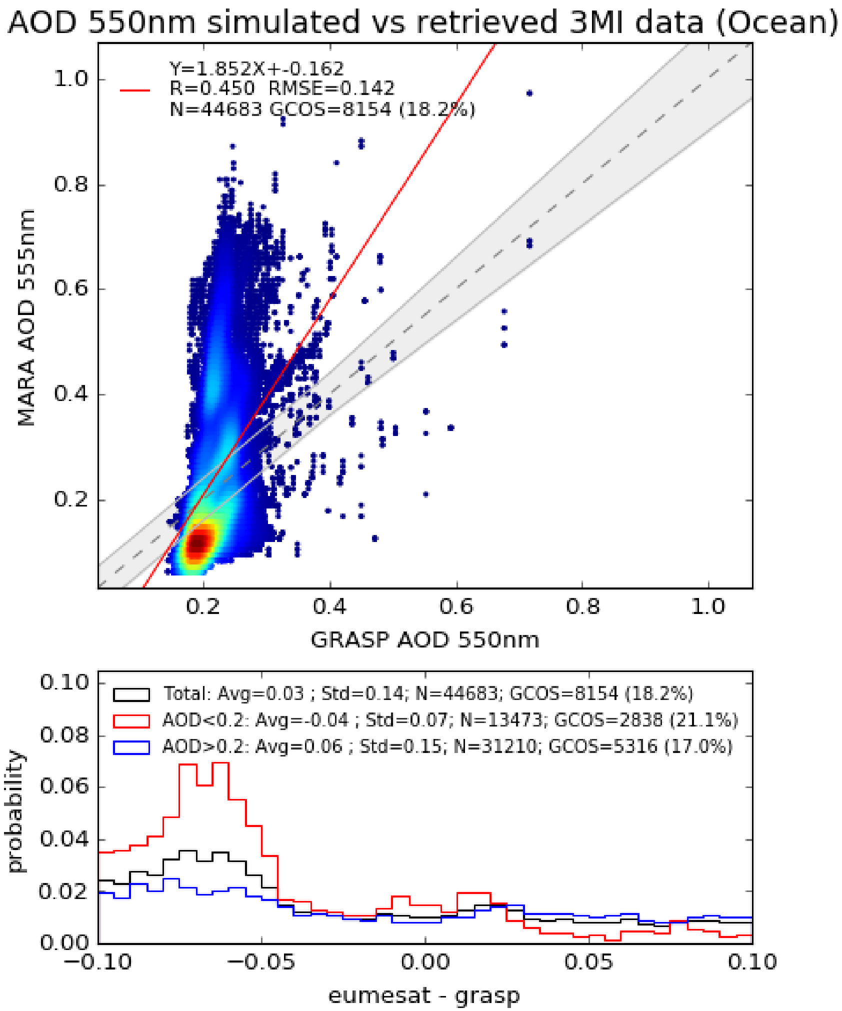
AOD (550)



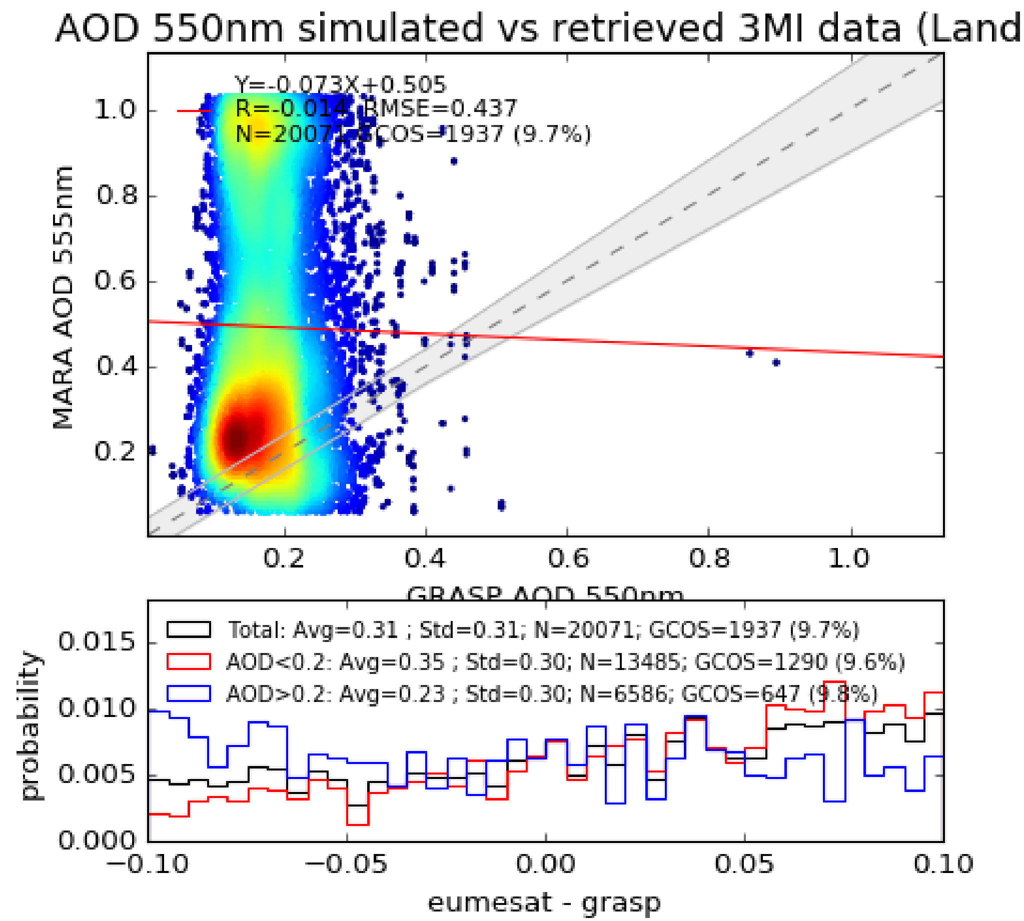
Comparison “GRASP simulated AOD” with retrieved by MARA (for one file)

AOD (555)

Ocean



Land



Project results/accomplishments:

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Task-2.2: 3MI Level 1C proxy data based on PARASOL climatology were simulated were generated and delivered: 1 complete orbit + 3 months over selected AERONET sites.

Task-3: The performance of 3MI LUT algorithm was evaluated. Based on the results the development of LUT algorithm was stopped due to its immaturity.

Task -4: Proposal for Enhanced Aerosol Retrieval Algorithm (WP-4)

WP manager: Dr. O. Dubovik

Start month: 6	**End month**: 9
Inputs: · GRASP algorithm.	**Outputs**: · Near - Real - Time Enhanced Aerosol Retrieval Algorithm. · The ATBD and other documentation of Near - Real - Time Enhanced Aerosol Retrieval Algorithm.

Actions:

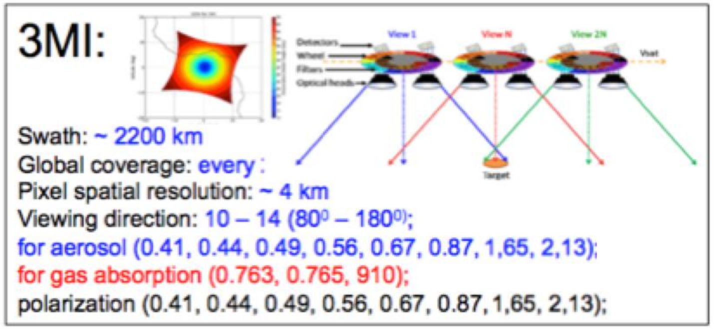
- Finding optimum trade-off between accuracy and speed of RT calculations;
- Identifying possibilities to reduce number of aerosol or surface parameters: possibilities of fixing height, angular shapes of BRDFs etc.
- Different retrieval scenarios will be implemented. The comparative analysis of retrieval speed and accuracy of all approaches will be conducted.
- Testing will be performed using the data prepared using real PARASOL data both regionally (over selected AERONET stations (Table 2)) and for selected observational orbits. The results of extended aerosol properties retrievals will be compared and validated with AERONET.

3MI:

- radiances & polarization

(410, 440, 490, 560, 670, 870, 1650, 2103 nm)

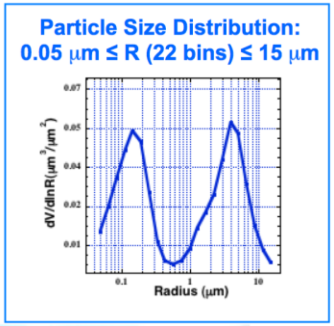
- 10- 14 viewing directions

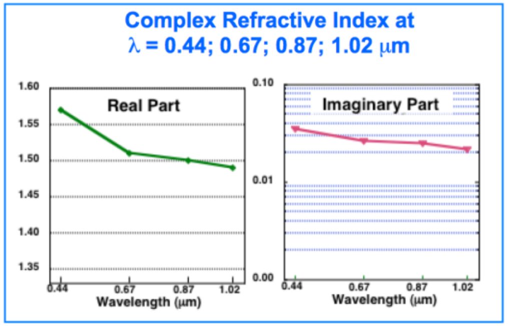


240 - 336 measurements

AEROSOL:

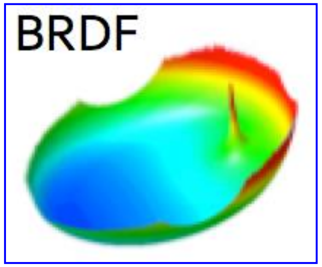
- size distribution (5 or more bins)
- spectral index of refraction (8 λ)
- sphericity fraction;
- aerosol height

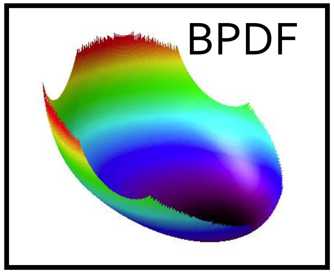




SURFACE:

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





55 = (5 (SD) +16 (ref. ind.) + 1 (nonsp.) + 24 (BRDF) +8 (BPDF) + 1 (height)

Questions for Task-4

Accuracy

How accurate retrieval should be ?

How accurate retrieval can be?

.

Speed:

-

How fast retrieval should be ?

How fast retrieval can be?

.

Multi-Source LSM approach:

$$\boldsymbol{P}_{1,2,3} = \boldsymbol{P}_1 \boldsymbol{P}_2 \boldsymbol{P}_3 \ldots \sim \exp\left(-\frac{1}{2\sigma_1^2} \sum_i \frac{\sigma_1^2}{\sigma_i^2} \left(\Delta \boldsymbol{f}_i^T \Delta \boldsymbol{f}_i\right)\right) = max \longrightarrow \sum_i \frac{\sigma_1^2}{\sigma_i^2} \left(\Delta \boldsymbol{f}_i^T \Delta \boldsymbol{f}_i\right) = min$$

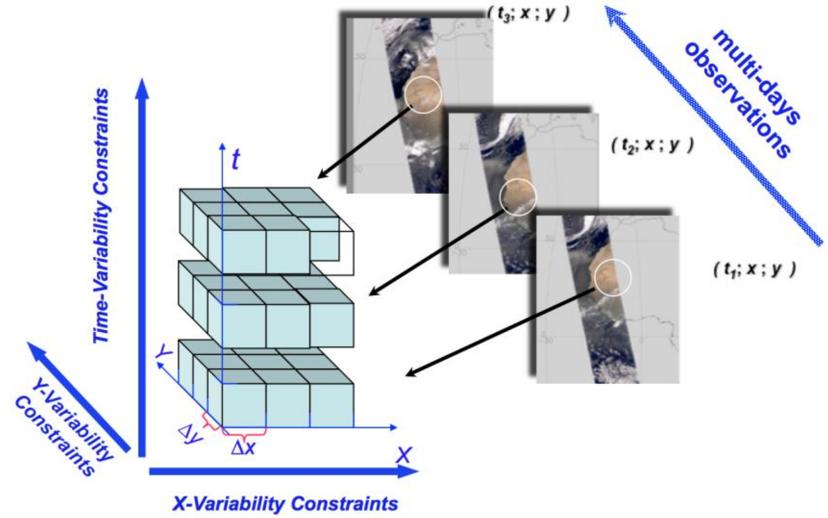
where $\Delta_i = \boldsymbol{f}_i^* - \boldsymbol{f}_i(\boldsymbol{a})$ and $\boldsymbol{f}_i^*$ - measurements or *a priori data*

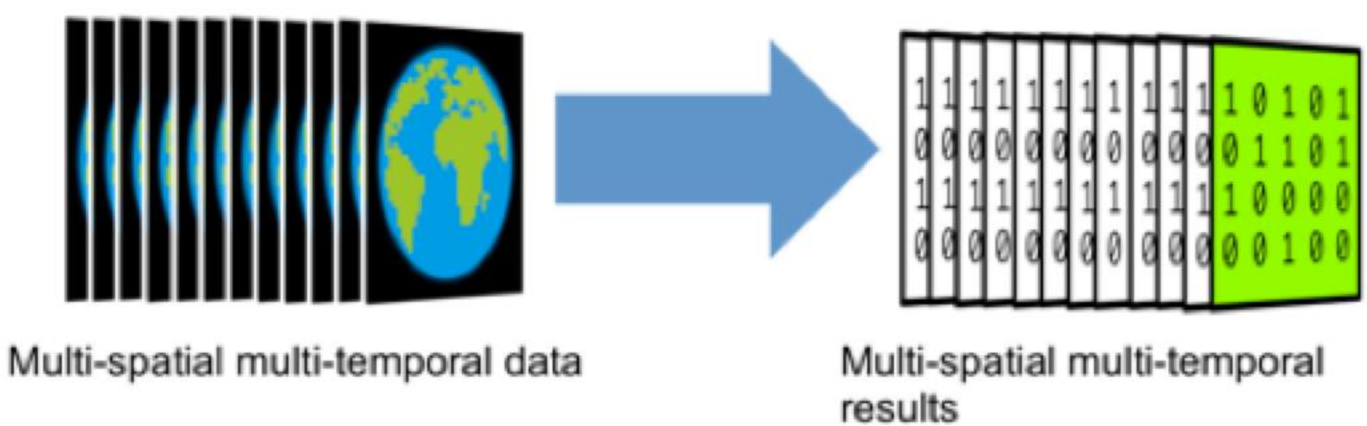
P (...) - *Probability Density Function (**Likelihood**)*

- Optimum data combination
- Optimum use of a priori information
- Continuous solution space
- Rigorous error estimations
- Large number of retrieved parameters with less assumption

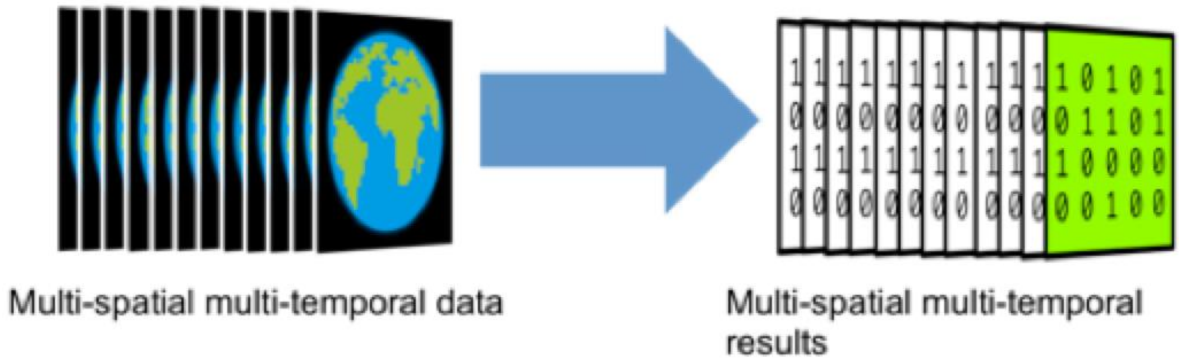
- More "sophisticated"
- Generally more time consuming

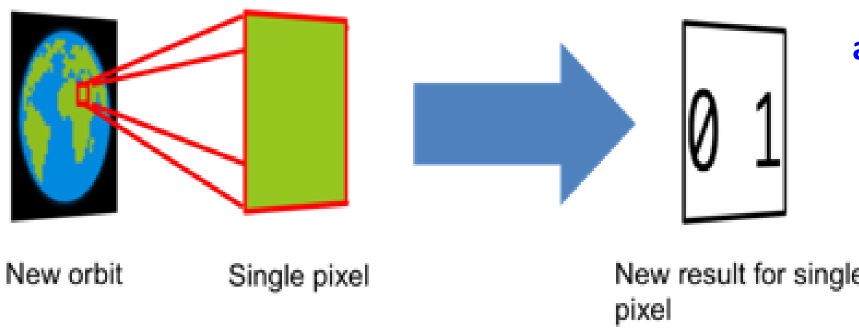
Utilization of multi-pixel time constraints for 3MI NRT?





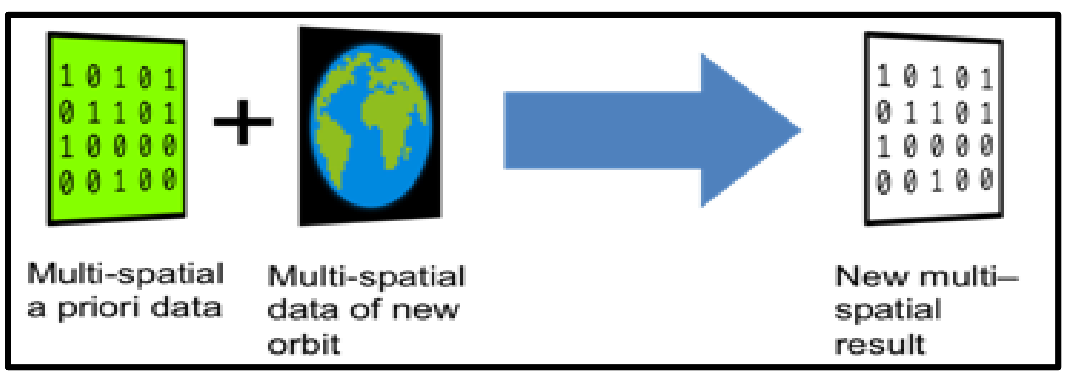
Utilization of multi-pixel time constraints for 3MI NRT?





all retrieved with single initial guess
(single – pixel, horizontal multi-pixel)

all retrieved with using surface reflectance from day before
(horizontal multi-pixel)



NRT

Forward Model

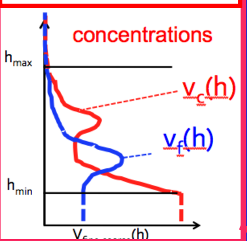
Vector of retrieved parameters :

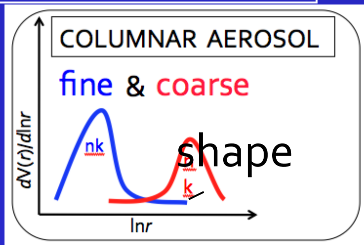
$\mathbf{a}^{aer}$ - aerosol properties

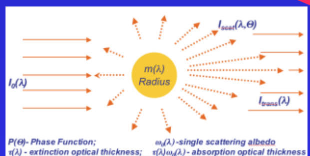
$\mathbf{a}^{surf}$ - surface properties

$\mathbf{a}^{aer}$ $\mathbf{a}^{surf}$

Vertical distribution





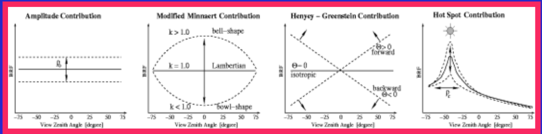


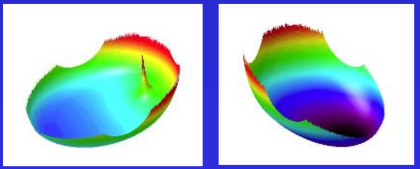
Aerosol single scattering

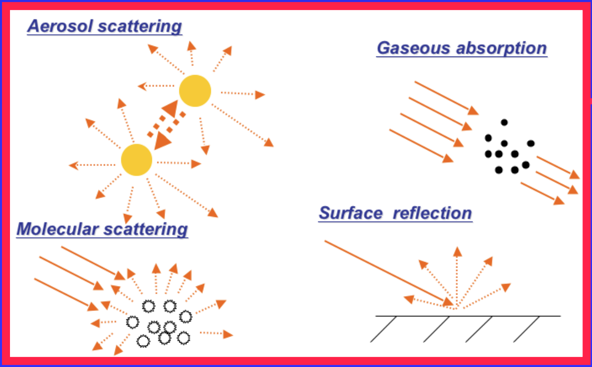
$\tau(\lambda, h)$, $\omega_0(\lambda, h)$, $P(\lambda, \Theta, h)$

Surface reflectance

BRDF | BPDF





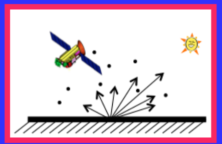


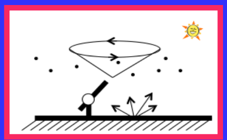
Multiple scattering effects

Radiative Transfer:

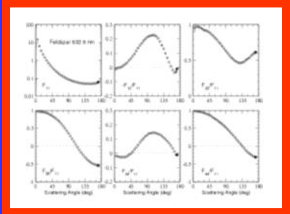
$F(\lambda, \Theta, \square)$

Simulated observations:





In situ, laboratory



Optimum forward model?

Aerosol:

.

- Shapes of particles;
- Assumptions on complex index of refraction;
- Assumptions on vertical distributions;
- Model of particle size distribution.

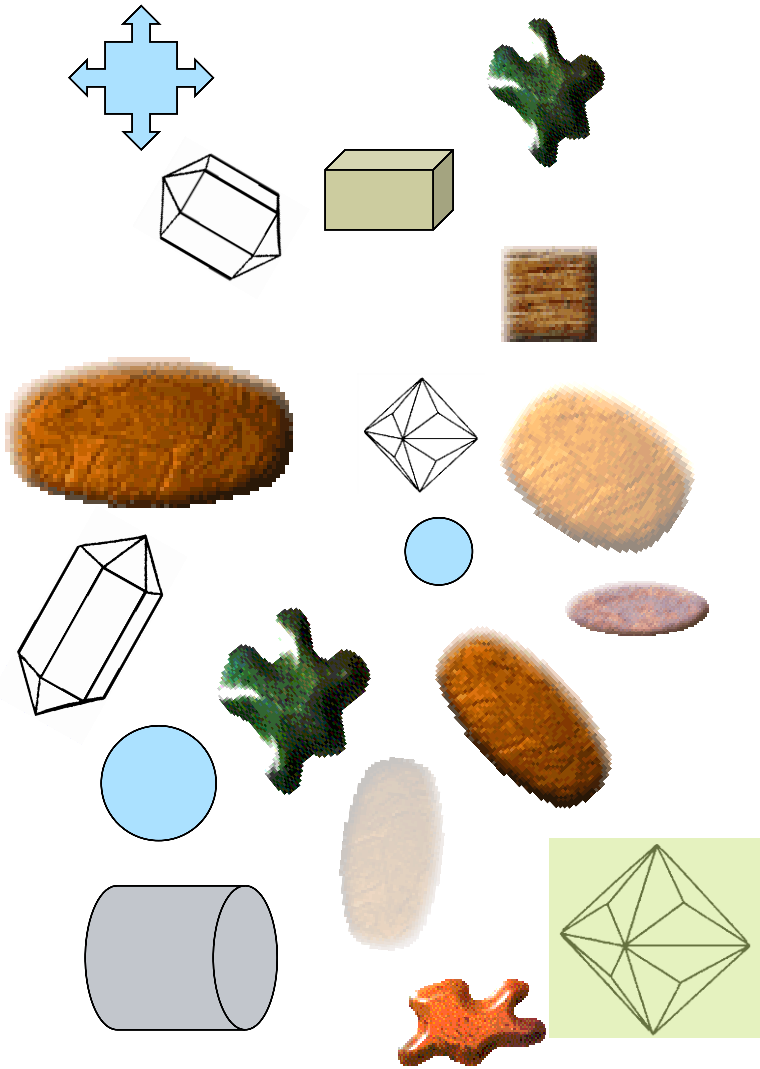
Surface:

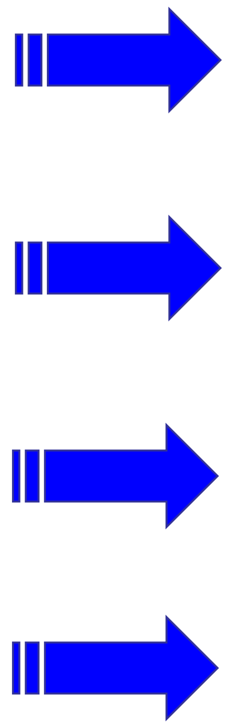
.

- Model of BRDF;
- Model of BPDF;

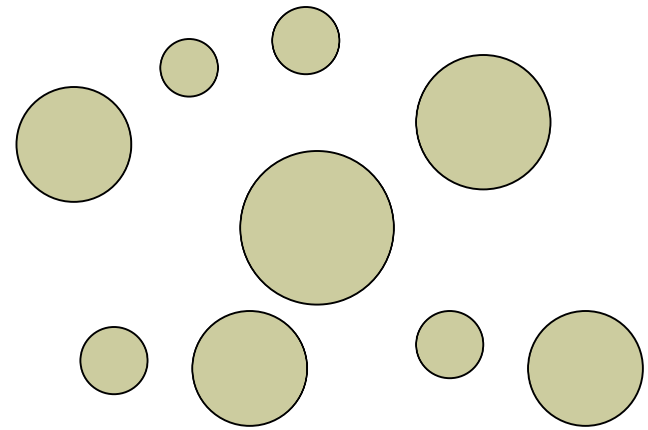
Dubovik et al., 2006

AERONET model of aerosol



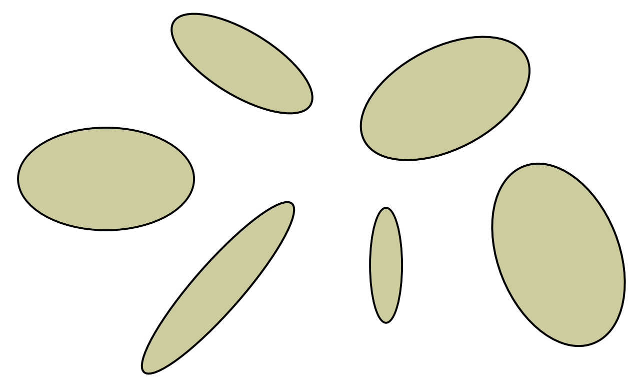


spherical:



Randomly oriented spheroids :

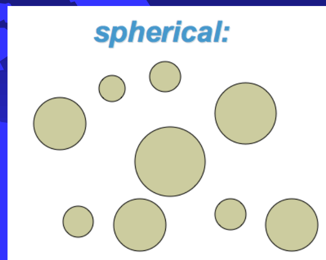
(Mishchenko et al., 1997)



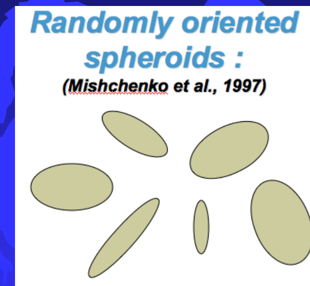
Mixing of particle shapes

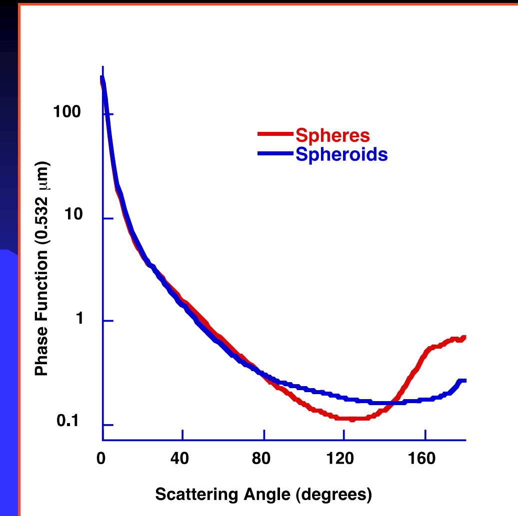
retrieved

C ×



+ (1-C) ×





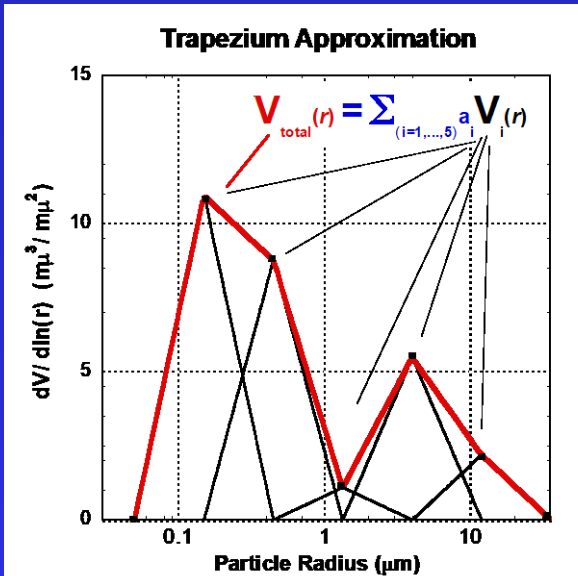
$$\tau(\lambda) = C \int_{r_{min}}^{r_{max}} K_\tau^{spherical}(k;n;r)V(r)dr + (1-C)\int_{r_{min}}^{r_{max}} \left(\int_{\varepsilon_{min}}^{\varepsilon_{max}} K_\tau^{\varepsilon}(k;n;r,\varepsilon)N(\varepsilon)d\varepsilon \right) V(r)dr$$

Aspect ratio distr.

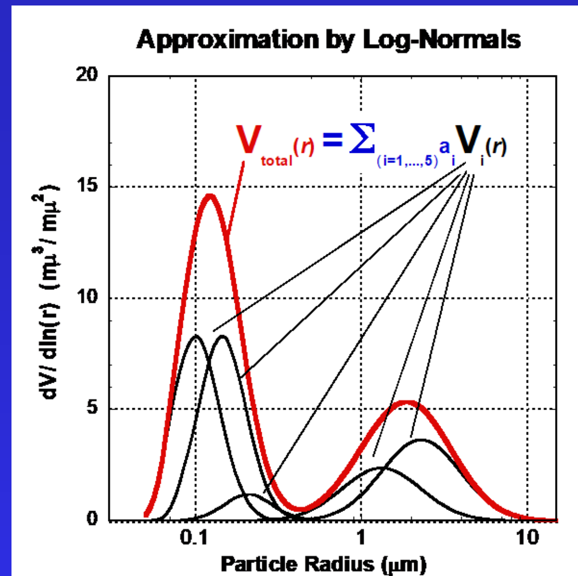
ASSUMPTIONS:

- dV/dlnr - volume size distribution is the same for both components;
- non-spherical - mixture of randomly oriented polydisperse spheroids;
- aspect ratio distribution $N(\varepsilon)$ is fixed to the retrieved by Dubovik et al. 2006

Aerosol representation in the algorithm:



Twomey 1977



Log-normal:

$$\frac{dV(r)}{d\ln r} = \sum_{i=1,\dots,N} C_i e^{-\frac{(\ln r_i - \ln r)^2}{2\sigma_i^2}}$$

C_i , r_i , σ_i - *retrieved*

for detailed description of size distribution

for moderately detailed description of size distribution

for bi-modal size distribution

- Size distribution is multi-component
- Each component may have same or different n(λ) and k(λ)

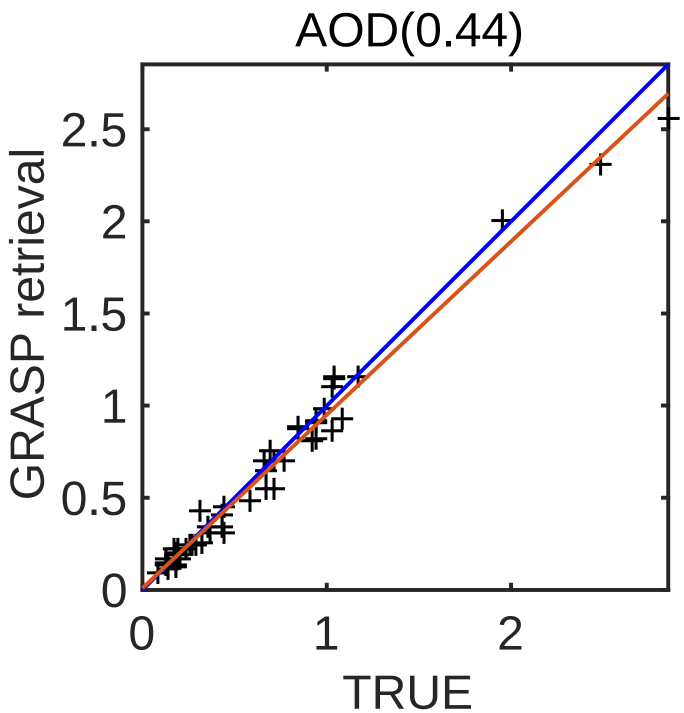
3MI sensitivity tests

- Sensitivity to different assumptions on on size distribution
- Effect of using a priori assumptions on surface reflectance

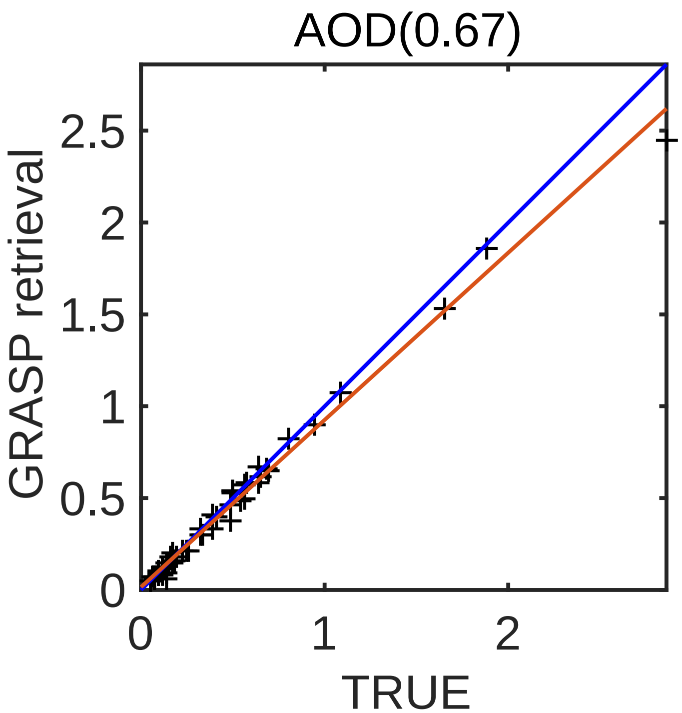
- Retrievals over Banizoumbou, Kanpur, Beijing, Mongu and Crete
- Model parameters taken from AERONET for aerosol and from POLDER/MODIS surface data
- Simulation made using high quality settings

Simulation - 22 bin and retrieval - 5 bin no a priori on surface

AOD



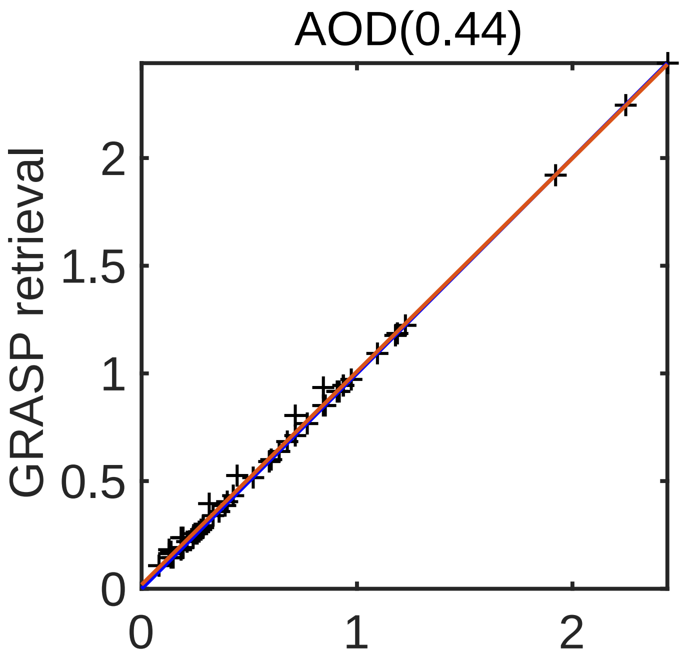
K=0.991 a=0.94 b=0.01 RMSE=0.085
N=50 Aver.=0.63924



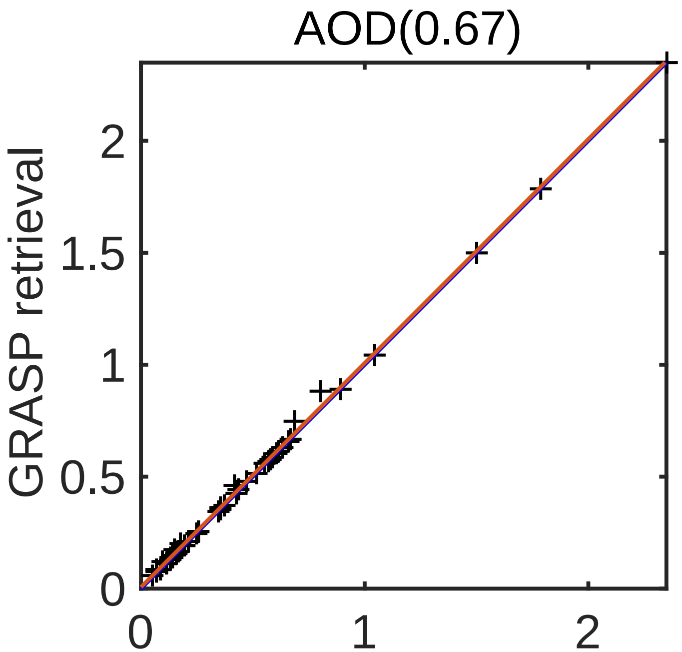
K=0.995 a=0.91 b=0.01 RMSE=0.070
N=50 Aver.=0.45412

Simulation - 22 bin and retrieval - 5 bin good a priori on surface

AOD



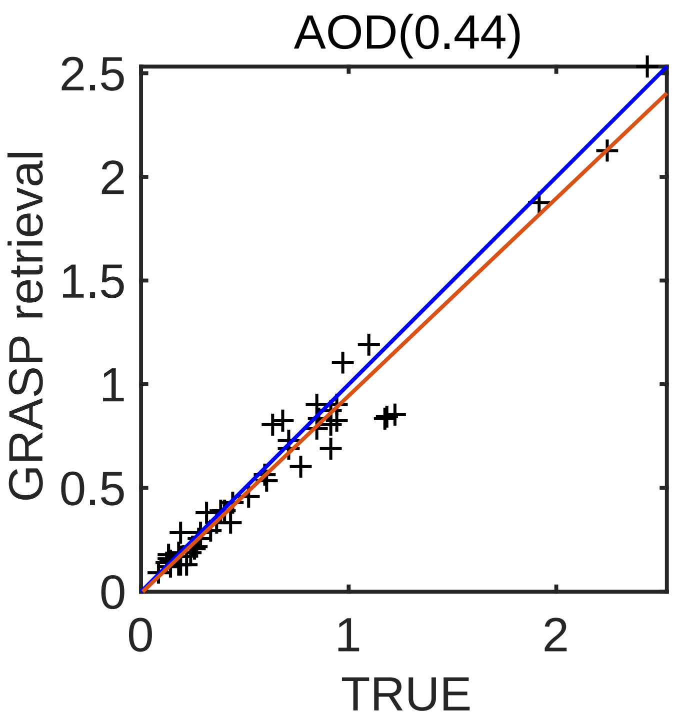
K=0.999 a=0.99 b=0.02 RMSE=0.030
N=50 Aver.=0.62199



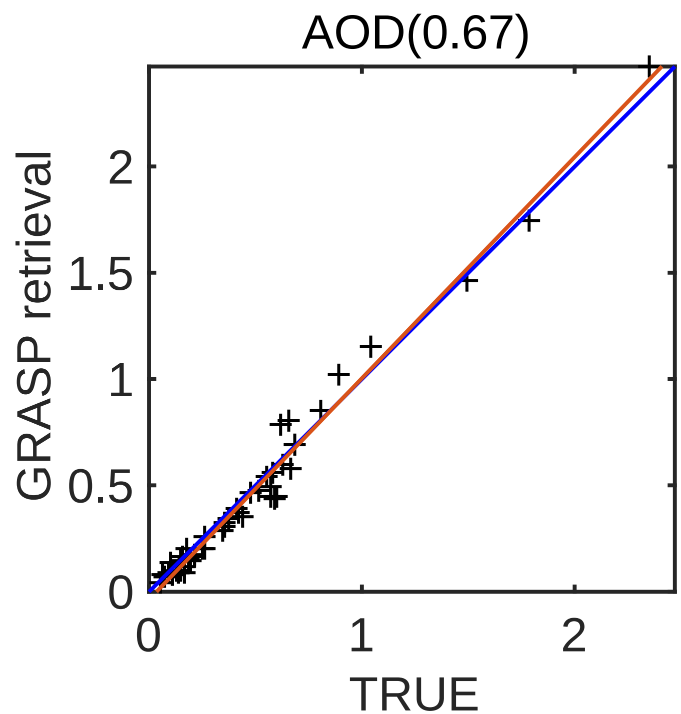
K=0.999 a=1.00 b=0.01 RMSE=0.018
N=50 Aver.=0.44798

Simulation -22 bin and retrieval - 2 log good a priori on surface

AOD



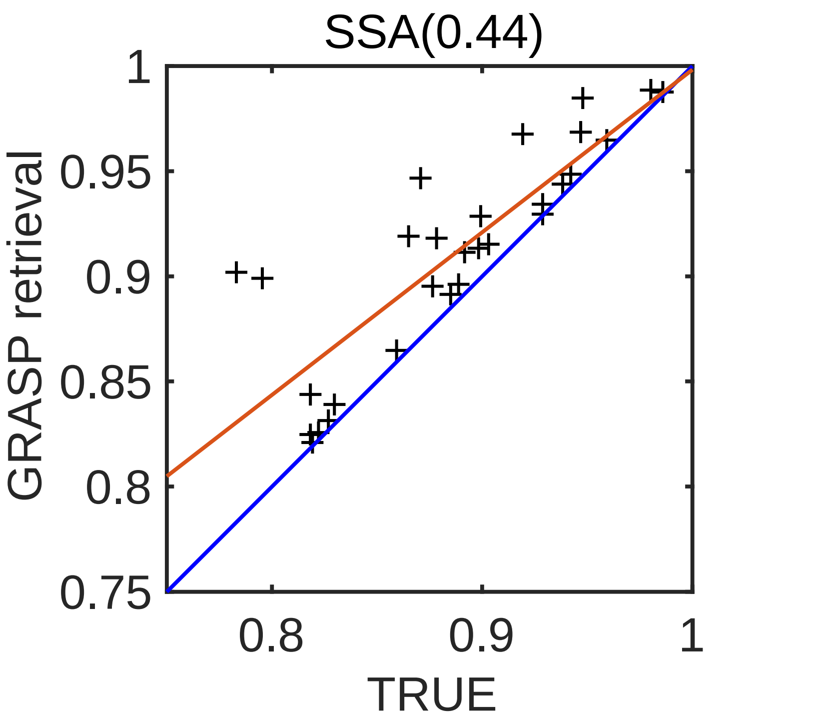
K=0.978 a=0.95 b=-0.01 RMSE=0.114
N=50 Aver.=0.62199



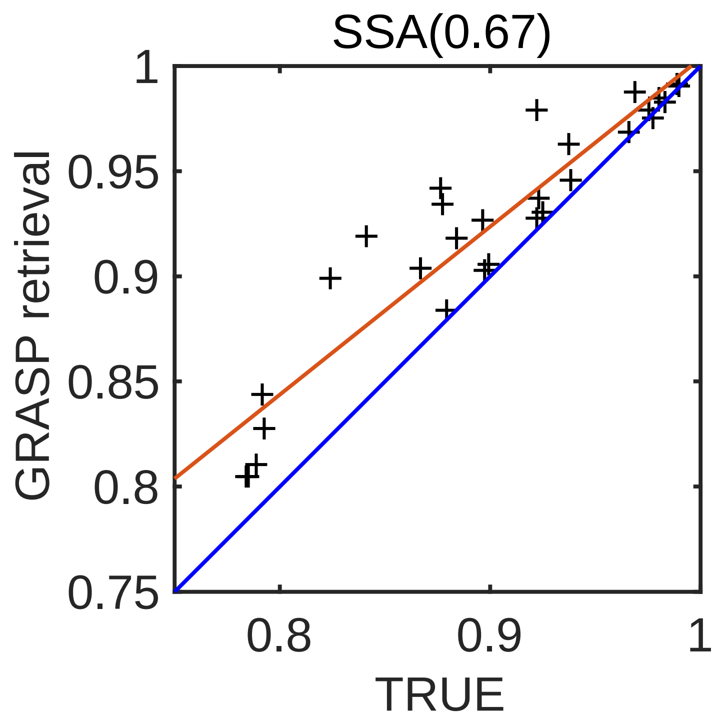
K=0.991 a=1.04 b=-0.04 RMSE=0.068
N=50 Aver.=0.44798

Simulation - 22 bin and retrieval - 5 bin no a priori on surface

SSA



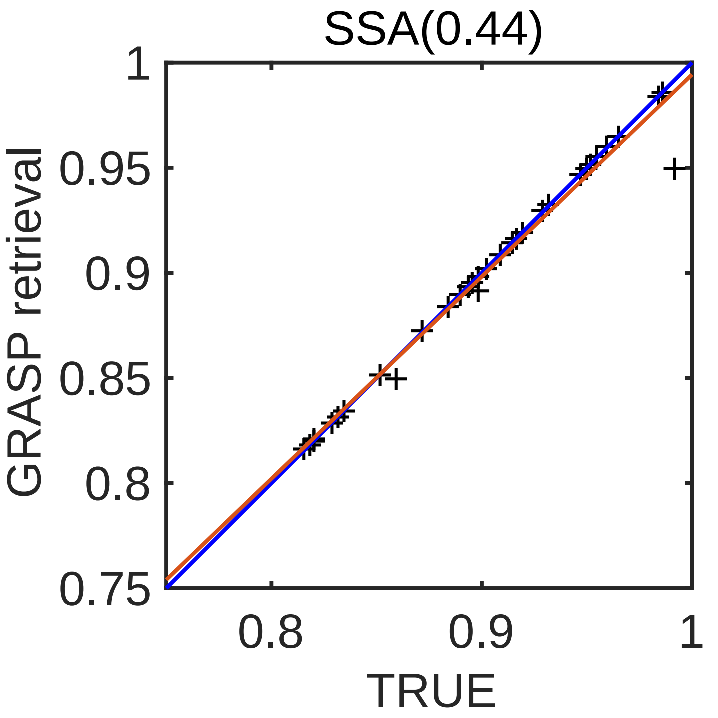
K=0.843 a=0.77 b=0.22 RMSE=0.038
N=29 Aver.=0.88653



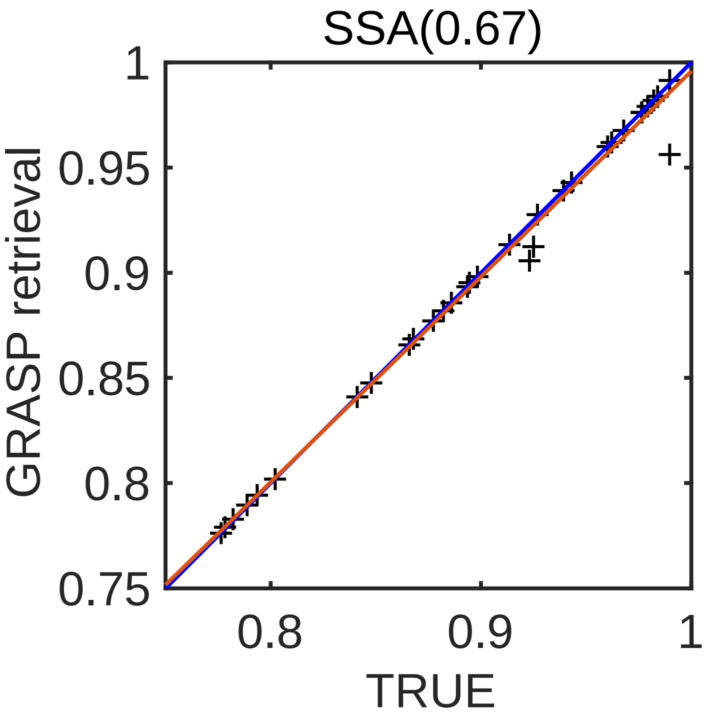
K=0.939 a=0.80 b=0.20 RMSE=0.034
N=29 Aver.=0.89937

Simulation - 22 bin and retrieval - 5 bin good a priori on surface, AOD > 0.2

SSA



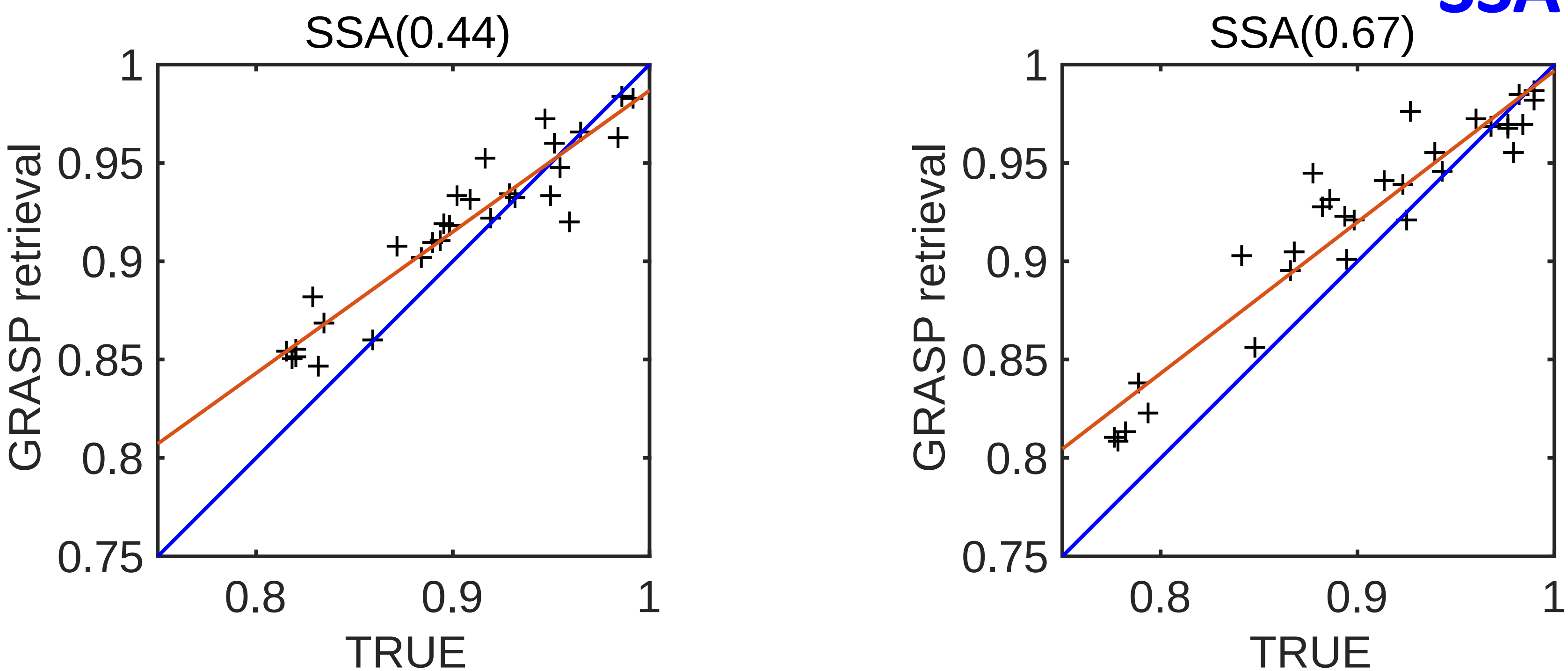
K=0.990 a=0.96 b=0.03 RMSE=0.008
N=32 Aver.=0.90072



K=0.995 a=0.98 b=0.02 RMSE=0.007
N=32 Aver.=0.90043

Simulation -22 bin and retrieval - 2 log good a priori on surface, AOD > 0.2

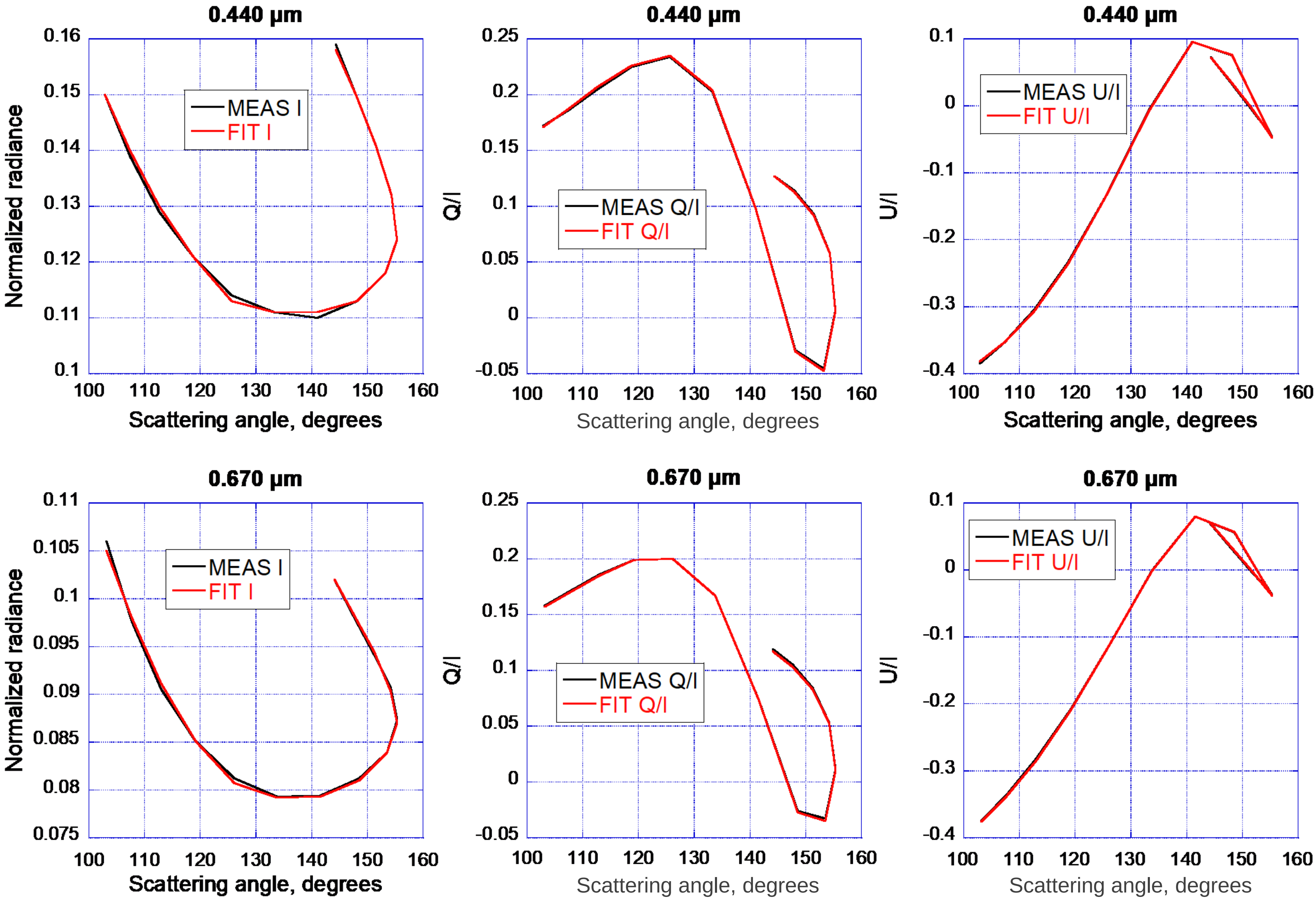
SSA



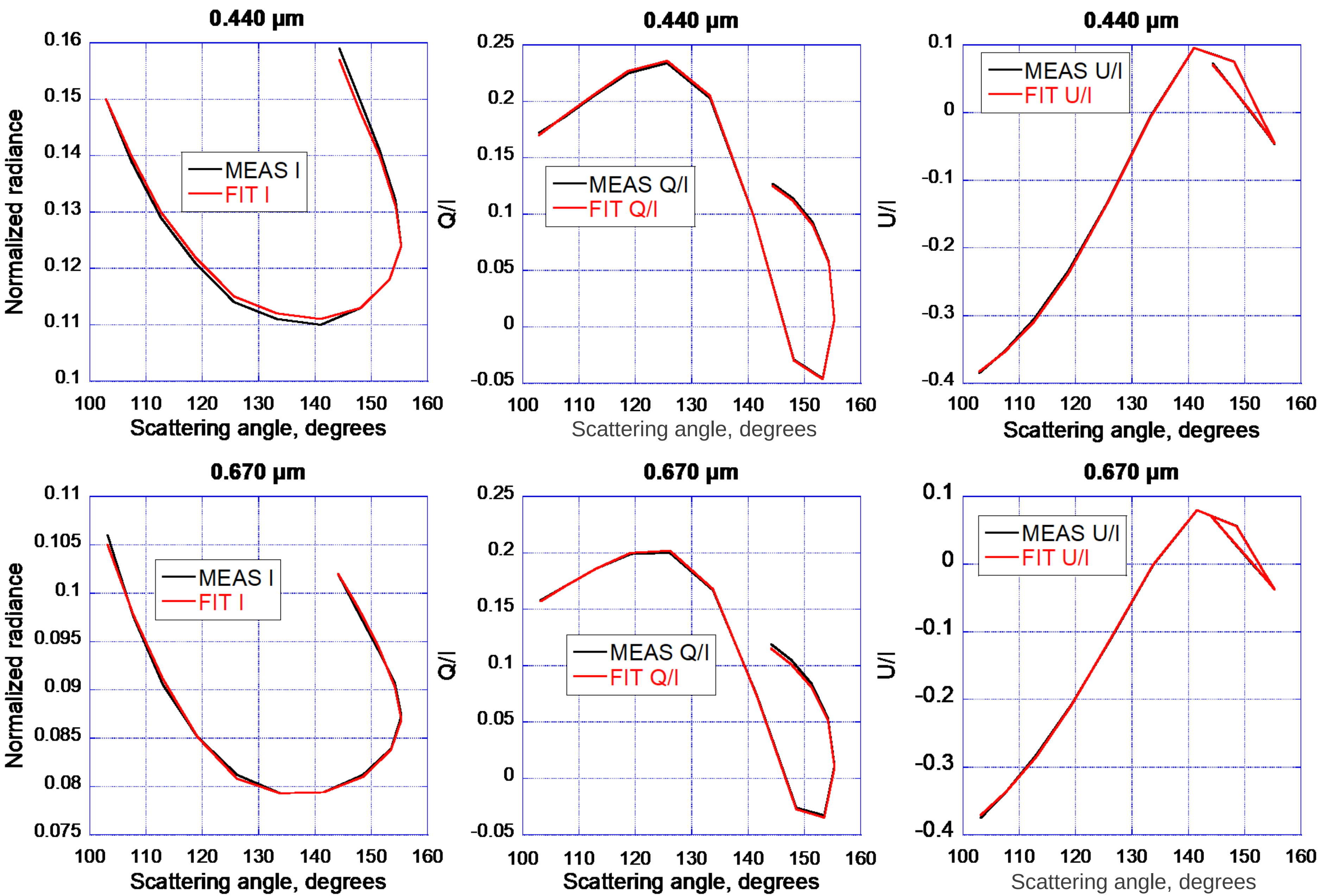
K=0.944 a=0.72 b=0.27 RMSE=0.025
N=30 Aver.=0.90191

K=0.952 a=0.77 b=0.23 RMSE=0.030
N=30 Aver.=0.90166

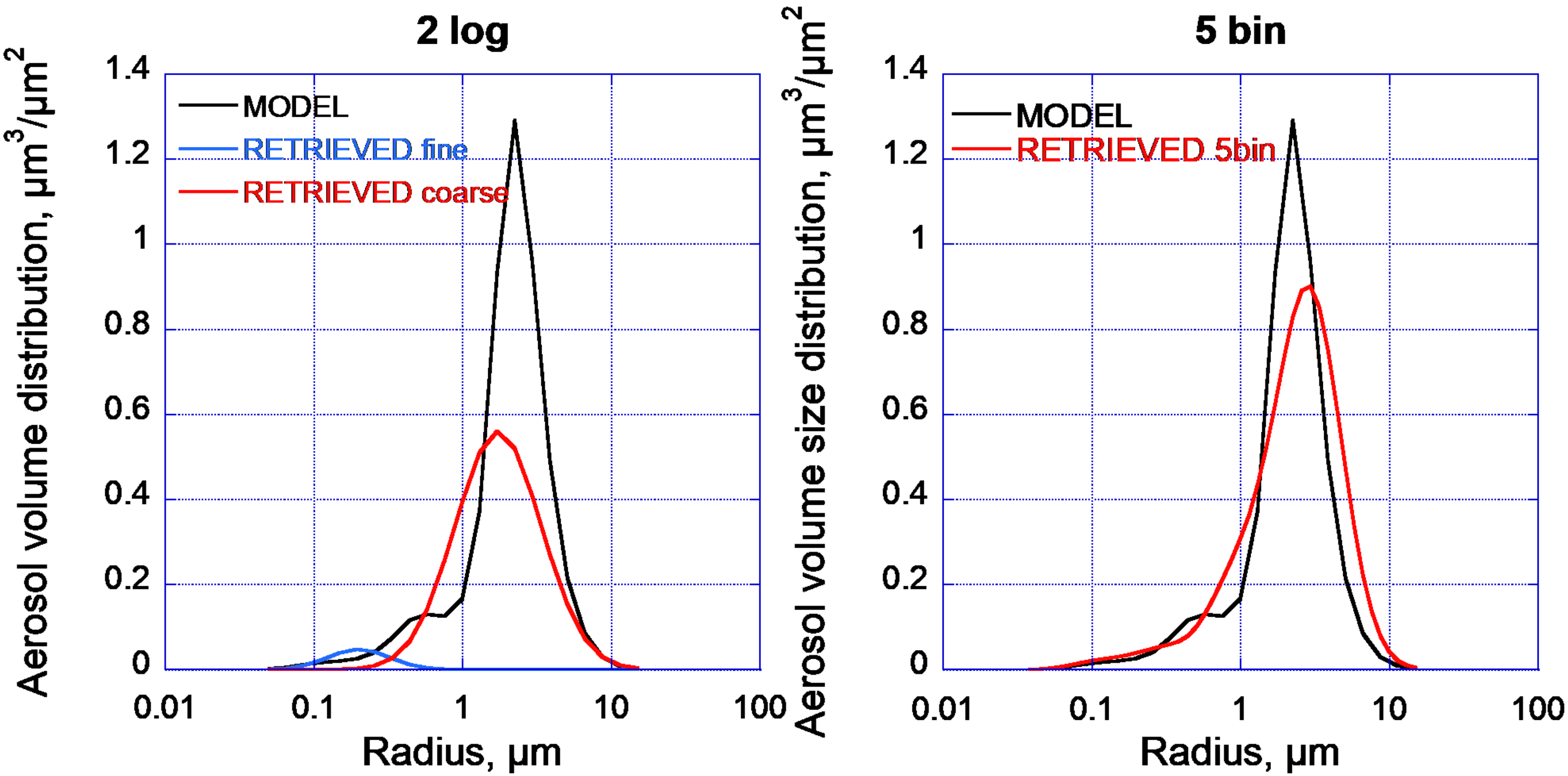
2 log retrieval (BANIZOMBOU): FITS



5bin retrieval (MONGU): FITS

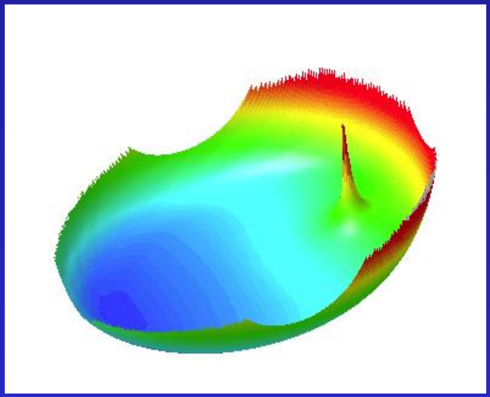


2 log and 5bin comparison BANIZOUMBOU



Surface Reflectance

BRDF

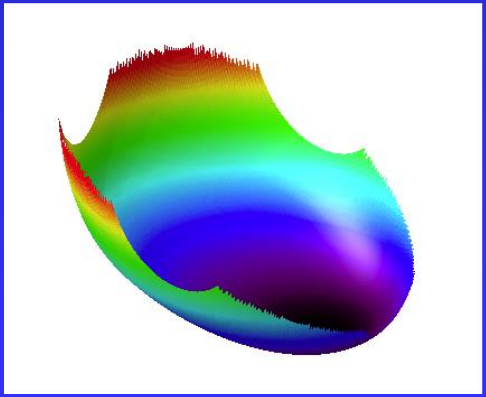


(1) ***Rahman-Pinty-Verstraete*** (RPV) model
(Rahman et al., 1993)

$$\boxed{\rho_{\mathbf{sfc}}(\vartheta_1,\varphi_1;\vartheta_2,\varphi_2) = \rho_0 M_i(k) F_{HG}(\Theta) H(h)}$$

(2) ***Li – Ross** model* (MODIS, etc)
(Ross, (1981); Li, X., Strahler (1992))

BPDF



(1) ***Maignan et al., (2009)***

$$\boxed{R_p^{surf}(q_s,q_v,j_r) = \frac{B\exp(-\tan(a_i))\exp(-v)}{4(m_0+m_1)}\mathbf{F}_p(g)}$$ (*B* - empirical parameter)

(2) ***Nadal and Bréon, (1999)***

(3) *Fresnel facet model for Gaussian surfaces*
(Litvinov et al., 2011)

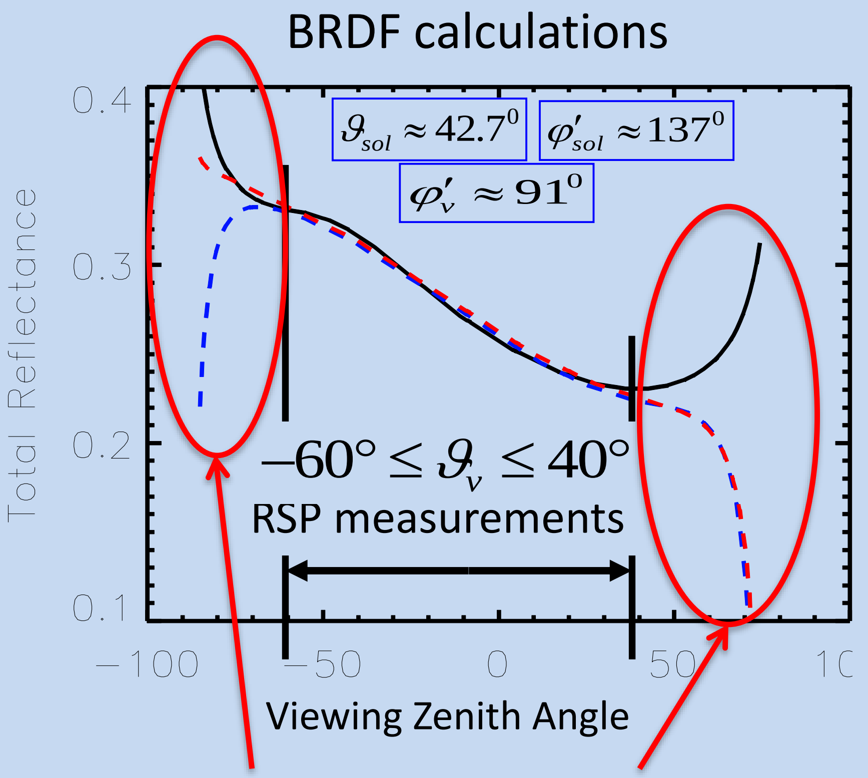
BRDF +BPDF

Physically based models

(1) ***Cox-Munk model (ocean surface)***

(2) *Physical models for land surface reflection matrix*
(Litvinov et al., 2012)

BRDF models uncertainties.

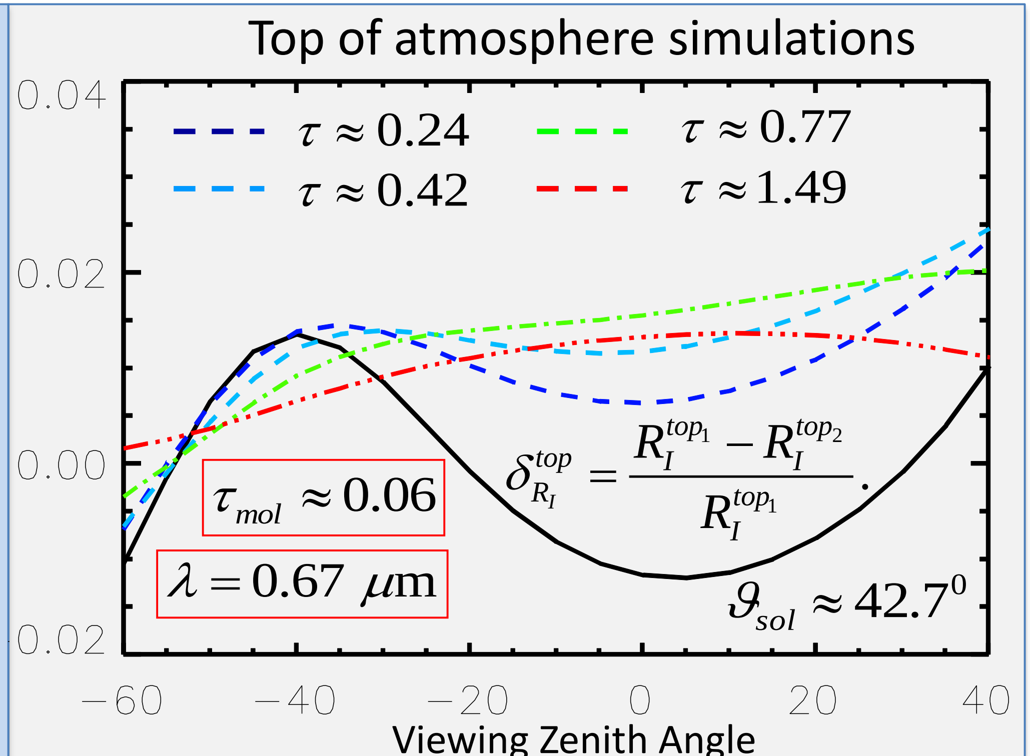


BRDF models uncertainties!

Black curves: **RPV model**

Blue curves: **Ross-Roujean model**

Red curves: **Ross-Li model**



Black curves: **the relative differences of the BRDF models (RPV and Ross-Li models)**

Color curves: **the relative differences of the top of atmosphere total reflectances (RPV and Ross-Li model, the same aerosol model)**

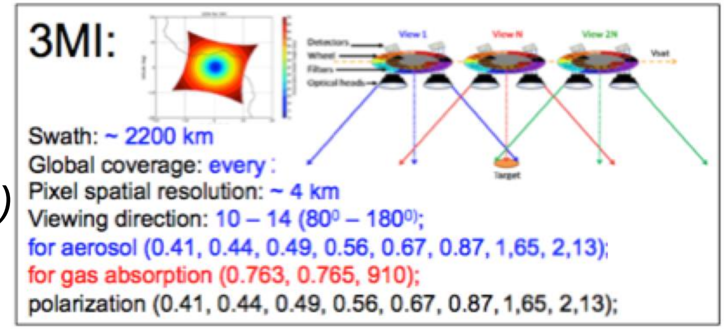
BRDF models uncertainties can provide up 2- 5% systematic error in top of atmosphere signal! (Litvinov et al., RSE, 2011)

3MI:

- radiances & polarization

(410, 440, 490, 560, 670, 870, 1650, 2103 nm)

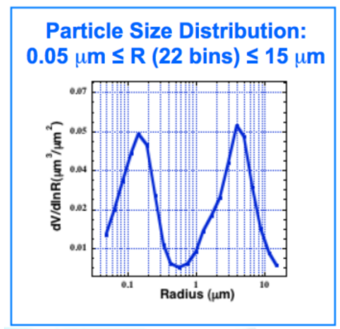
- 10- 14 viewing directions

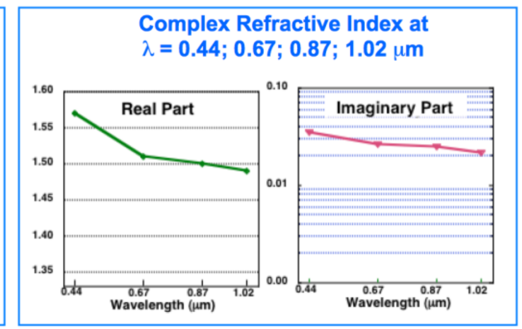


240 - 336 measurements

AEROSOL:

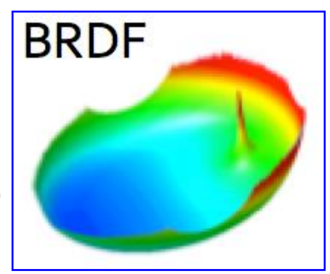
- size distribution (5 bins)
- spectral index of refraction (8 λ)
- sphericity fraction;
- aerosol height

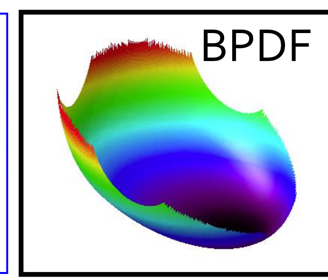




SURFACE:

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





55 = (5 (SD) +16 (ref. ind.) + 1 (nonsp.) + 24 (BRDF) +8 (BPDF) + 1 (height)

Project results/accomplishments:

Task-1: Set of aerosol models for LUT algorithms was reviewed corrected;

Task-2.1: Independent co-registration function was developed, and corresponding 3MI Level 1C were prepared and delivered;

Task-2.2: 3MI Level 1C proxy data based on PARASOL climatology were simulated were generated and delivered: 1 complete orbit + 3 months over selected AERONET sites.

Task-3: The performance of 3MI LUT algorithm was evaluated. Based on the results the development of LUT algorithm was stopped due to its immaturity.

Task-4: The enhance NRT 3MI algorithm has been proposed

Task-5 Testing of Enhanced NRT Aerosol Retrieval Algorithm (WP-5)

WP manager: O. Dubovik

Start month: 9	**End month**: 12
Inputs: · Enhanced NRT aerosol retrieval algorithm. · Level 1c Test Synthetic Data Set for 3MI orbits. · Level 1c Test Proxy Data Set for 3MI orbits based on PARASOL/GRASP retrieval results. · Level 1c Test Proxy 3MI Data Set over selected AERONET sites.	**Outputs**: · Report on the results of the tests on enhanced NRT enhanced aerosol retrieval algorithm. · The updated ATBD for corrected algorithm (if possibilities of improving the algorithm will be identified).

Actions:

- Evaluation of Baseline EUMETSAT Enhanced Algorithm on the Level 1c Test Synthetic Data Set for 3MI selected orbits;
- Evaluation of Baseline EUMETSAT Enhanced Algorithm on the Level 1c Test Proxy Data Set for 3MI orbits;
- Evaluation of Baseline EUMETSAT Enhanced Algorithm on the Level 1c Test Proxy Data Set produced over selected AERONET sites.

Speed for inversion of one orbit:

Question*: what is exact time requirement?*

Point of depart:

~ *1.5 millions pixel in 40 min at 100 cores cluster*

Speed for inverting one orbit:

Possible trade-offs in configuration: ~ factor 2

- "not retrieving" surface;

- degrading accuracy;

- decreasing number of retrieved parameters.

Evident practical trade-offs in configuration:

- not using all channels (or polarization at all channels); ~ factor 2

- decreasing spatial resolution: (7 km) ~ factor 4

Further sophisticated improvements with no lose of accuracy :

- RT, etc. since improvements; ~ factor 2

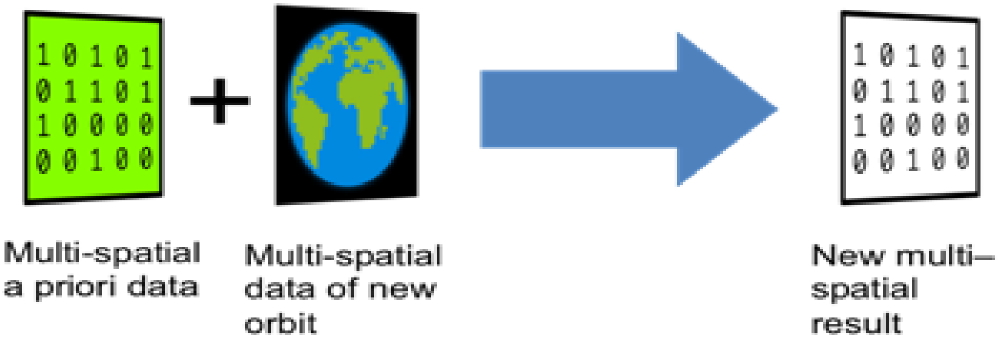
- IT improvements;) ~ factor 2

Case 1,2: single – pixel, no surface a priori

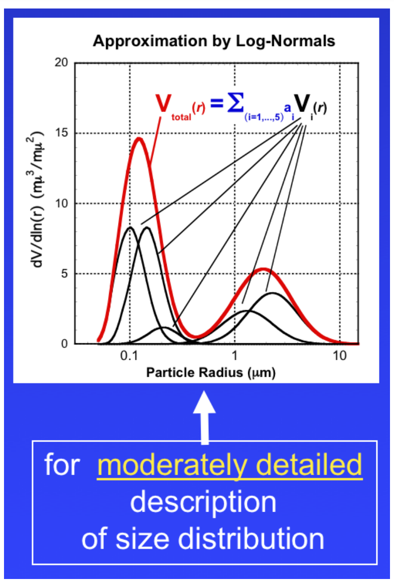
Case 1 - **HP,**

Case 2 - **"optimized"**

Trades off: accuracy/speed: **HP, "optimized"**



- single initial guess
- single set of a priori constraints
- multi – pixel only horizontal



Retrieved

n(λ) + k (λ)

At 8 wavelengths

Sphericity fraction

AOD(λ), SSA(λ)

At 8 wavelengths

Etc.

- single initial guess
- single set of a priori constraints
- multi – pixel only horizontal

Trades off: accuracy/speed: HP, ”optimized”

Case 1 - HP,

Accuracy in RT calculations:

for the to 3MI observations: **M=21**, **N_1= 10, N_2= 10**
for Jacobian matrices: **M=15**, **N_1= 7, N_2= 10**

Absolute accuracy of RT calculations: **0.0001**

Case 1 – “optimized”,

Accuracy in RT calculations:

for fit to 3MI observations: **M=15**, **N_1= 5, N_2= 4**
for Jacobian matrices: **M=15**, **N_1= 4, N_2= 4**

Absolute accuracy of RT calculations: **0.0005**

M - the number of terms in the expansion of the truncated phase function;
N_1 - the number of terms in the Gaussian quadrature for zenith integration ;
N_2 - the number of terms in Fourier series of Stocks parameters expansion;

no surface a priori or with a priori surface

Speed for inverting one orbit:

Assumptions:

- 500 000 cloud-free pixels in orbit;

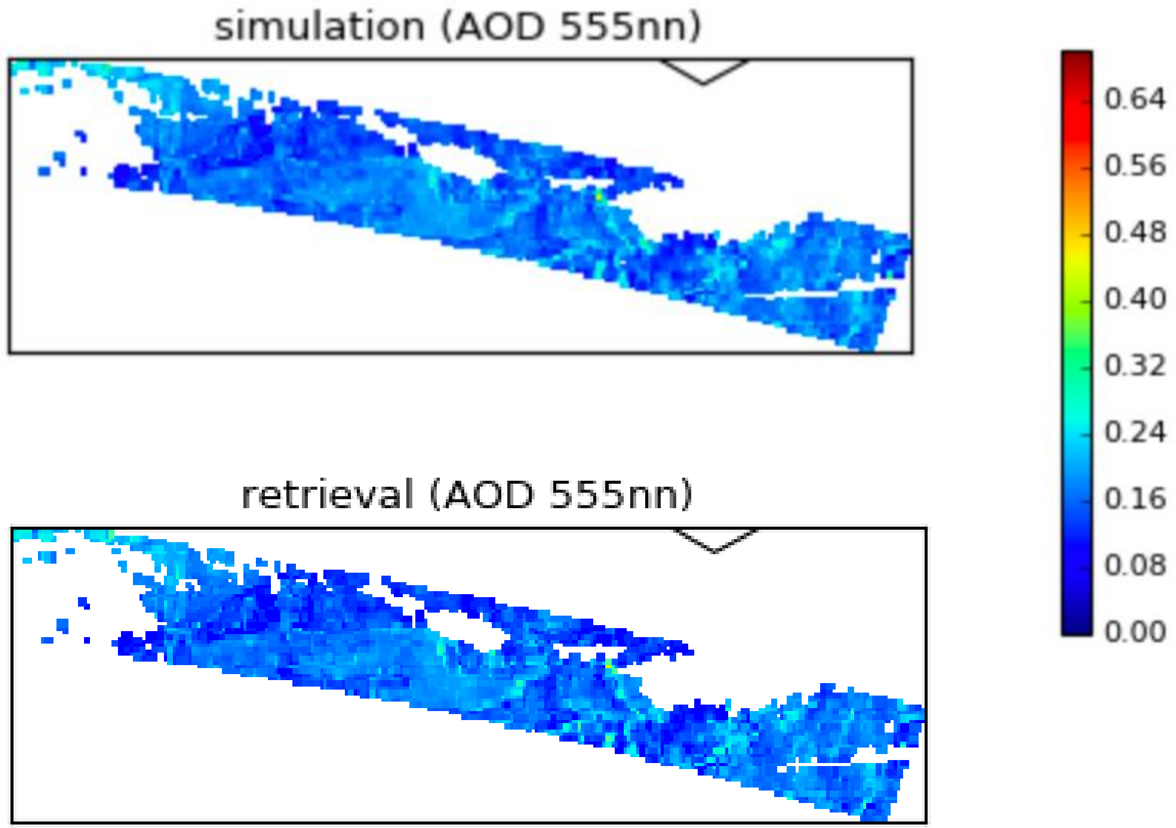
- 100 cores cluster is used;

Performances:

- **Case 1**, HP – high precision, 2 sec per pixel: ~ **160 min**

Case 1: no a priori on surface

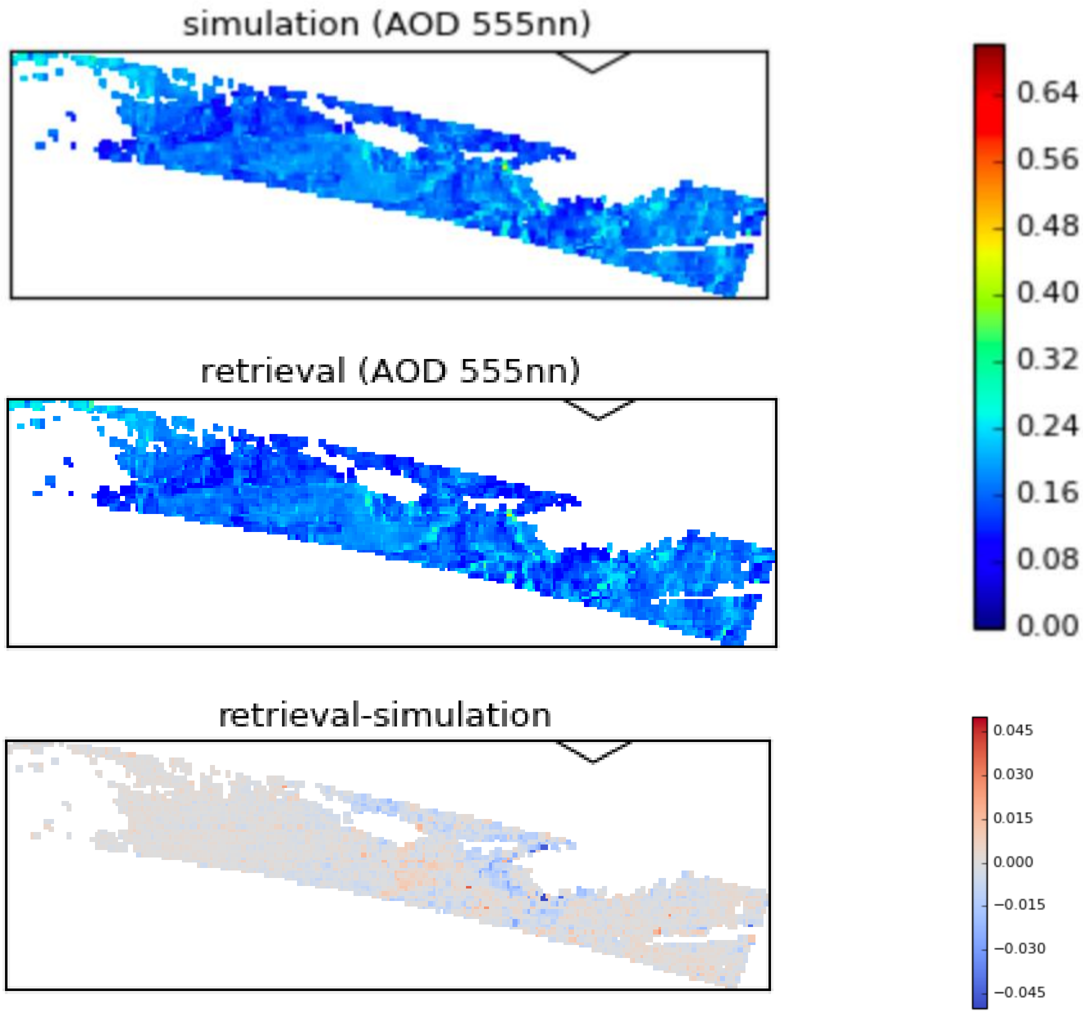
HP – high performance



Quite low AOD !!!!

Case 1: no a priori on surface

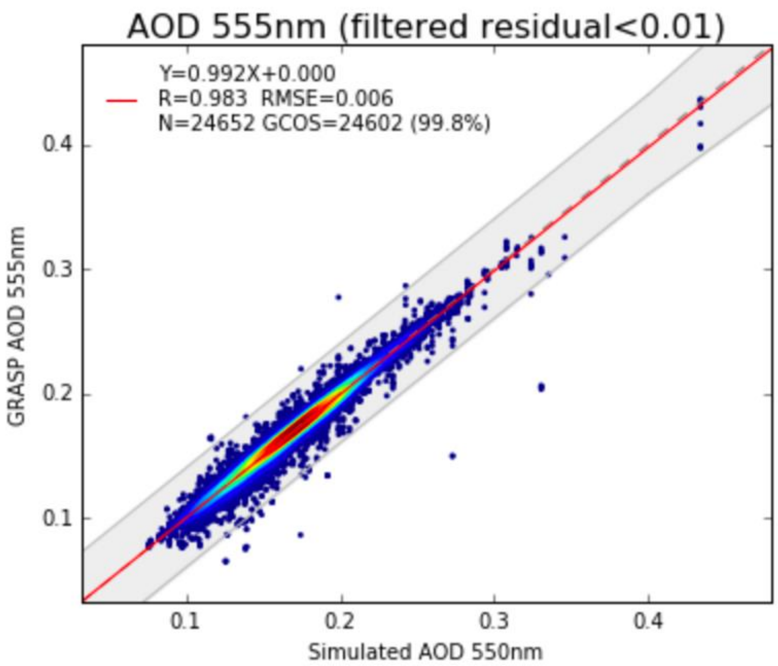
HP – high performance

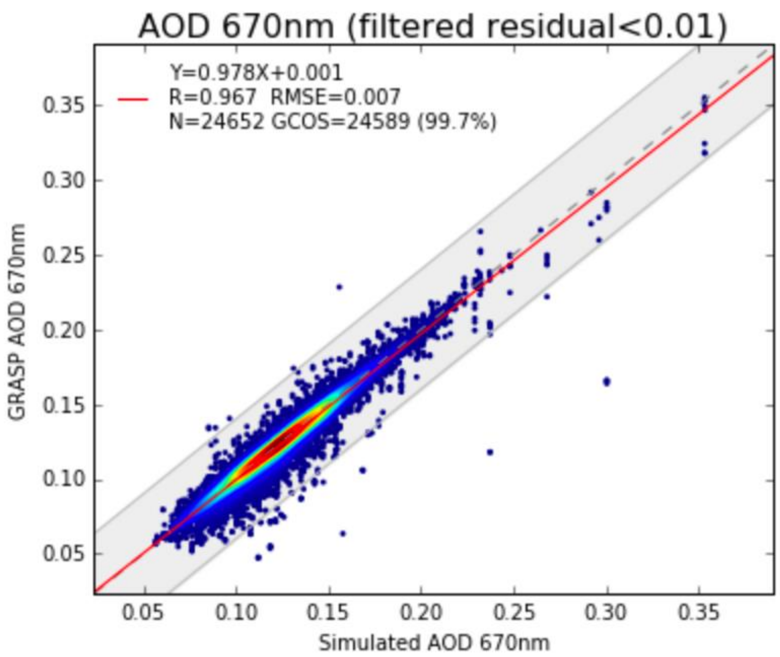


Quite low AOD !!!!

Case 1: no a priori on surface

HP – high performance

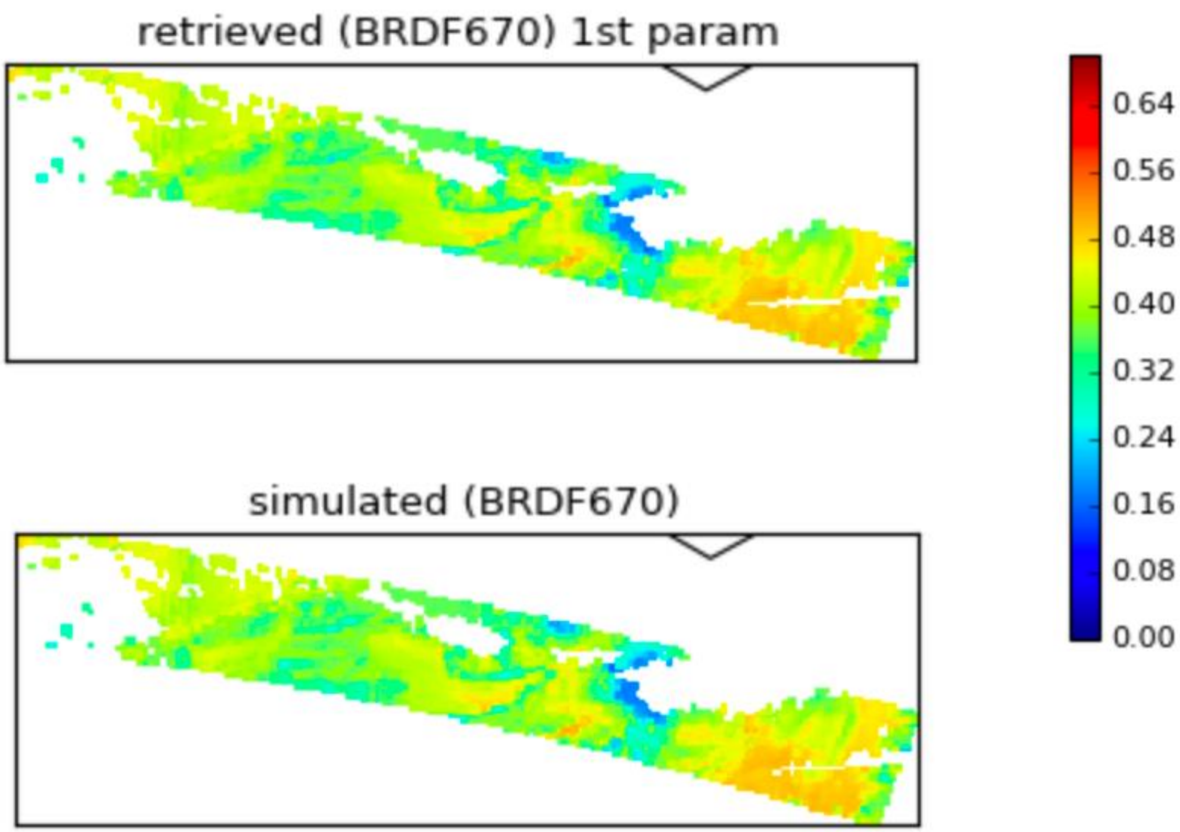




Case 1: no a priori on surface

HP – high performance

Surface-BRDF

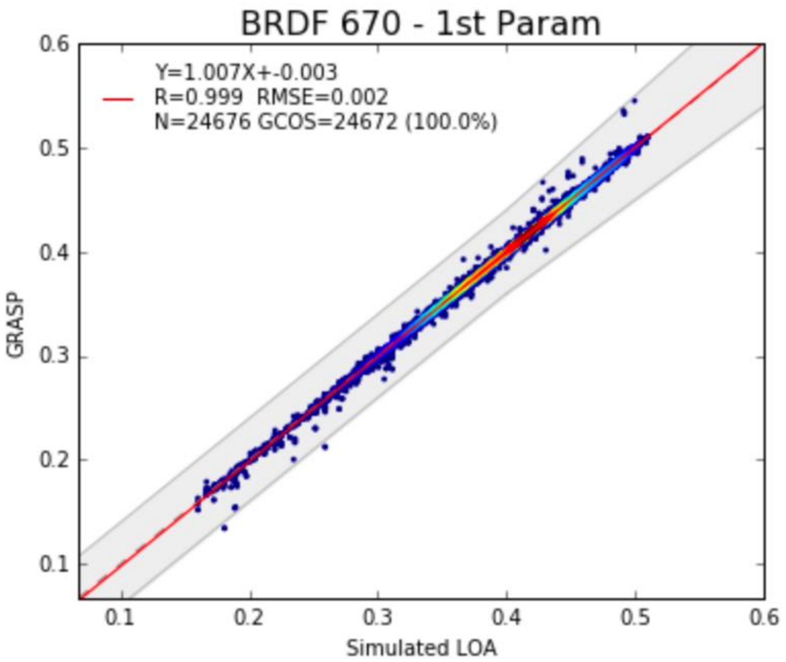


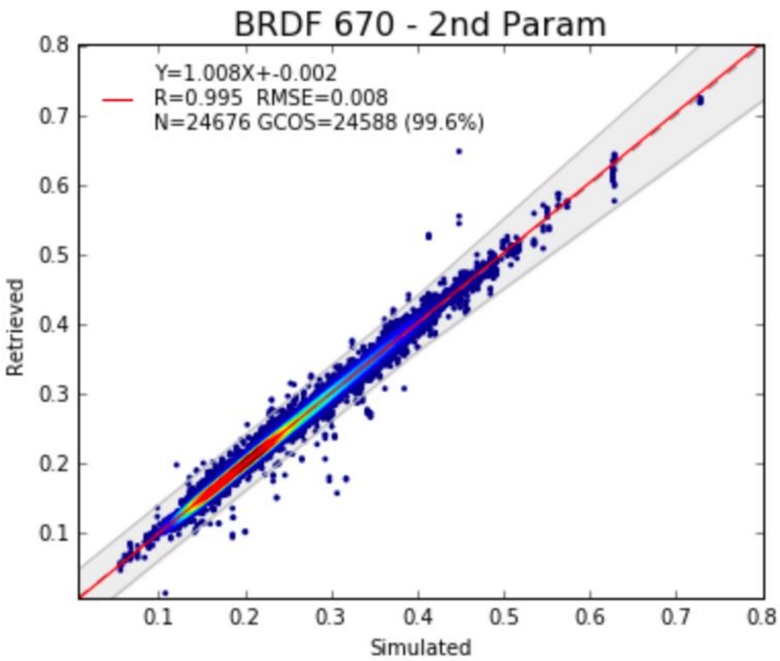
Very bright surface! + Quite low AOD ! **- Very difficult case**

Case 1: no a priori on surface

HP – high performance

Surface-BRDF

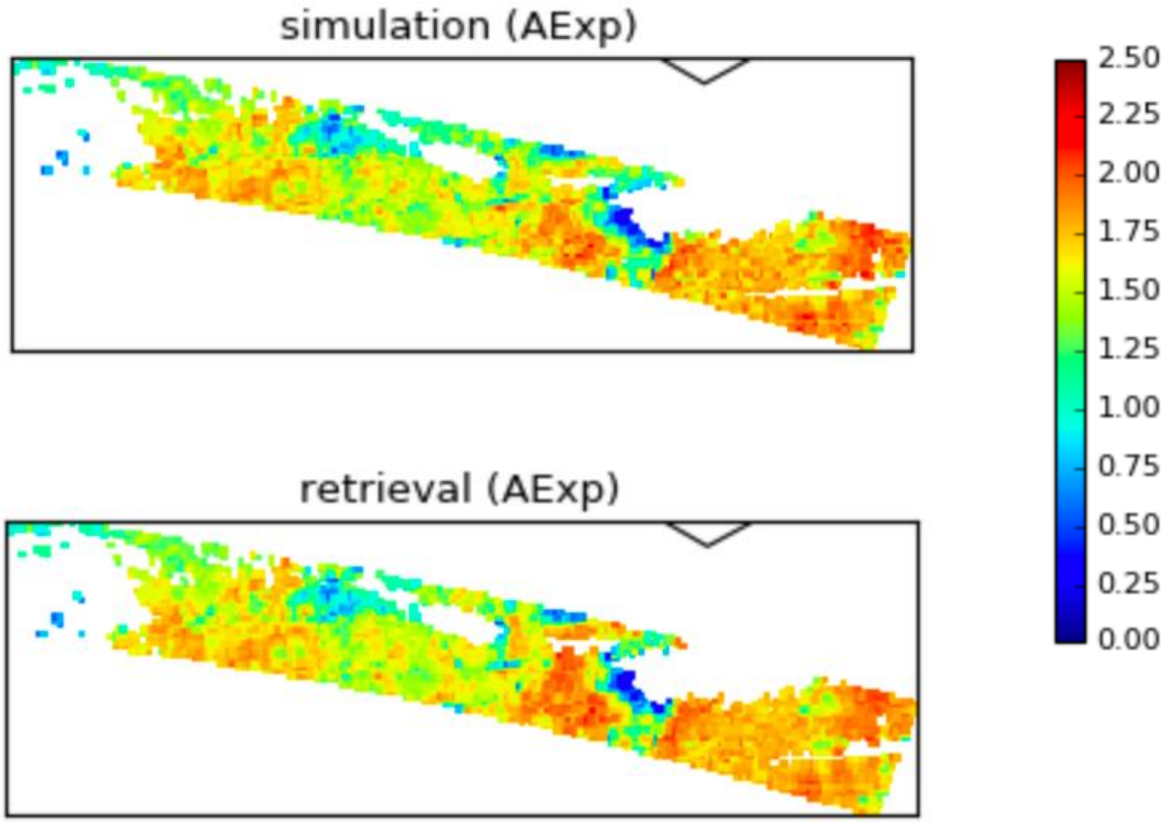




Case 1: no a priori on surface

HP – high performance

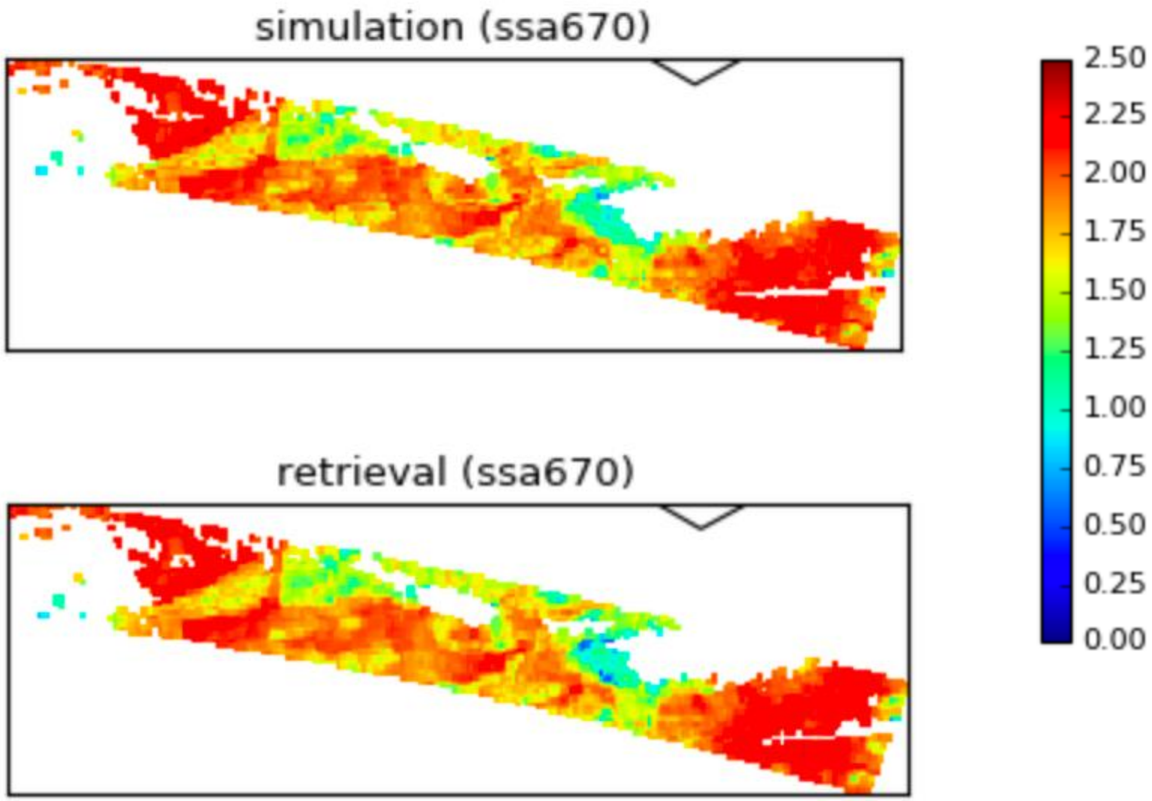
Angstrom Exponent



Case 1: no a priori on surface

HP – high performance

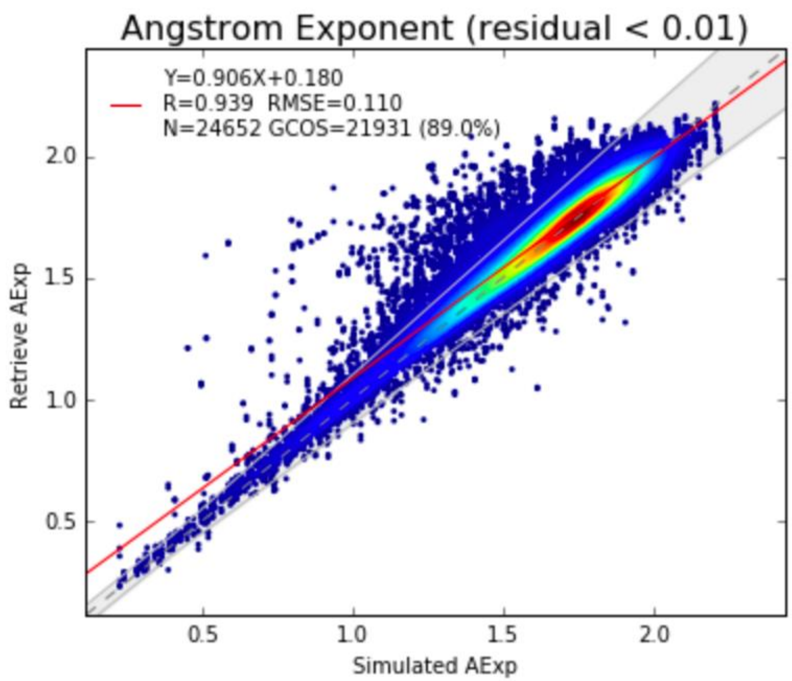
SSA(670)



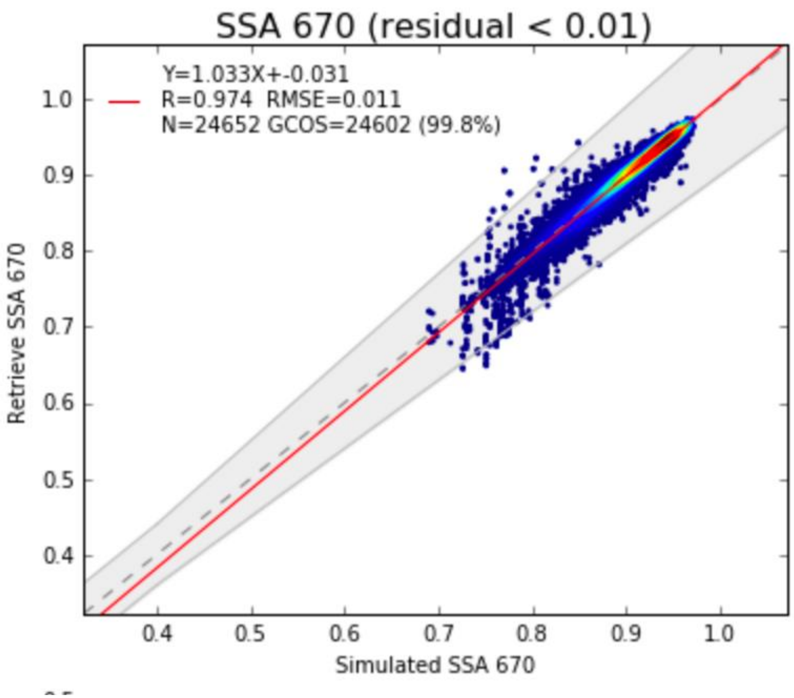
Case 1: no a priori on surface

HP – high performance

Angstrom Exponent

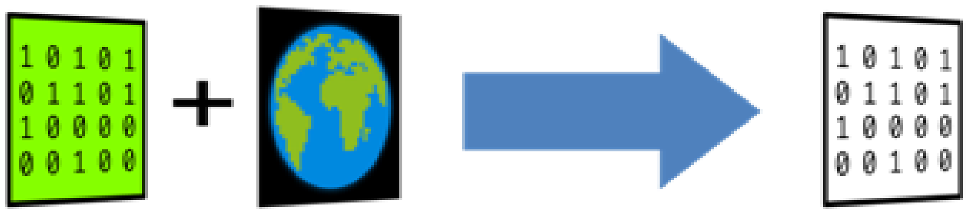


SSA



Case 3 (main): a priori constraints on surface

Trades off: accuracy/speed: ”optimized”

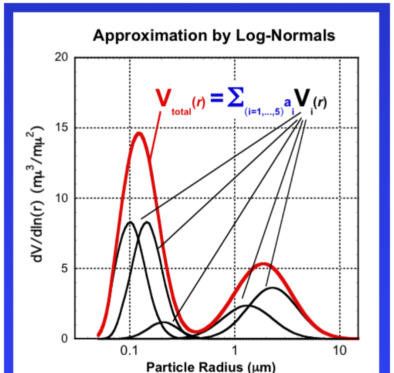


Multi-spatial a priori data

Multi-spatial data of new orbit

New multi–spatial result

- single initial guess
- single set of a priori constraints
- multi – pixel only horizontal



for moderately detailed description of size distribution

Retrieved

n(λ) + k (λ)

At 8 wavelengths

Sphericity fraction

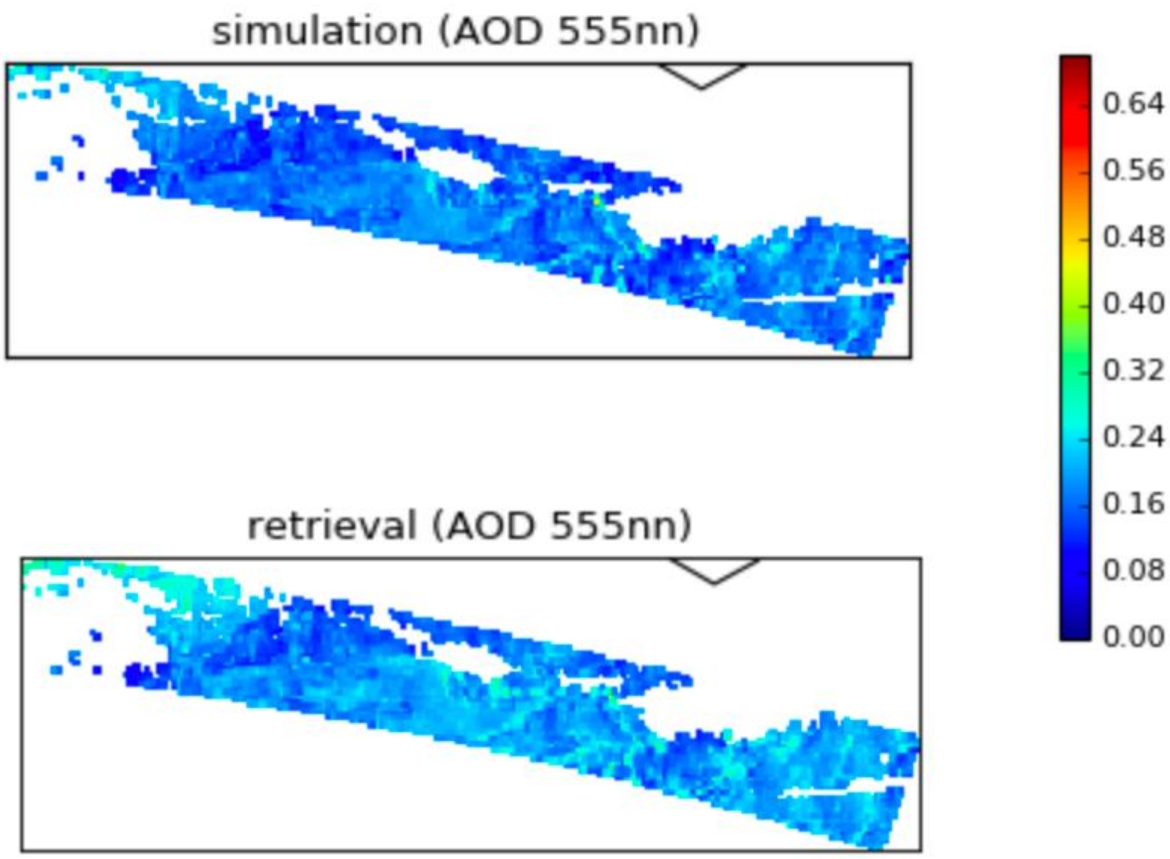
AOD(λ), SSA(λ)

At 8 wavelengths

Etc.

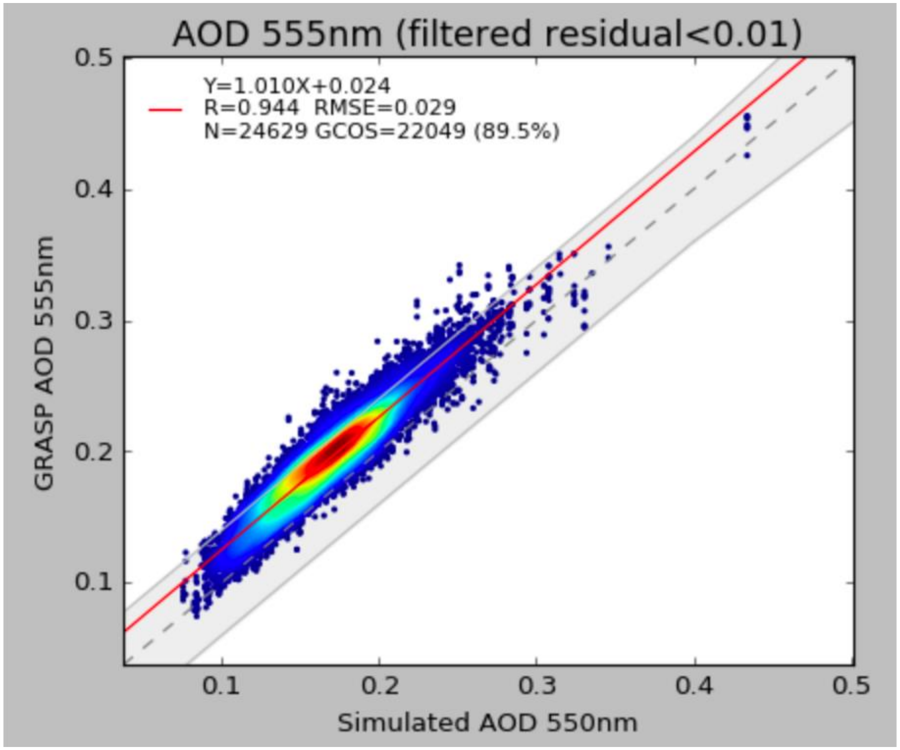
Case 3: a priori constraints on surface

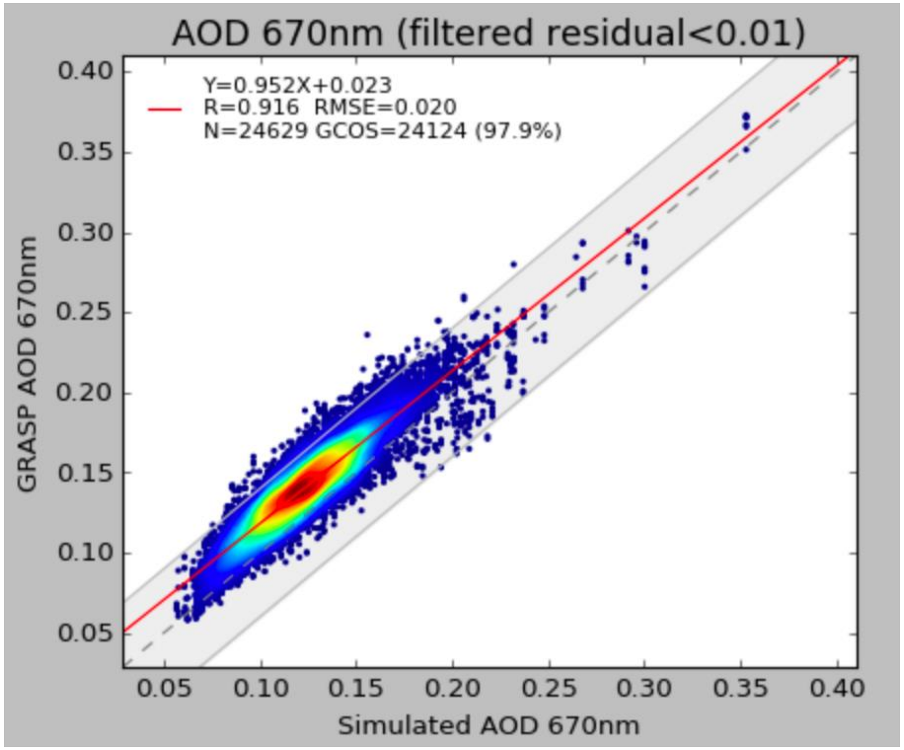
HP – optimized



Case 3: a priori constraints on surface

HP – optimized

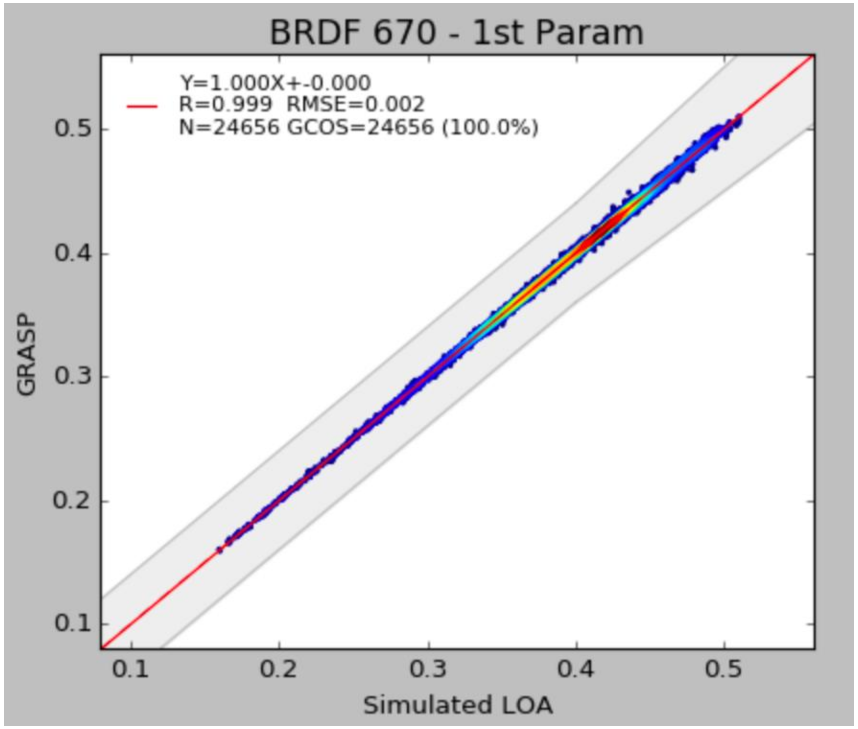


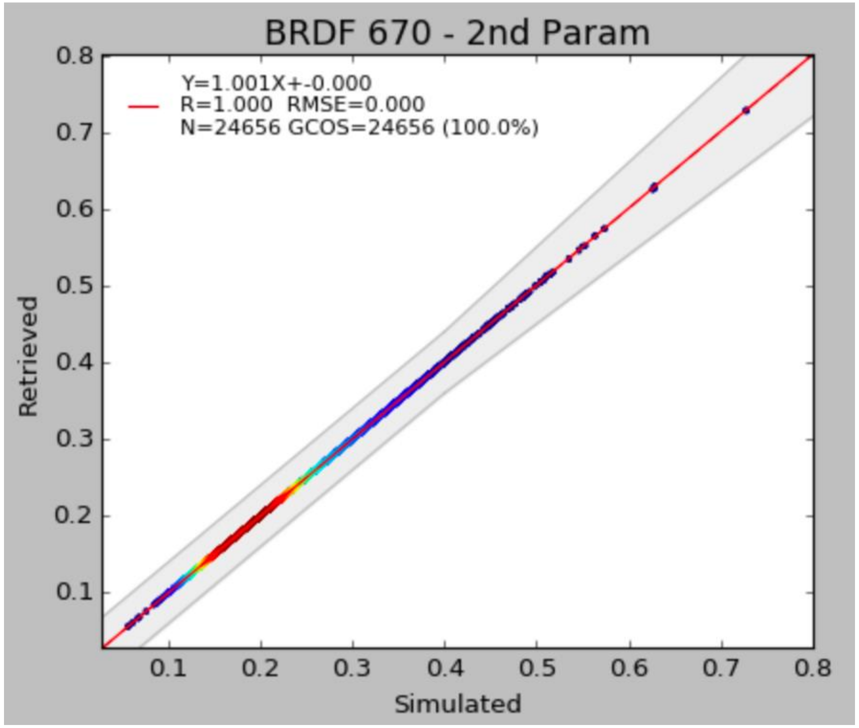


Case 3: a priori constraints on surface

HP – optimized

Surface-BRDF

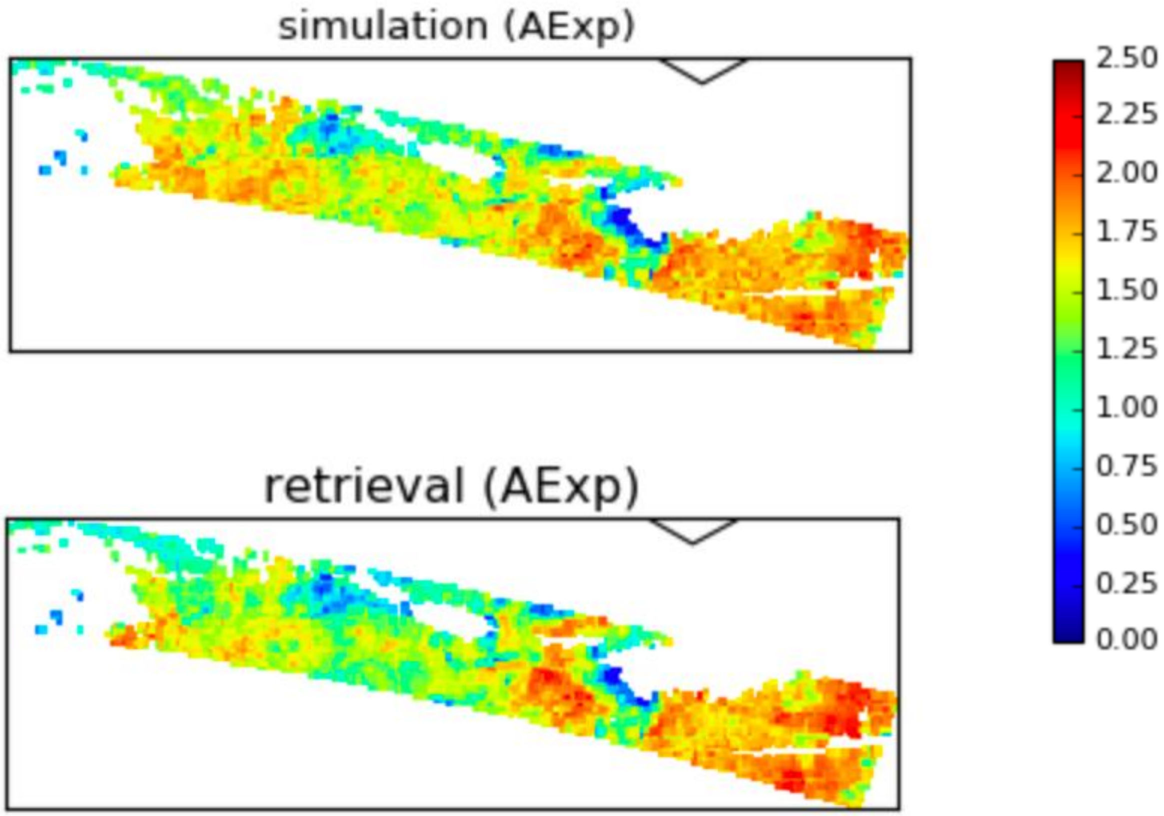




Case 3: a priori constraints on surface

HP – optimized

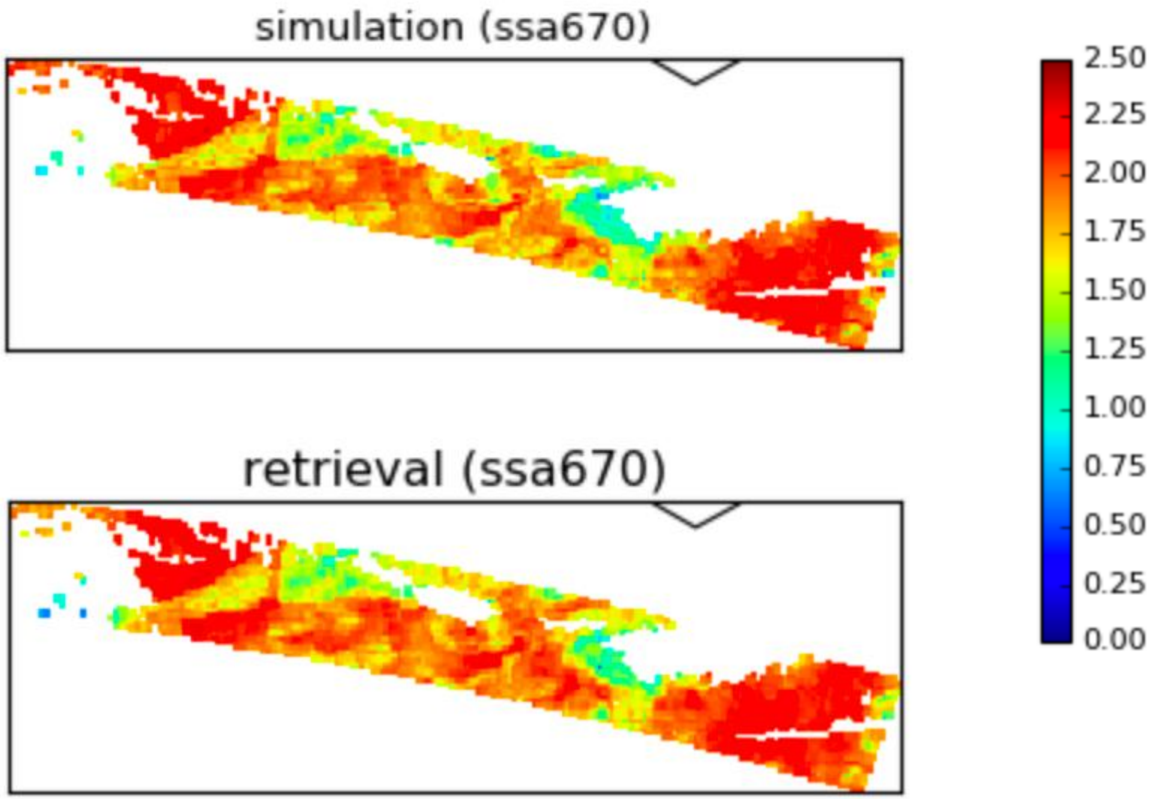
Angstrom Exponent



Case 3: a priori constraints on surface

HP – optimized

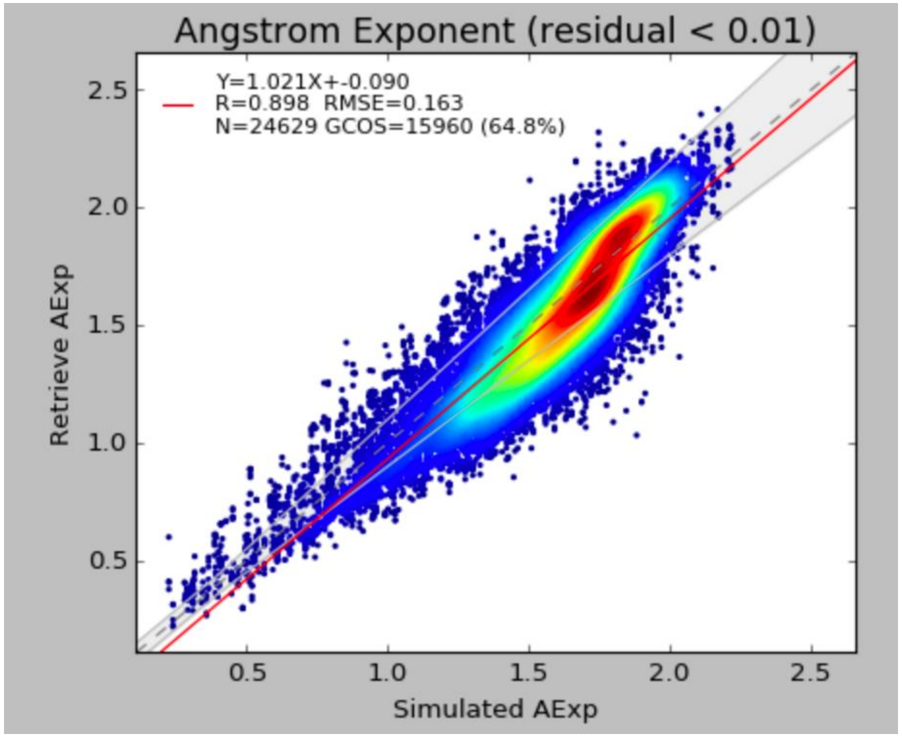
SSA(670)



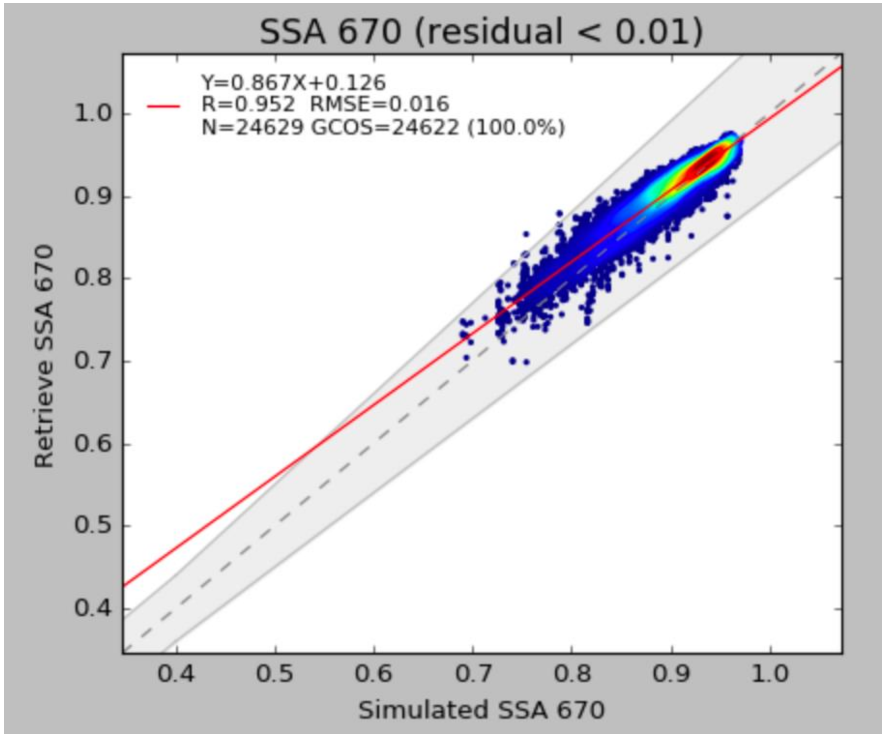
Case 3: a priori constraints on surface

HP – optimized

Angstrom Exponent



SSA



Speed for inverting one orbit:

Assumptions:
- *500 000 cloud-free pixels in orbit;*
- *100 cores cluster is used;*

Performances:

Factor 8

- **Case 1**, HQ, 2 sec per pixel: ~ **160 min**
- **Case 1.a**, 4λ **acceleration >2 time**
- **Case 2**, Optimized, 0.5 sec per pixel: ~ **40 min**
- **Case 3**, Optimized with a priori surface, 0.2 sec per pixel: ~ **20 min**
- **Case ???**, < 0.1 sec per pixel: < **10 min**

Project results/accomplishments:

Task-1: Set of aerosol models for LUT algorithms was reviewed corrected;

Task-2.1: Independent co-registration function was developed, and corresponding 3MI Level 1C were prepared and delivered;

Task-2.2: 3MI Level 1C proxy data based on PARASOL climatology were simulated were generated and delivered: 1 complete orbit + 3 months over selected AERONET sites.

Task-3: The performance of 3MI LUT algorithm was evaluated. Based on the results the development of LUT algorithm was stopped due to its immaturity.

Task-4: The enhance NRT 3MI algorithm has been proposed

Task-5: The enhanced NRT Aerosol Retrieval Algorithm has been extensively tested for accuracy and speed. Recommendations have been made.

Speed for inverting one orbit:

Assumptions:

- 500 000 cloud-free pixels in orbit;
- 100 cores cluster is used;

Performances:

Factor 8

- **Case 1**, HQ,	2 sec per pixel: ~ **160 min**
- **Case 1.a**, 4λ	**acceleration >2 time**
- **Case 2**, Optimized,	0.5 sec per pixel: ~ **40 min**
- **Case 3**, Optimized with a priori surface,	0.2 sec per pixel: ~ **20 min**
- **Case ???**,	< 0.1 sec per pixel: < **10 min**

Optimal Segment Sizes

Seconds per pixel

Segment Size (N x N)	test1	test2	test3	test4
2 x 2	3.33	0.34	0.16	0.26
10 x 10	**3.30**	**0.33**	**0.14**	**0.23**
15 x 15	3.44	0.36	0.14	0.24
20 x 20	3.79	0.38	0.15	0.24
25 x 25	4.42	0.42	0.15	0.26

Factor 12

There is little variation in processing time when varying the segment sizes.
It is suggested to optimize this for retrieval accuracy.

Evaluated GRASP Settings

Single vs. Multi Pixel Inversion

Test 1
Single Pixel
High Precision
Full Retrieval

Full Retrieval vs. Pre-Calculated Aerosol Models

Test 2
Multi Pixel
Optimized
Full Retrieval

Surface Handling

Test 3
Multi-Pixel
Models
Fixed Surface

Test 4
Multi-Pixel
Models
a-priori Surface

These settings were generated and supplied by another EUM study.
This study only evaluated the computational performance.

- single initial guess
- single set of a priori constraints
- multi – pixel only horizontal

Trades off: accuracy/speed: HP, ”optimized”

Case 1 - HP,	**Case 1 – “optimized”,**
Accuracy in RT calculations:	Accuracy in RT calculations:
for the to 3MI observations: **M=21, N_1= 10, N_2= 10**	for fit to 3MI observations: **M=15, N_1= 5, N_2= 4**
for Jacobian matrices: **M=15, N_1= 7, N_2= 10**	for Jacobian matrices: **M=15, N_1= 4, N_2= 4**
Absolute accuracy of RT calculations: **0.0001**	Absolute accuracy of RT calculations: **0.0005**
Number of vertical layers: **50**	Number of vertical layers: **5**

M - the number of terms in the expansion of the truncated phase function;
N_1 - the number of terms in the Gaussian quadrature for zenith integration ;
N_2 - the number of terms in Fourier series of Stocks parameters expansion;

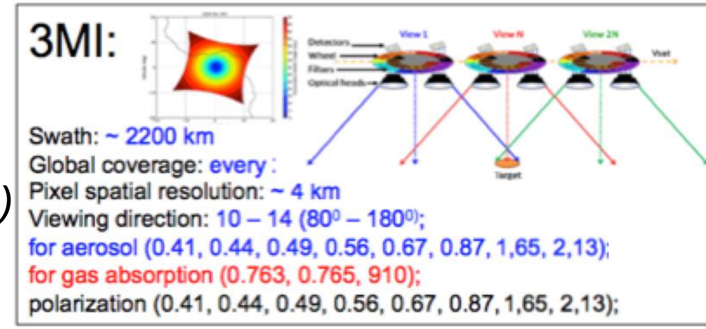
no surface a priori or with a priori surface

3MI:

- radiances & polarization

(410, 440, 490, 560, 670, 870, 1650, 2103 nm)

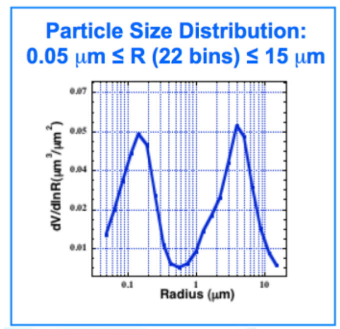
- 10- 14 viewing directions

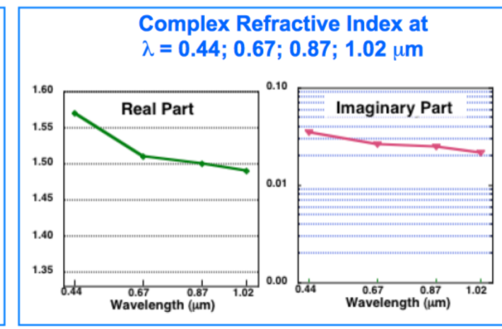


240 - 336 measurements

AEROSOL:

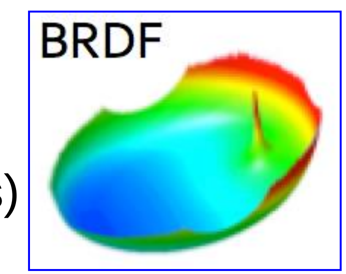
- size distribution (5 bins)
- spectral index of refraction (8 λ)
- sphericity fraction;
- aerosol height

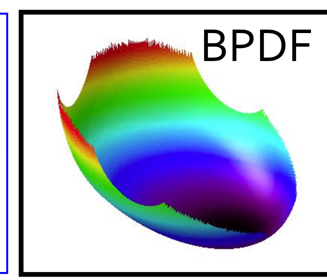




SURFACE:

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





55 = (5 (SD) +16 (ref. ind.) + 1 (nonsp.) + 24 (BRDF) +8 (BPDF) + 1 (height)

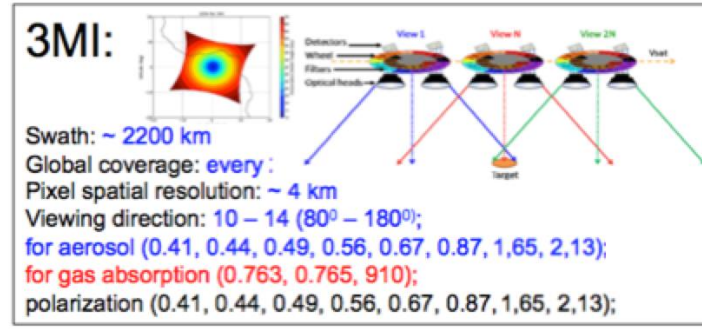
AEROSOL - external mixture of models

3MI:

- radiances & polarization

(410, 440, 490, 560, 670, 870, 1650, 2103 nm)

- 10- 14 viewing directions

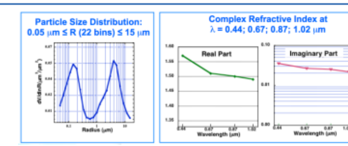


240 - 336 measurements

AEROSOL:

- 5 or more concentrations
- aerosol height

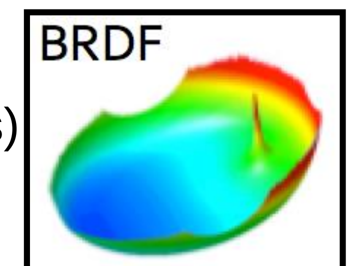
External mixture

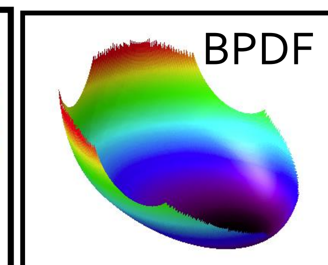


$$\tau_{scat} = c_i \sum_{i=1}^{N} \int K^{i}_{scat}(\lambda; n_i; k_i; r) V_i(r) N_i(e)$$

SURFACE:

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





38 = (5 (SD) + 24 (BRDF) +8 (BPDF) + 1 (height)) per pixel

Optimal Segment Sizes

Seconds per pixel

Segment Size (N x N)	test1	test2	test3	test4
2 x 2	3.33	0.34	0.16	0.26
10 x 10	**3.30**	**0.33**	**0.14**	**0.23**
15 x 15	3.44	0.36	0.14	0.24
20 x 20	3.79	0.38	0.15	0.24
25 x 25	4.42	0.42	0.15	0.26

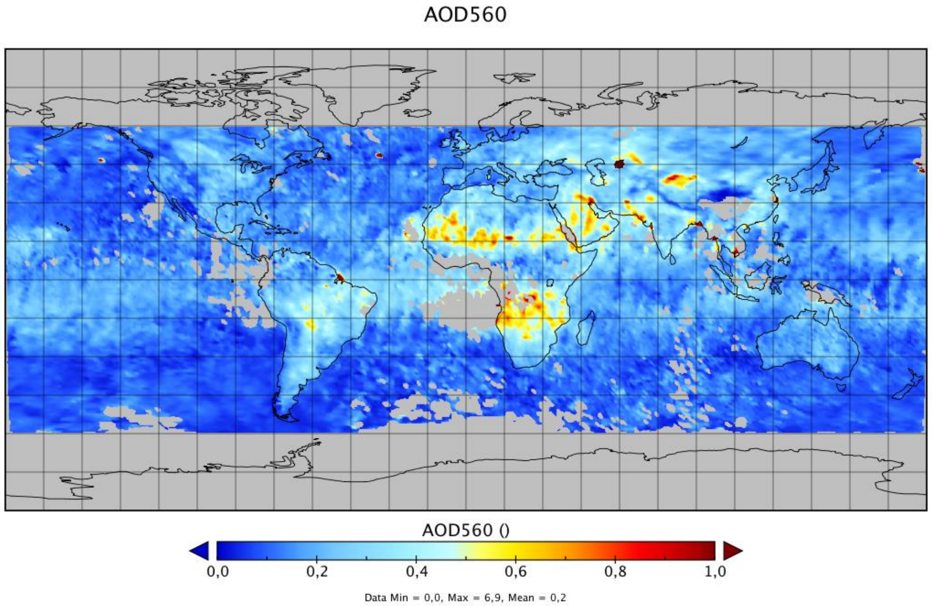
Factor 12

There is little variation in processing time when varying the segment sizes.
It is suggested to optimize this for retrieval accuracy.

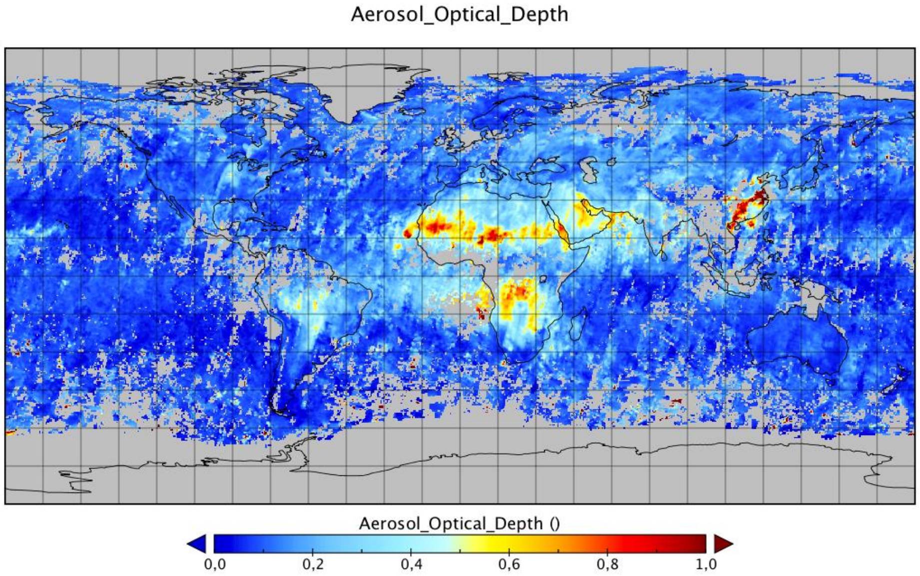
Imagery comparisons

September 2008

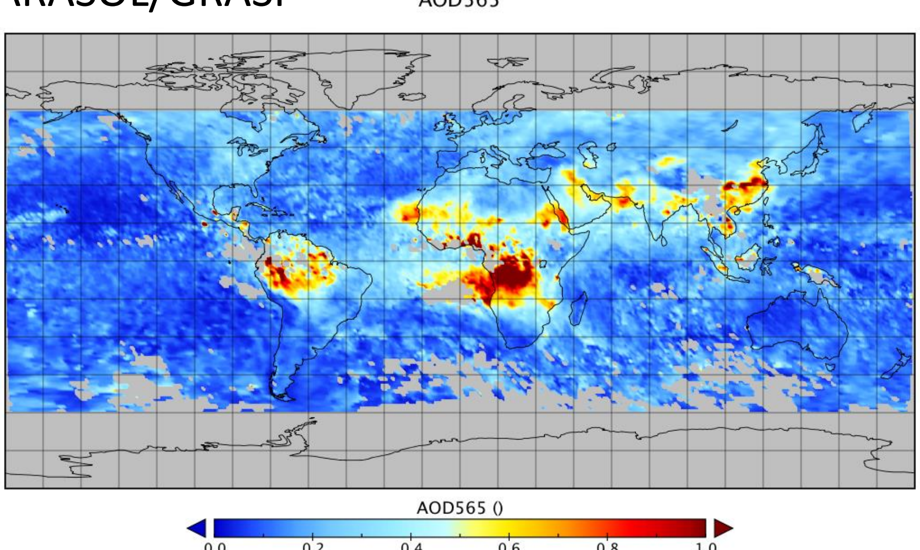
MERIS/GRASP



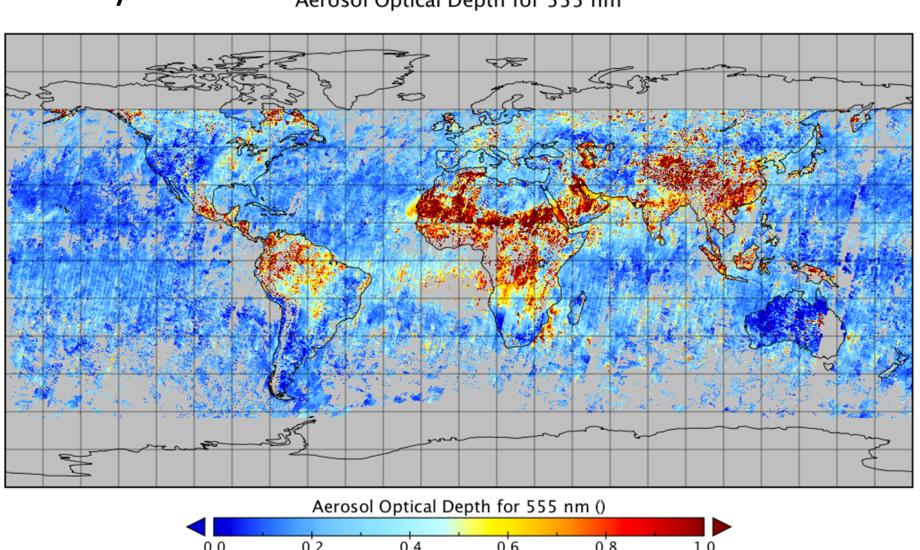
MISR/Operational



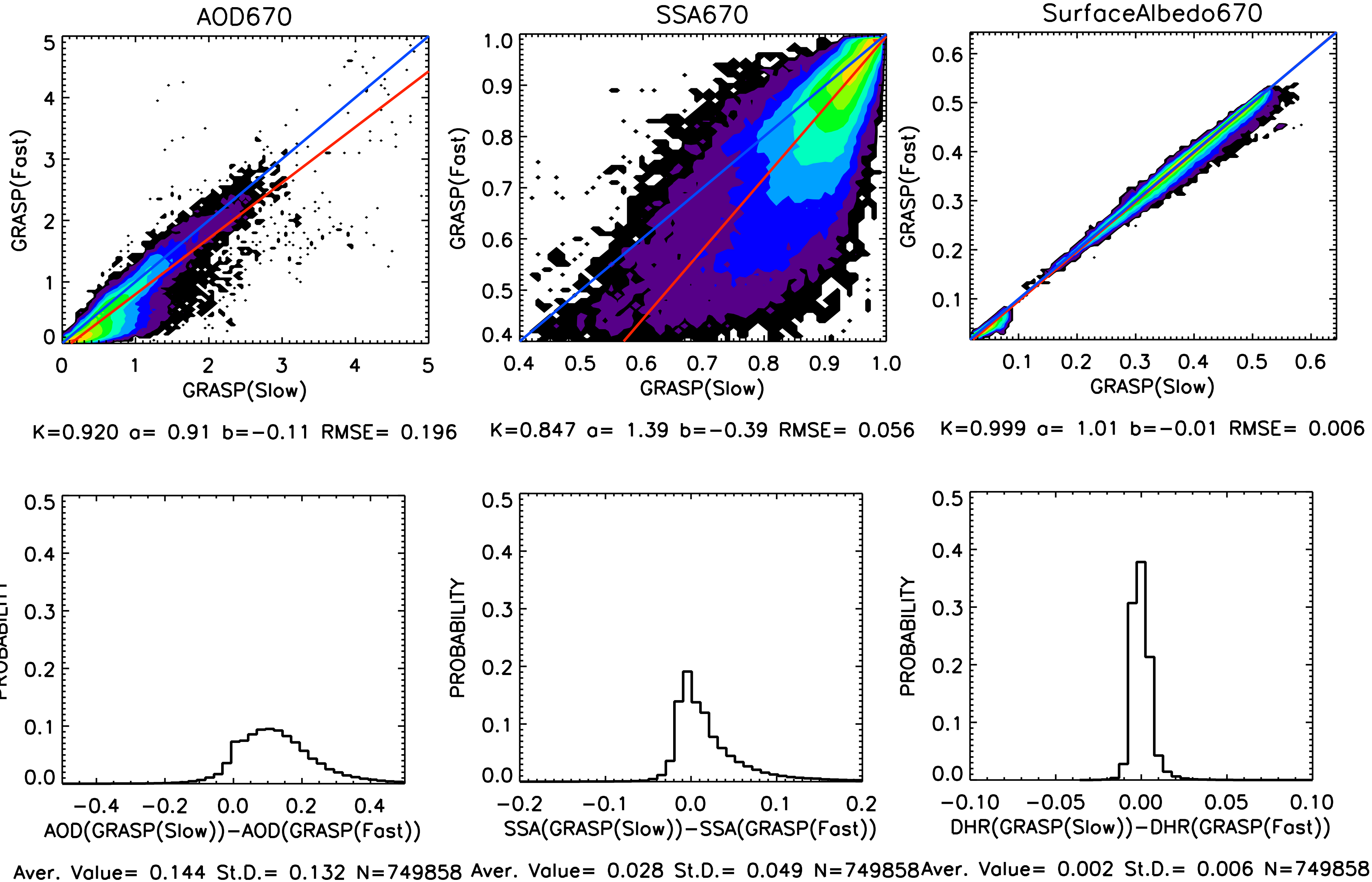
PARASOL/GRASP



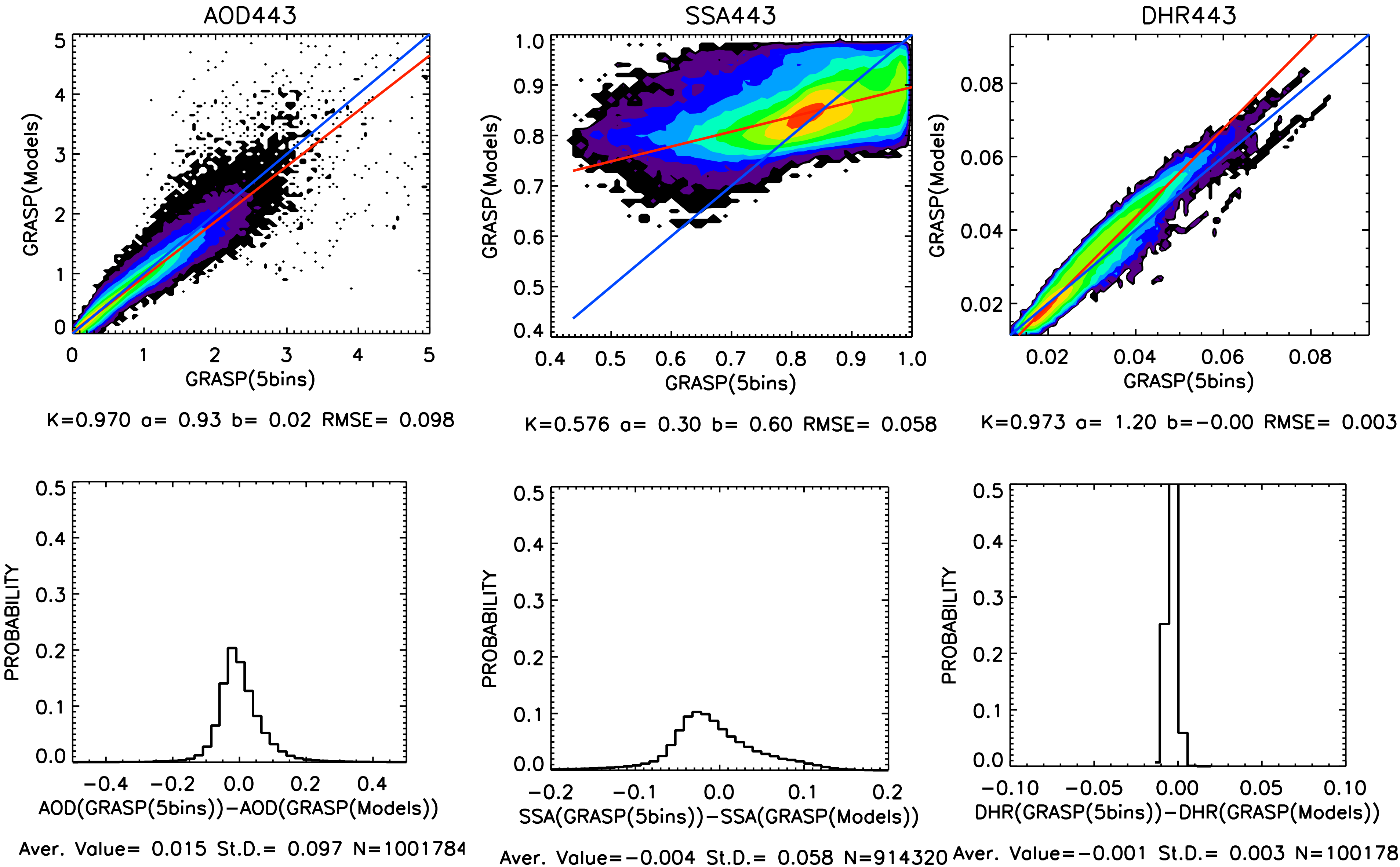
MISR/GRASP



GRASP “optimized” mode vs. GRASP “hp” mode. Dakar

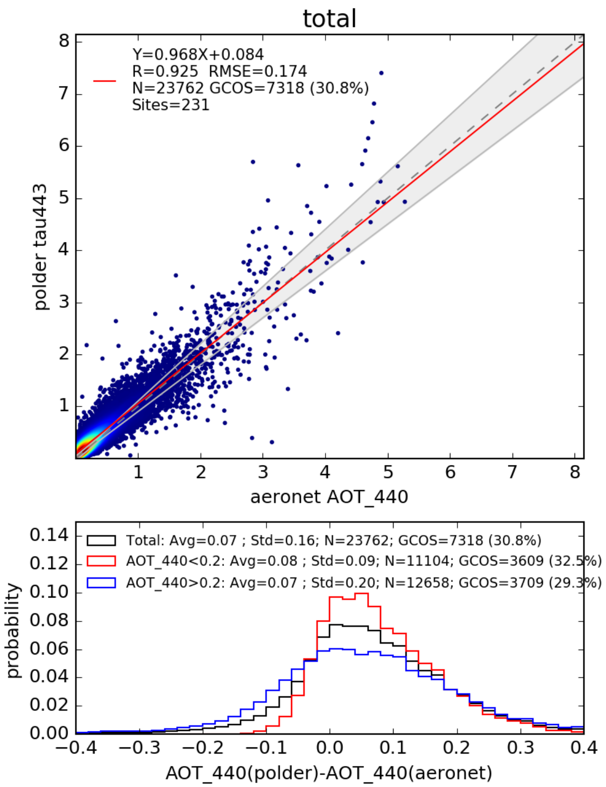


Mongu Models vs GRASP hp 5 bins

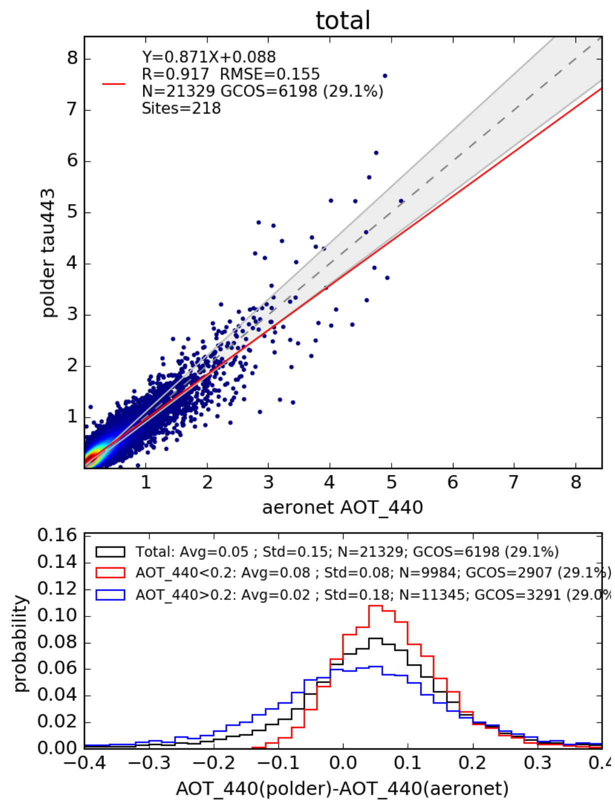


PARASOL Full archive validations (over land)

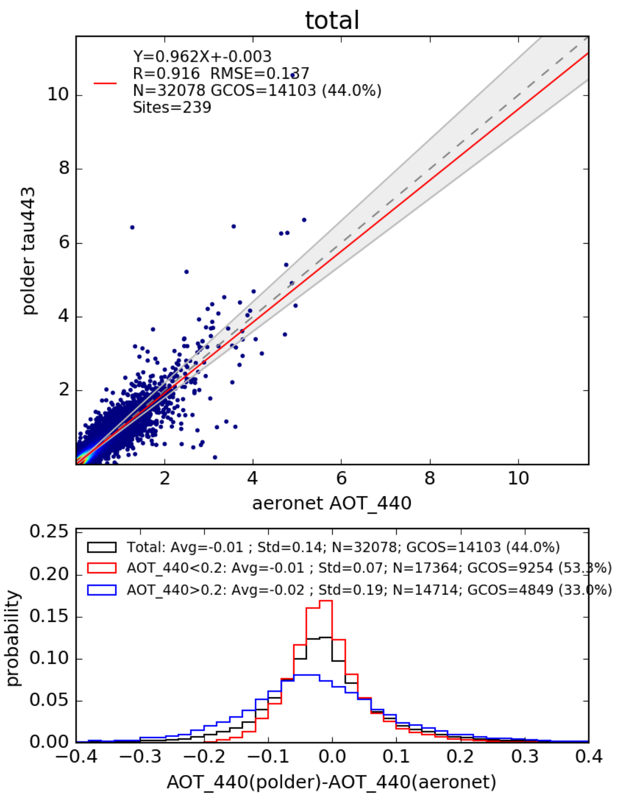
HP



Optimized

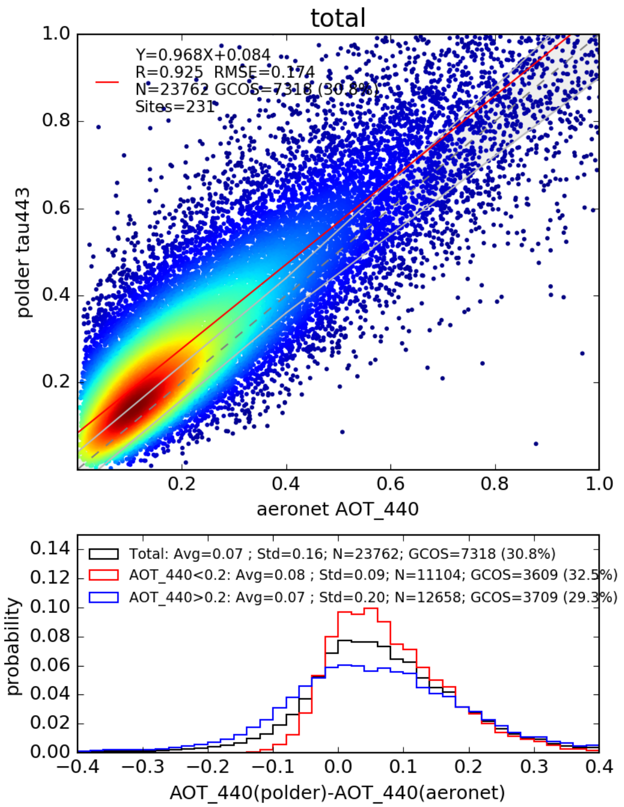


Models mixture

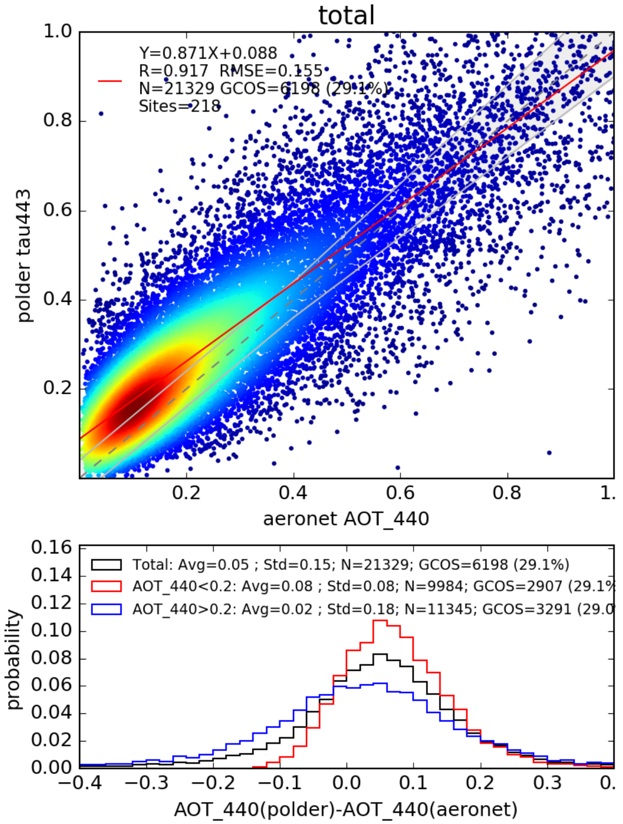


PARASOL Full archive validations (over land)

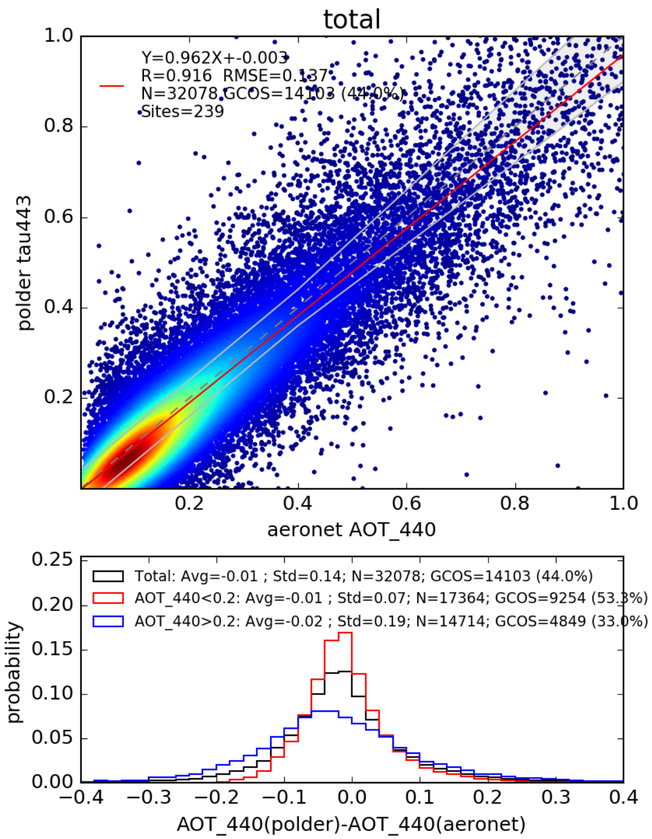
HP



Optimized

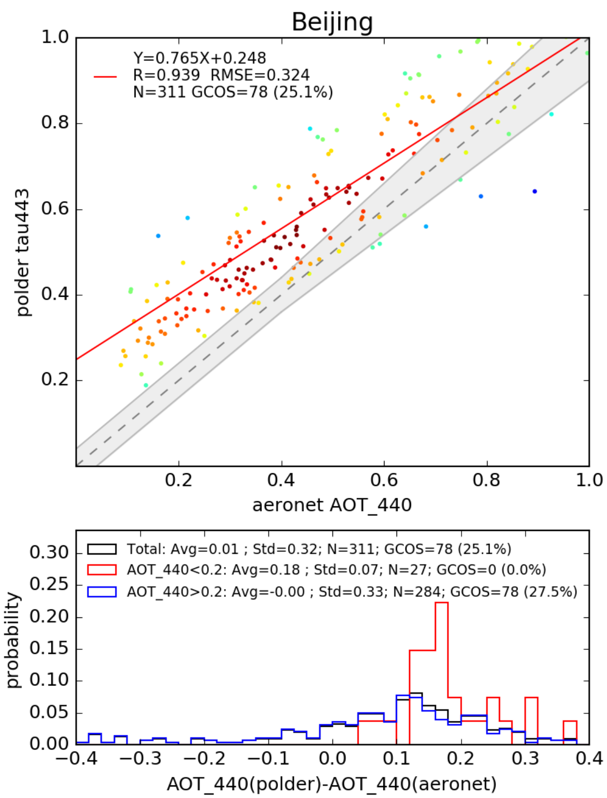


Models mixture

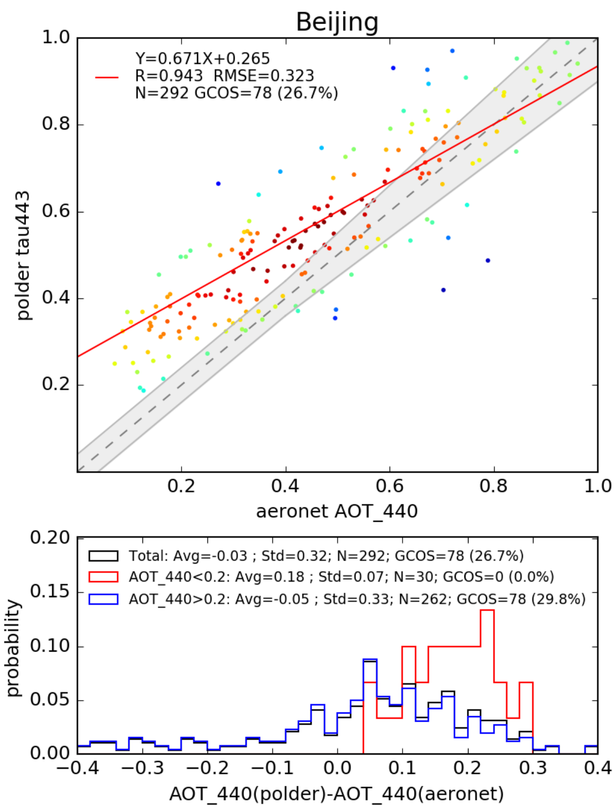


PARASOL validations, Beijing

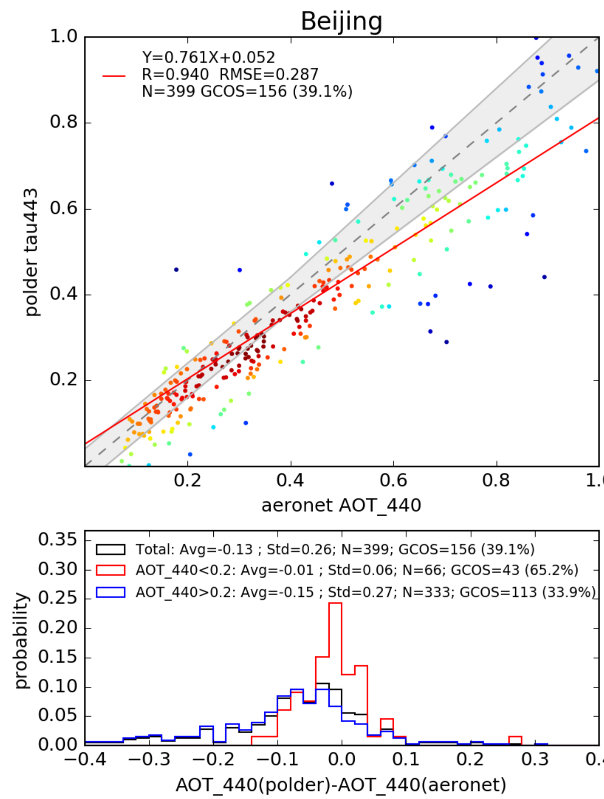
HP



Optimized

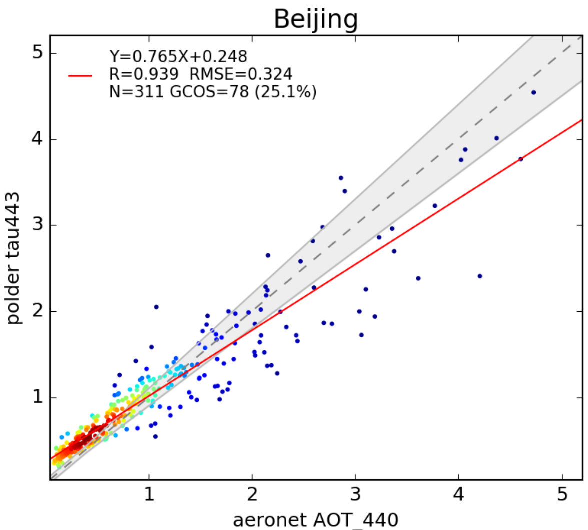


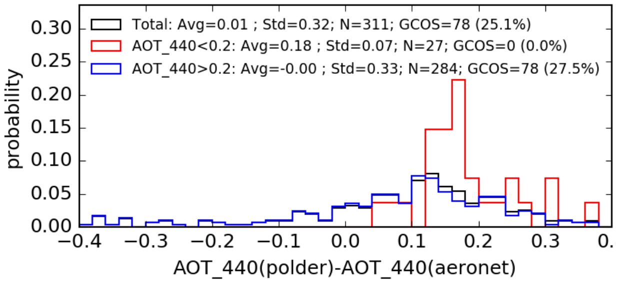
Models mixture



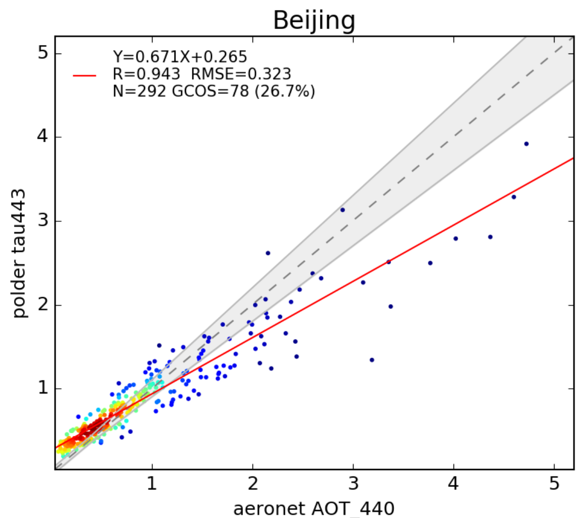
PARASOL validations, Beijing

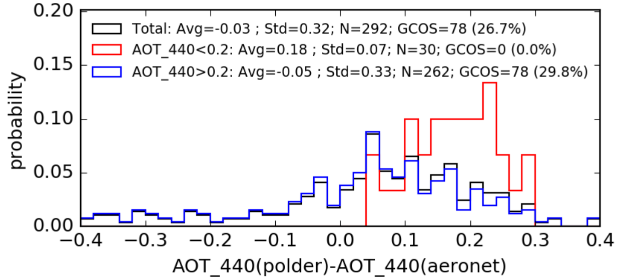
HP



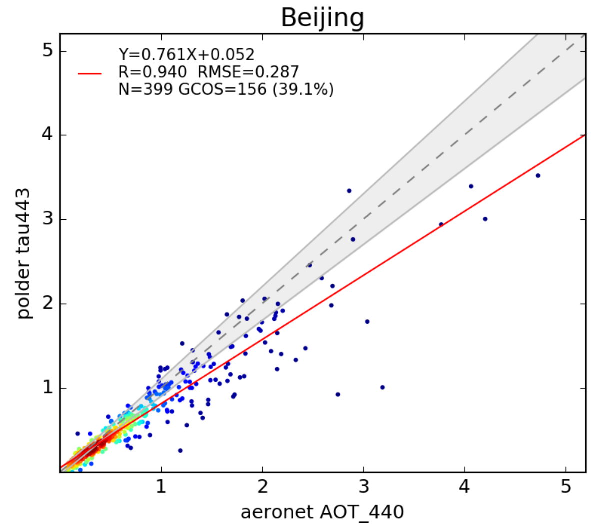


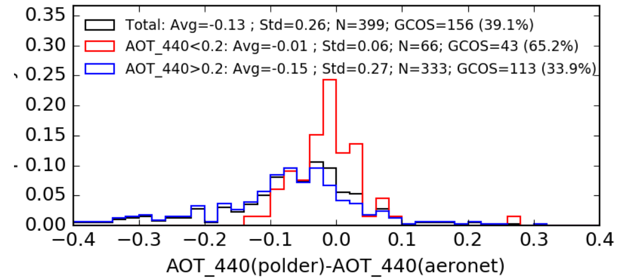
Optimized





Models mixture





Task-6: Evaluation of EUMETSAT Co-registration Function (WP-6)

WP manager: F. Poustomis

Start month: 12	**End month**: 14
Inputs: · Level 1c Test Synthetic Data Set over 3MI orbits. · Level 1c Test Proxy Data Set over 3MI orbits. · EUMETSAT Co-registration function description. · Level 1c Test Synthetic Data Set co-registered with EUMETSAT function. · Level 1c Proxy Data Set co-registered with EUMETSAT function.	**Outputs**: · The report on the evaluation of EUMETSAT co-registration function and suggestions for its improvement.

Actions:

- Task 6.1. Level 1c Test Data Set co-registration comparison

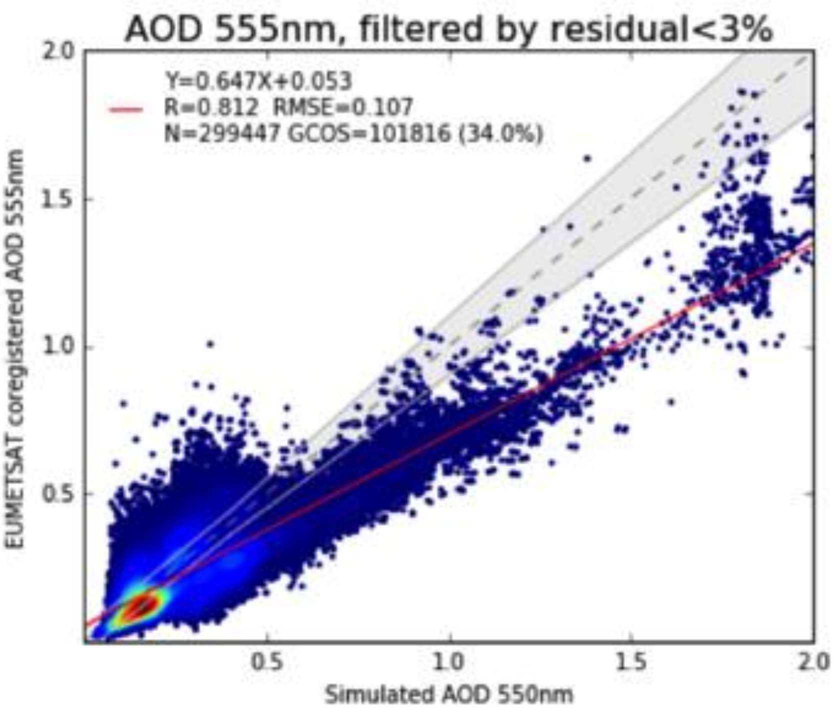
The Level 1c Data Sets generated in Task 2 will be compared with the Level 1c Data Sets generated using EUMETSAT co-registration function

- Task 6.2. Performance of the aerosol properties retrieval algorithm on 1c datasets

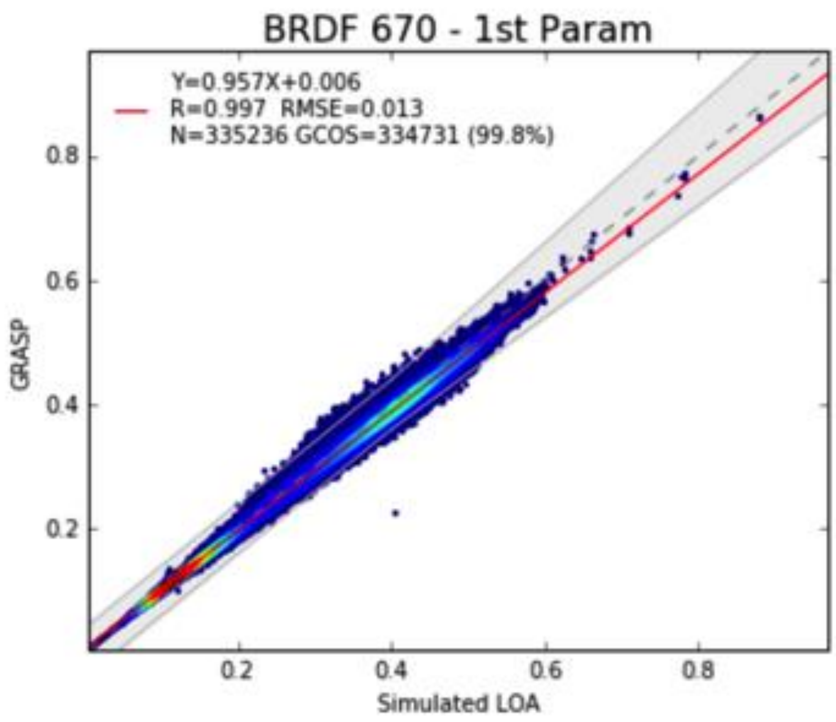
Possible effects caused by differences in co-registration algorithms on aerosol/surface properties retrieval will be analysed using series of the retrieval tests.

Inversion of the 1C Level data co-registered by EUMETSAT:

AOD (555)



1-st par BRDF (670)



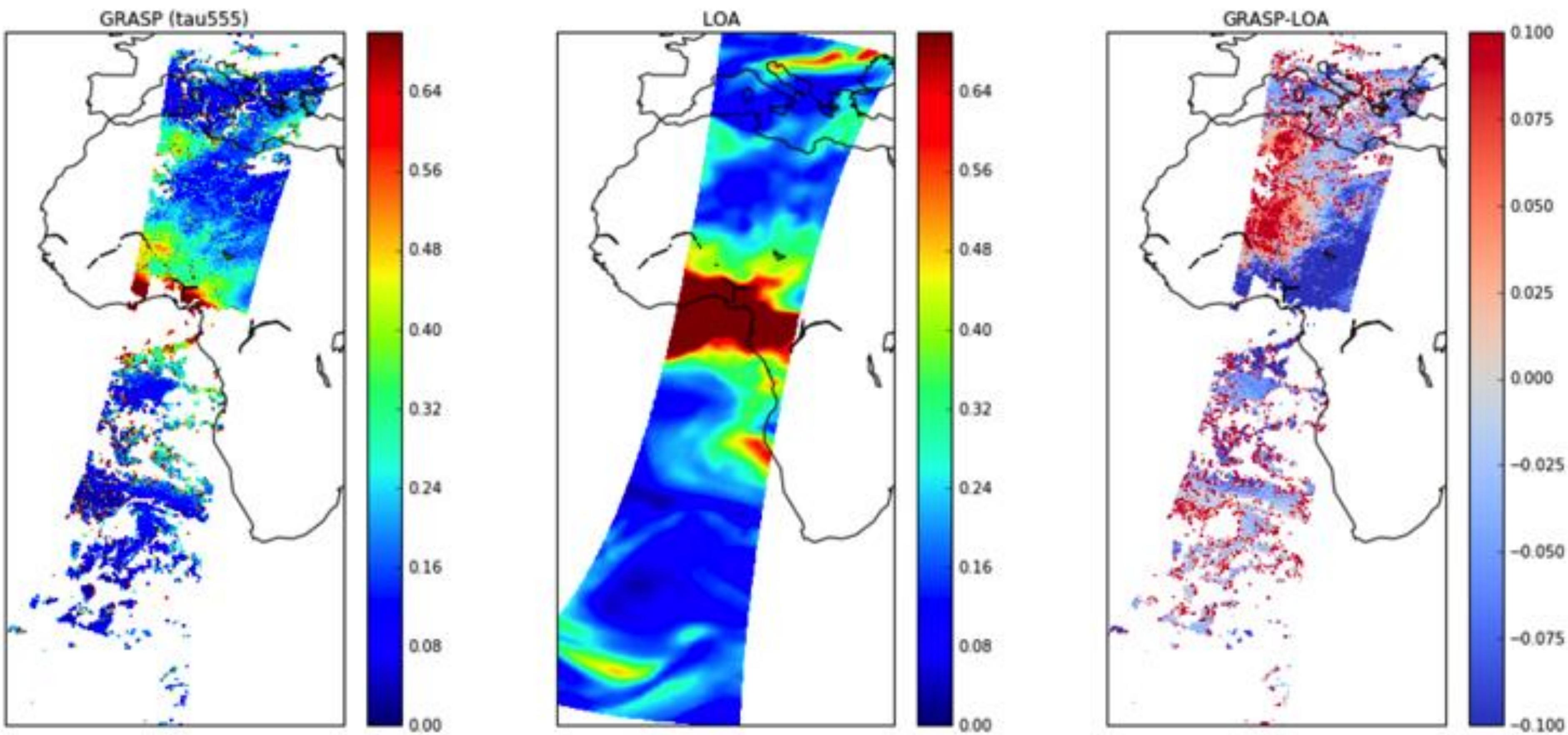
Inversion of the 1C Level data co-registered by EUMETSAT:

AOD (555)

Retrieved

Assumed

Difference

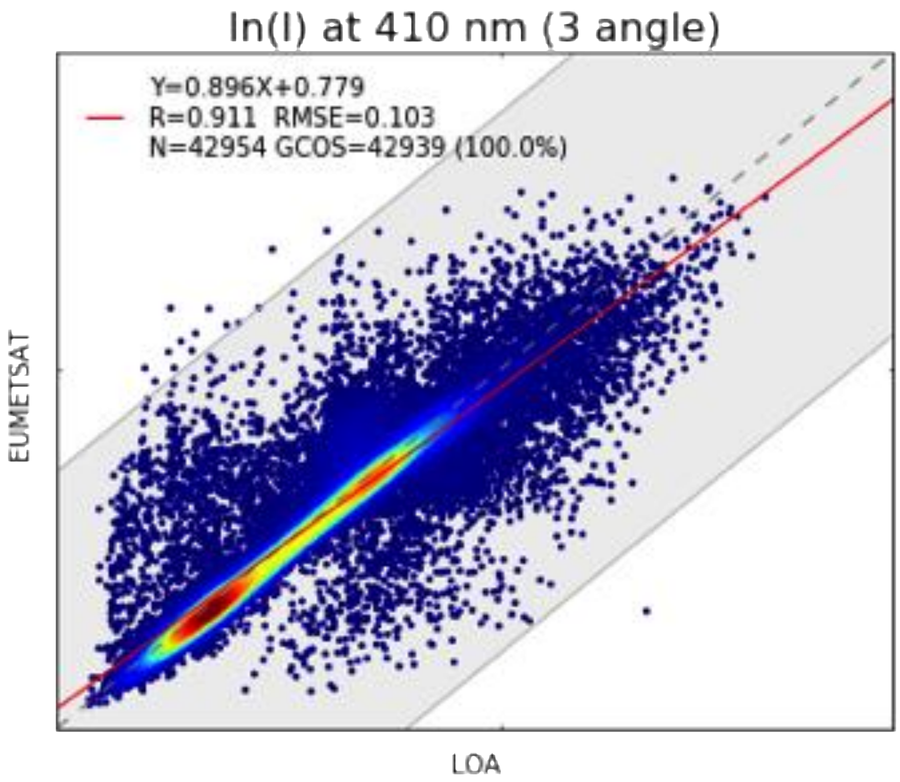


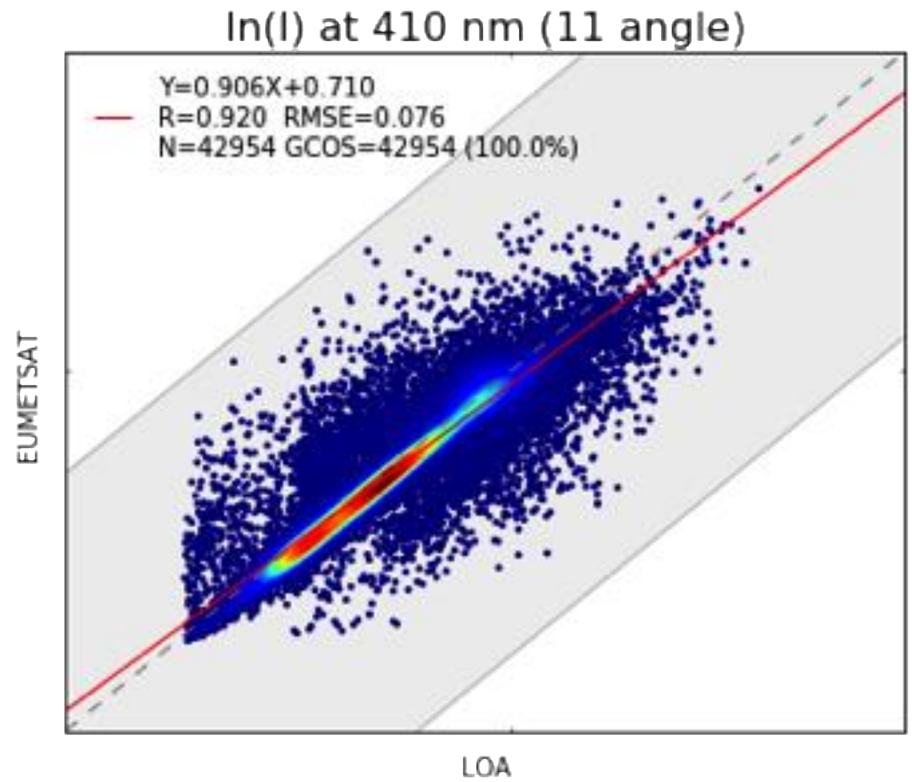
Comparison of "ideal" 1C Level data with 1C Level co-registered by EUMETSAT:

Radiances in logarithmic scale

RMSE= ~ 10%

RMSE= ~ 8%

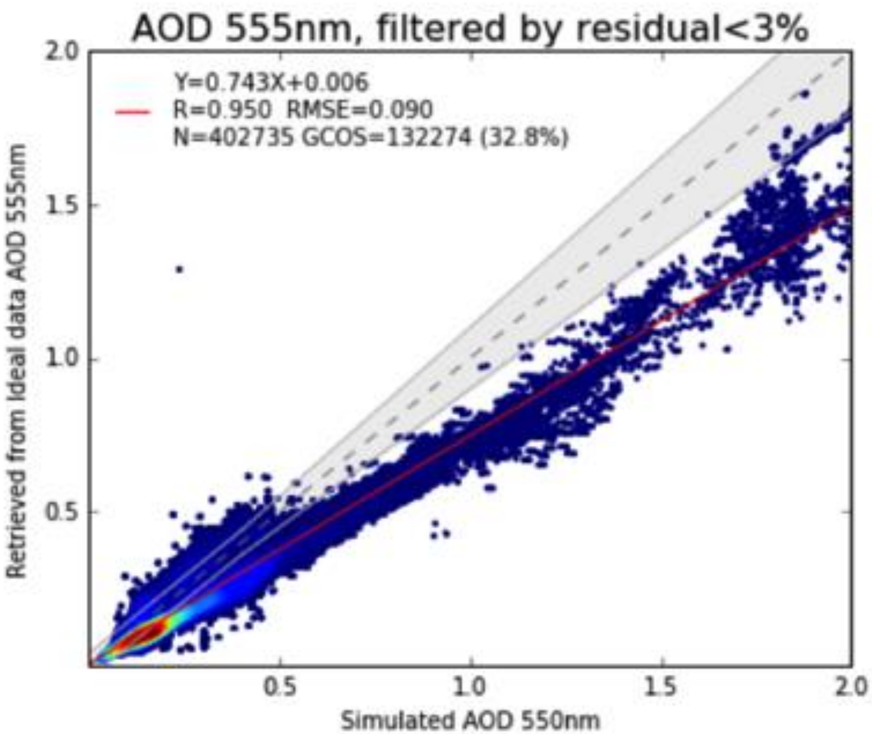




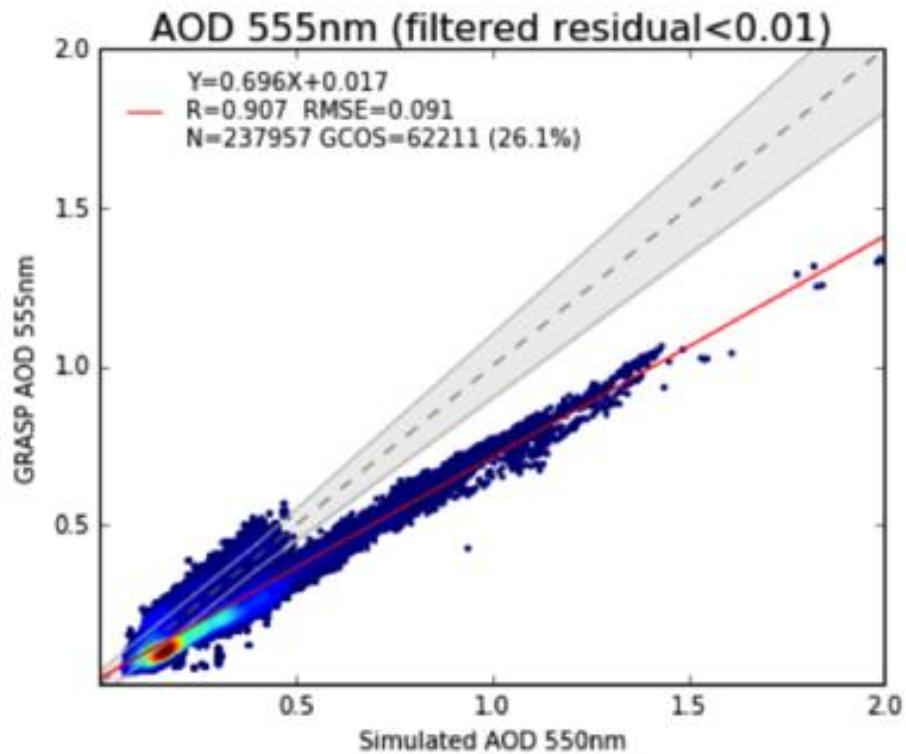
Inversion of the "ideal" 1C Level data :

AOD (555)

Fitting error < 3%



Fitting error < 1%



Inversion of the "ideal" 1C Level data :

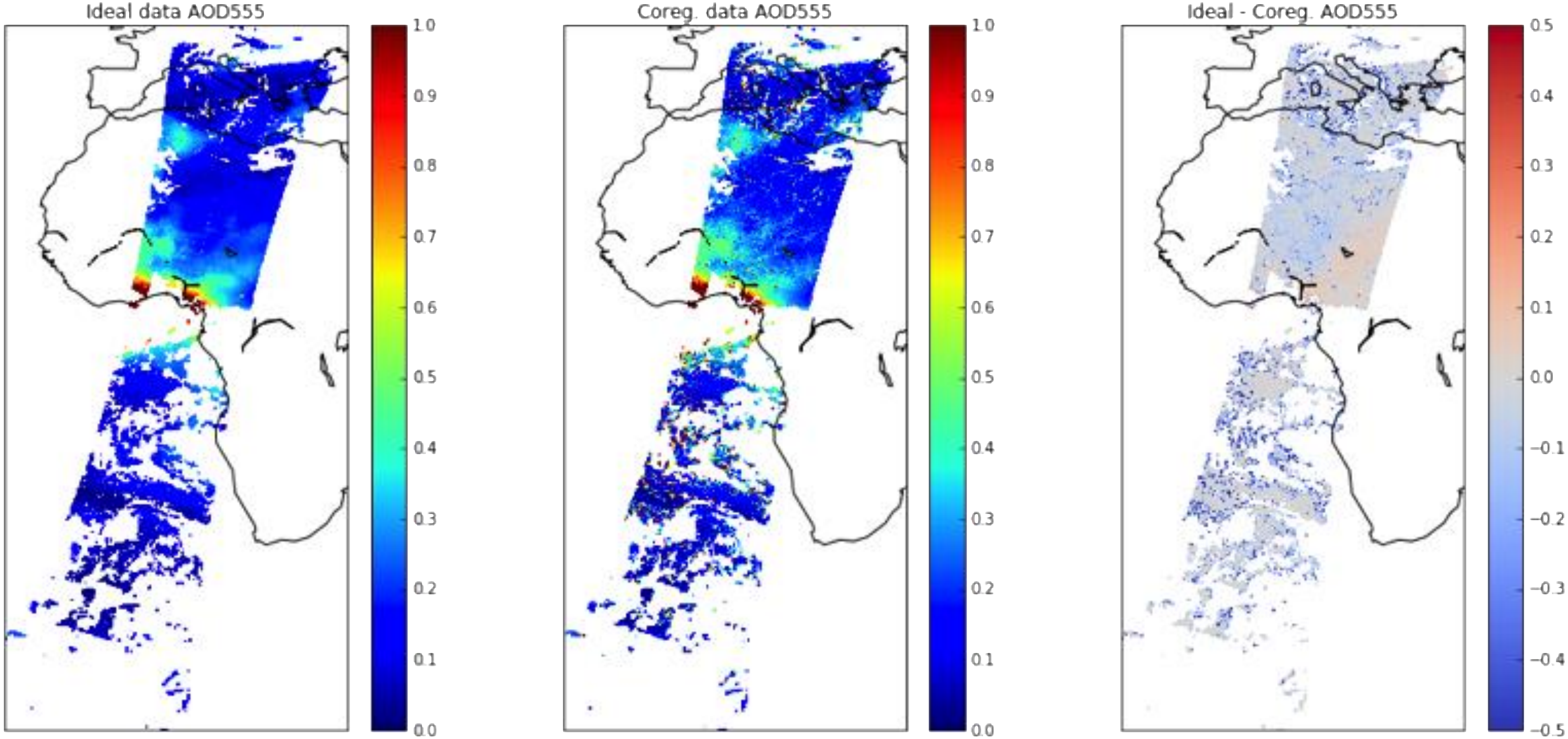
Optimized

AOD (555)

Retrieved

Assumed

Difference



Inversion of the ”ideal” 1C Level data :

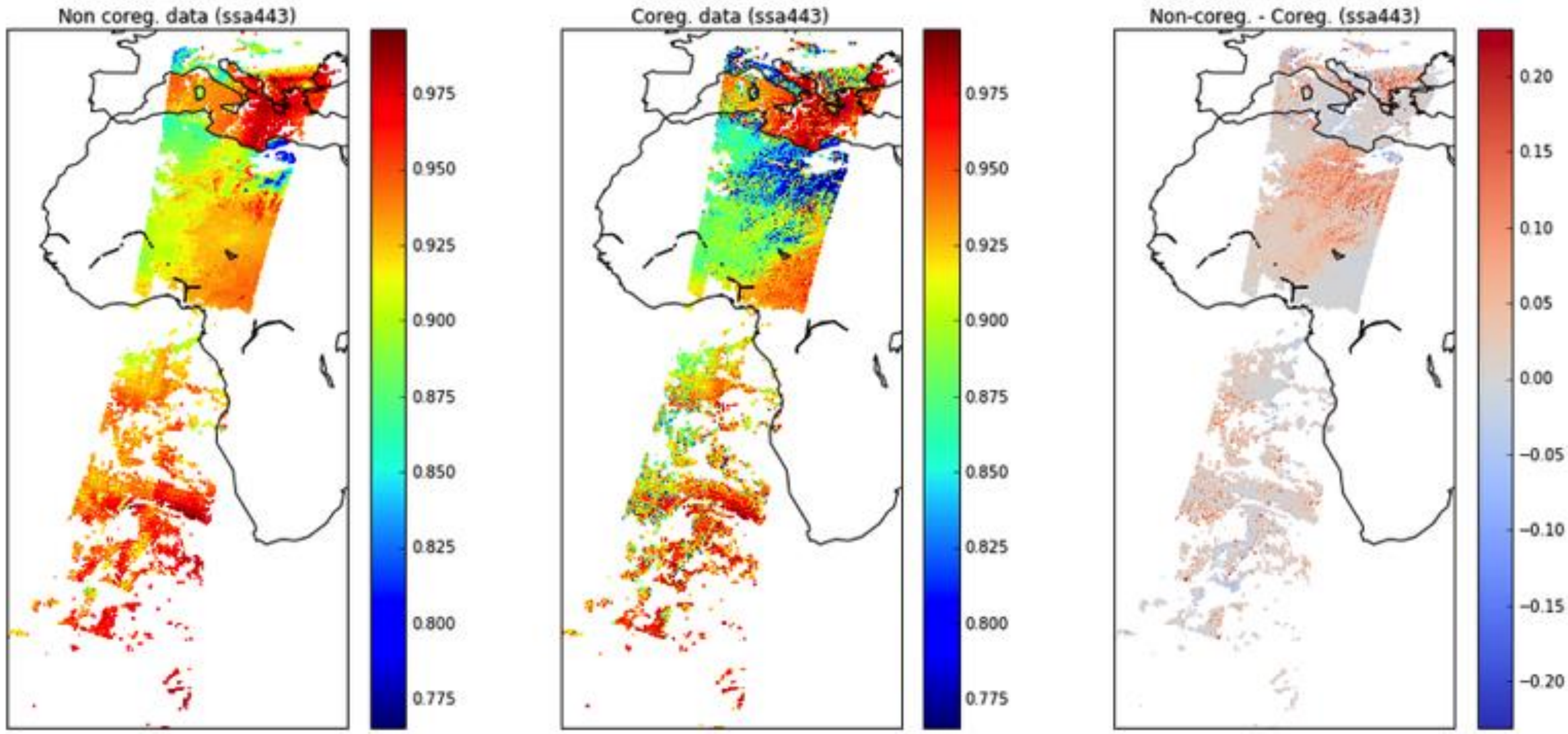
SSA (440)

Optimized

Retrieved

Assumed

Difference



Potential reasons for the disagreement:

Objective differences:

- **Differences in Solar Zenith Sngle** :
  - in Synthetic LOA data SZA changes by 1^0 , not in GRASP;
  - *model for vertical distribution of aerosol is not the same*;
- **Aerosol models are not the same.**
- **Molecular scattering**:
  - Molecular scattering is taken from climatologies by LOA, while in GRASP it is approximated
- **Gas absorption**:
  - in GRASP no gas absorption correction;
  - in Synthetic LOA data there is gas absorption
- **Something else?**:

Inconsistencies :

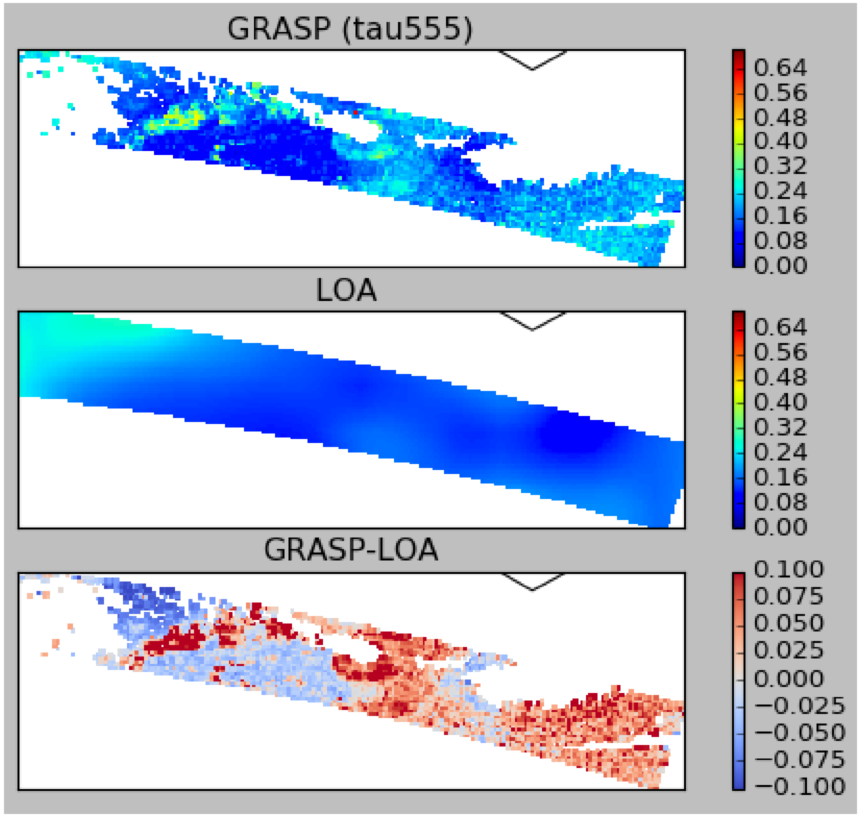
- **In data reading or processing?**
- **In modeling surface BRDF or BPDF** (LOA used spectrally depend 2 and 3 parameters)**?**
- **In modeling aerosol ???**
- **In RT or else ?**

WE TRY TO CLARIFY

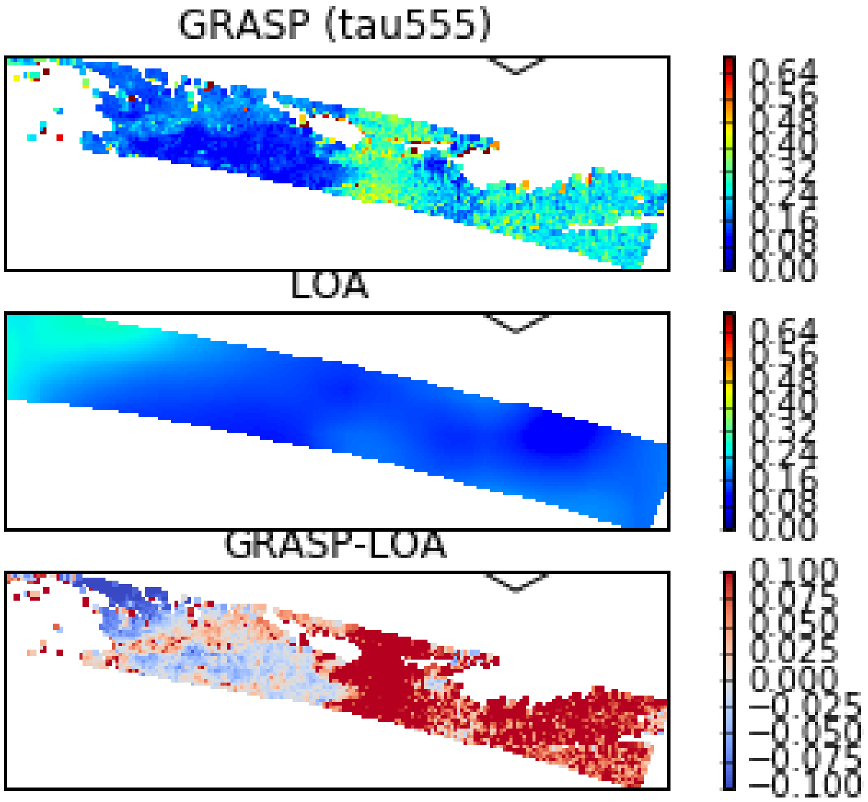
The case (a few aerosol over very bright surface) is HARD, but not a problematic if no inconsistencies

GRASP retrieval from LOA and EUMETSAT C1 level files

For LOA C1



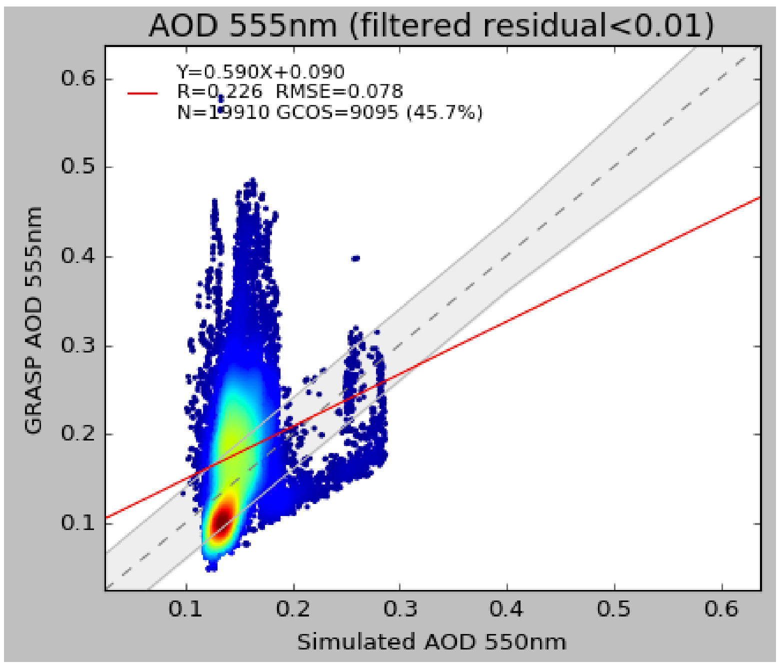
For C1 co-registered by EUM

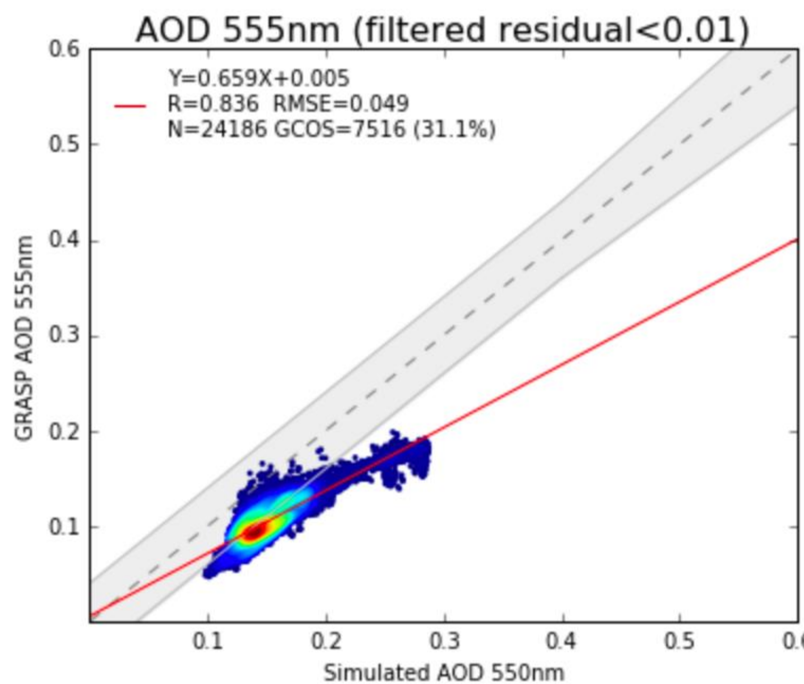


GRASP retrieval from LOA and EUMETSAT C1 level files

For LOA C1 (With Gas absorption)

For LOA C1 (No Gas absorption)

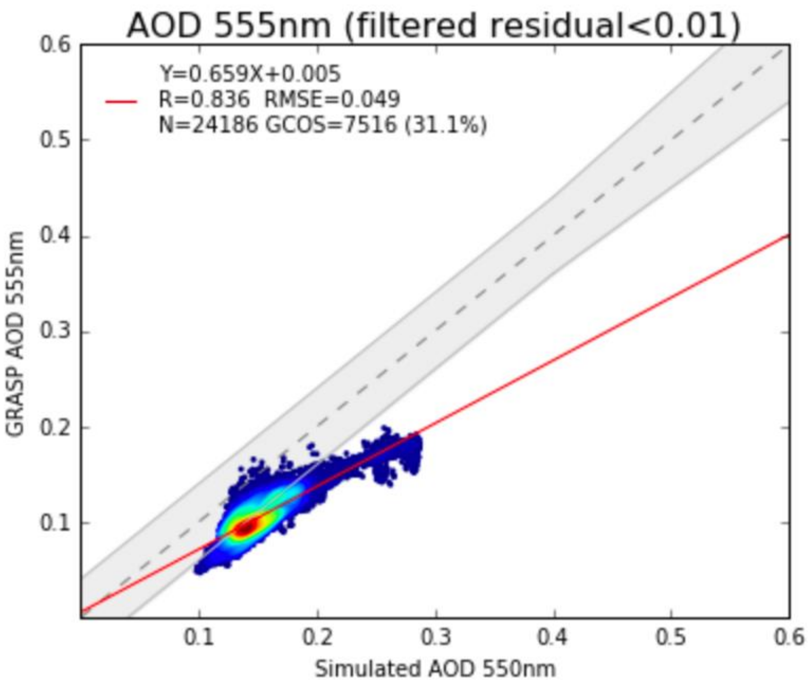


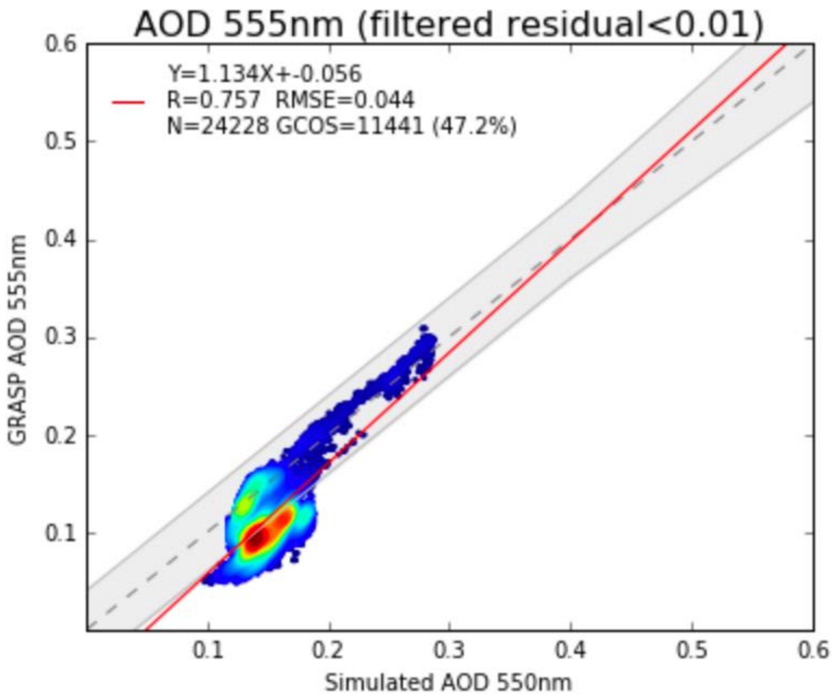


GRASP retrieval from LOA and EUMETSAT C1 level files

For LOA C1 (No Gas absorption)

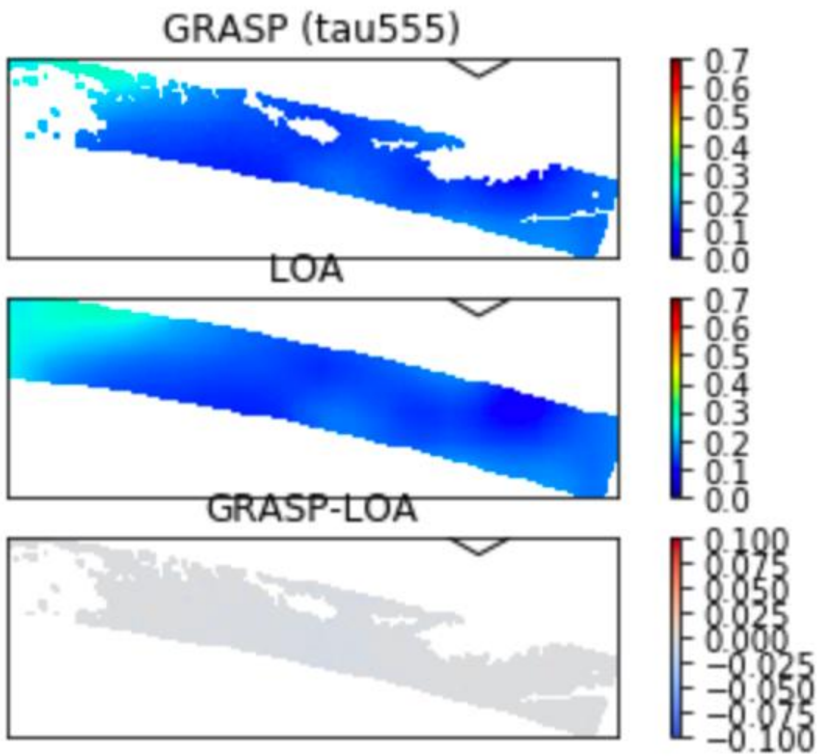
For LOA C1 (No Gas absorption, corrected BRDF)



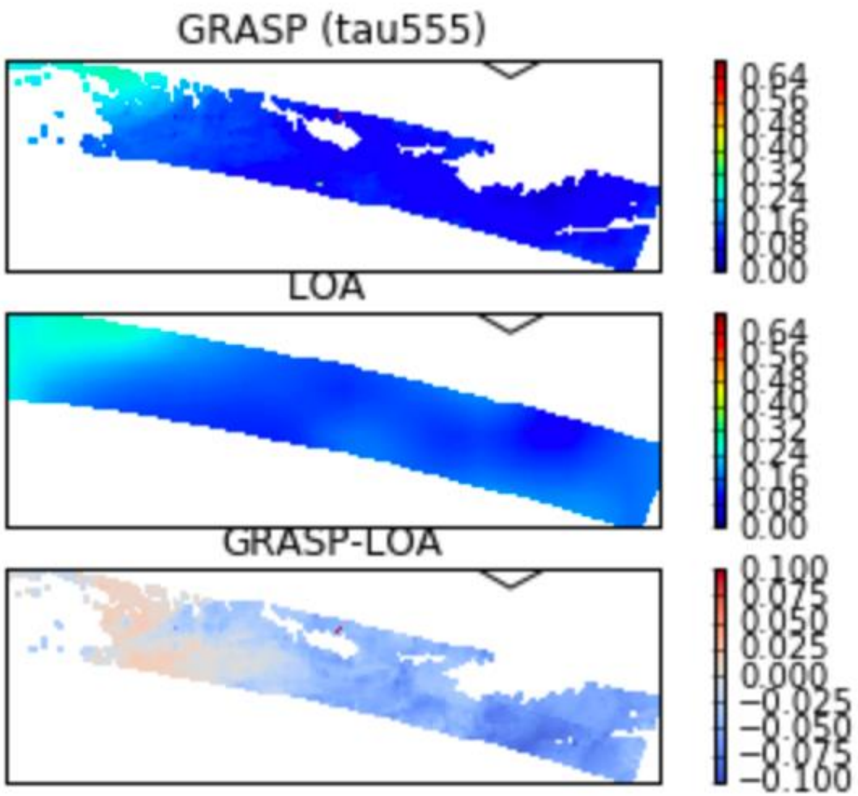


GRASP retrieval from LOA C1 level file

For C1 simulated by GRASP)



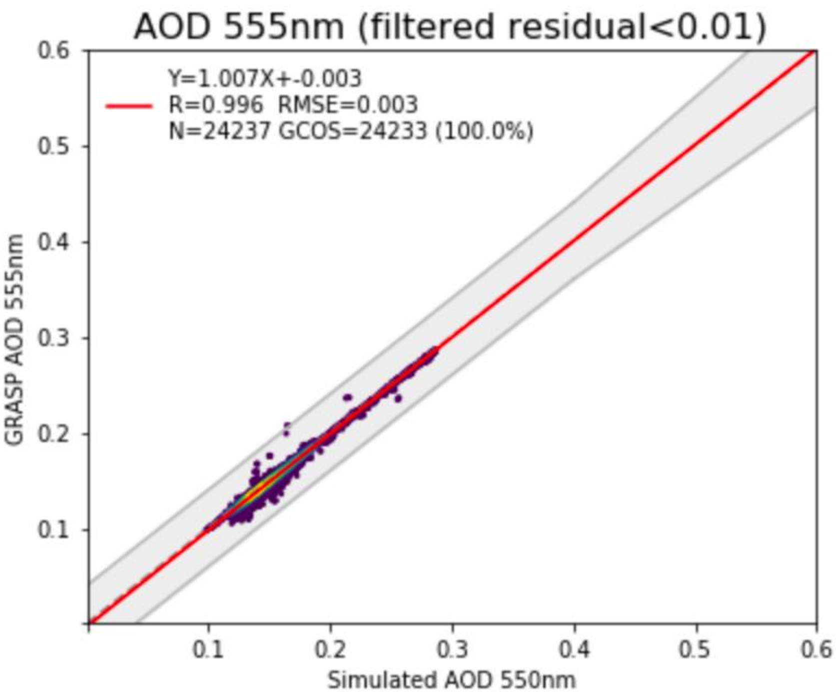
For LOA C1 (No Gas absorption, corrected BRDF)

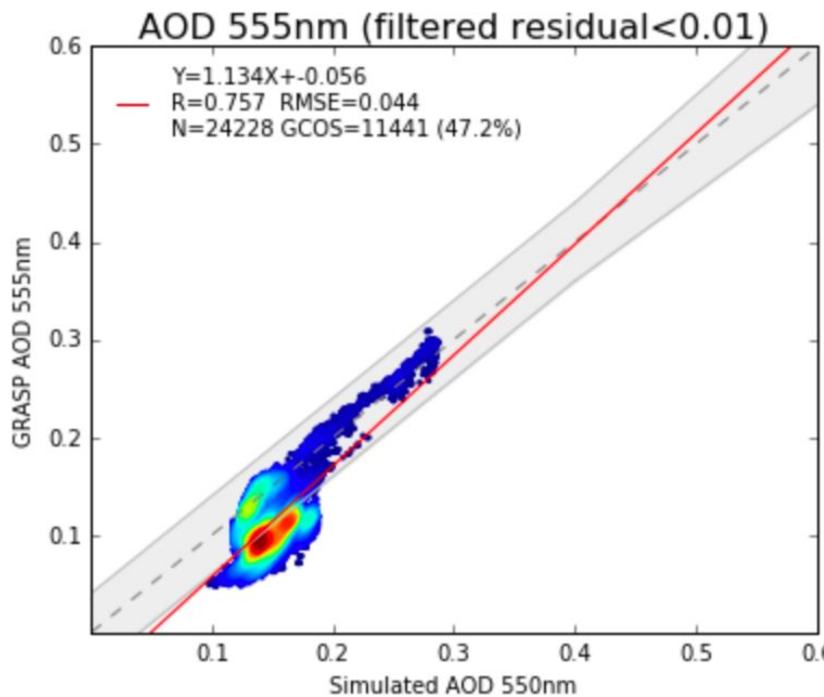


GRASP retrieval from LOA and EUMETSAT C1 level files

For C1 simulated by GRASP

For LOA C1 (No Gas absorption, corrected BRDF)

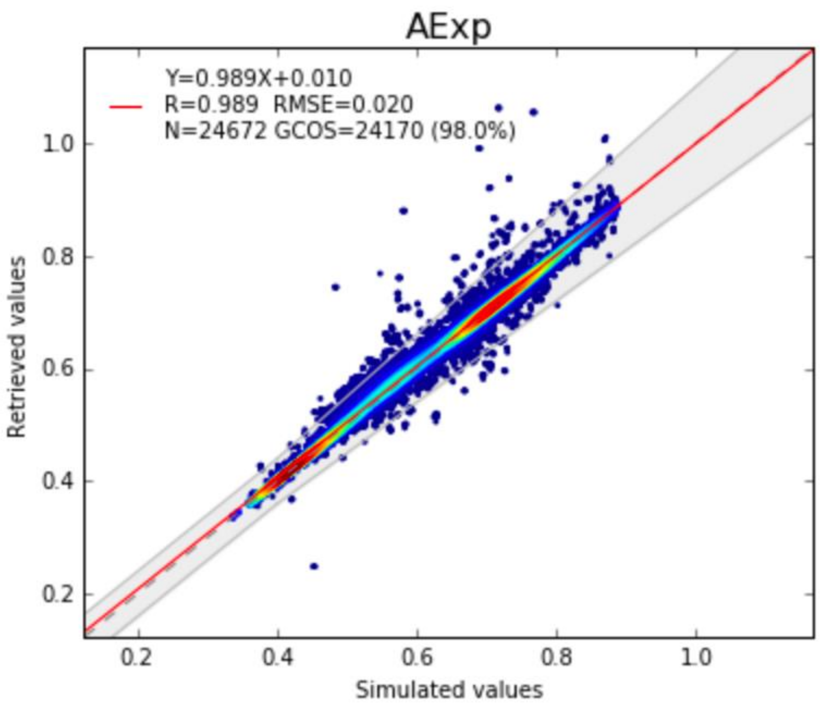




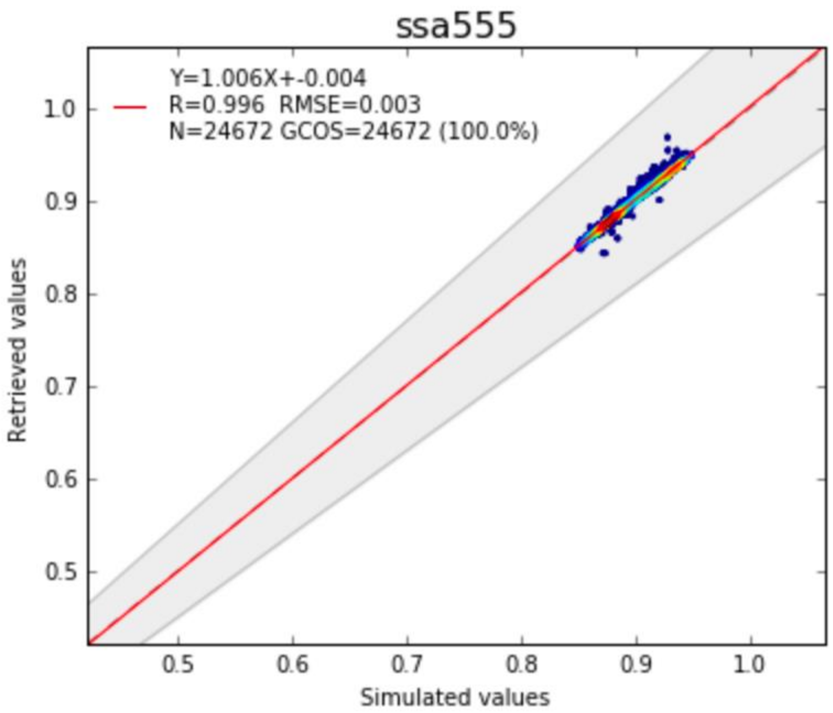
GRASP retrieval from LOA and EUMETSAT C1 level files

For C1 simulated by GRASP

Angstrom



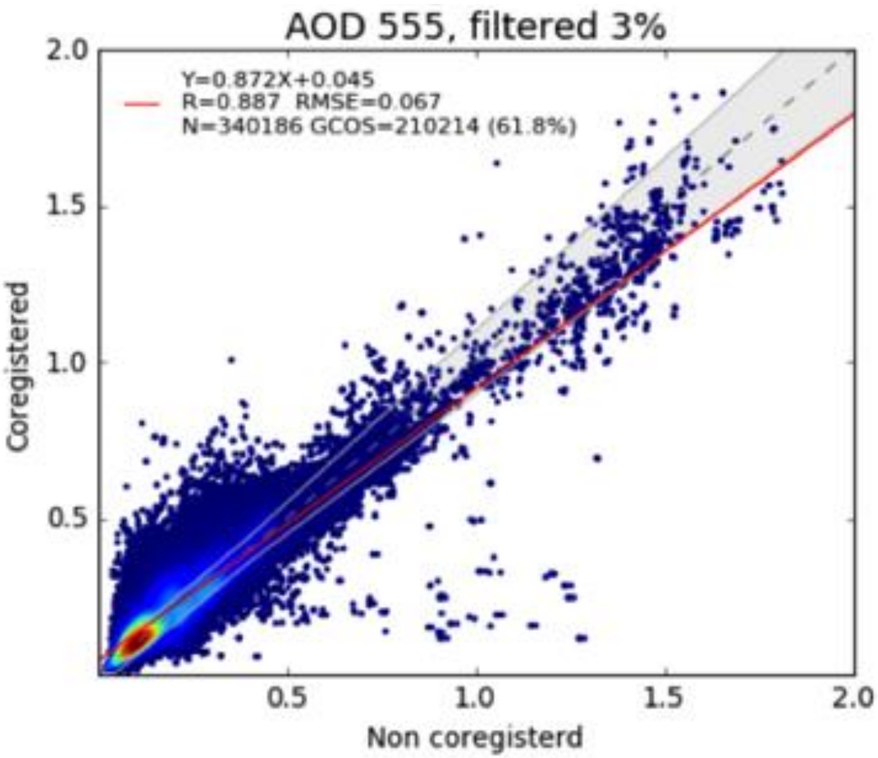
SSA(555)



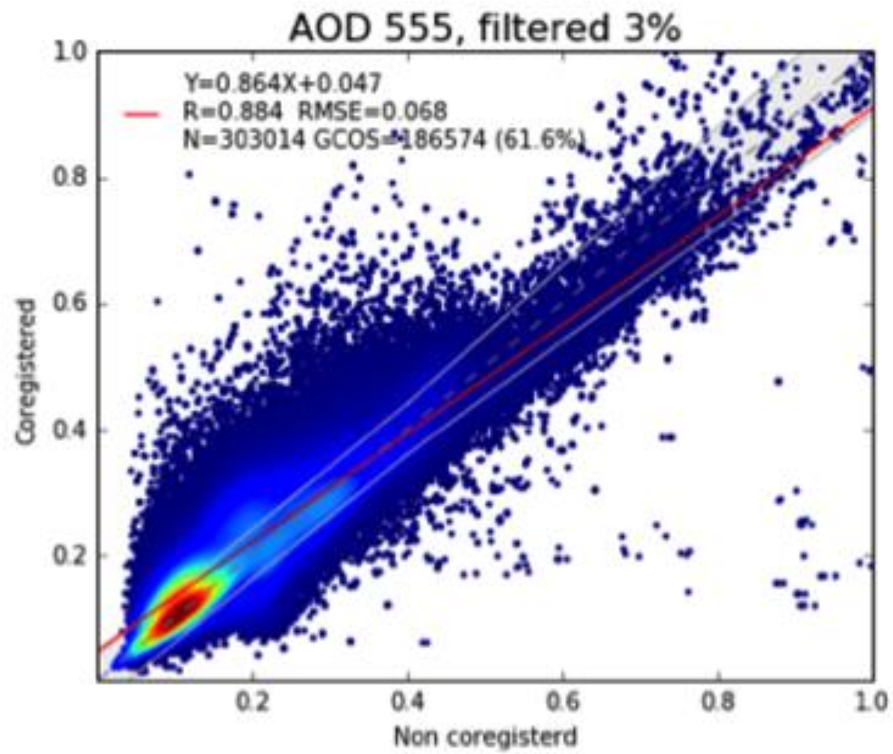
Inversion results of the 1C Level data co-registered by EUMETSAT compared to results from "ideal" 1C Level data :

AOD (555)

AOD(555) < 1.0



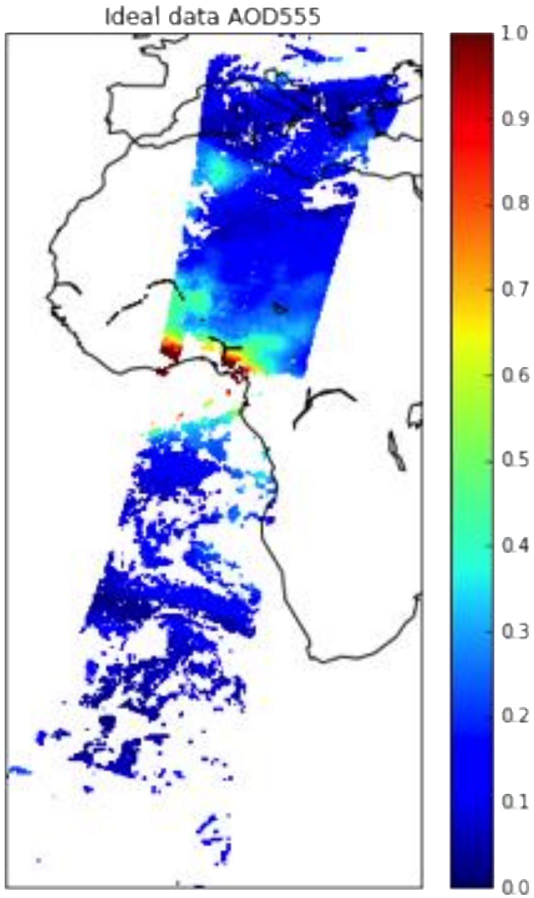
AOD(555) < 2.2



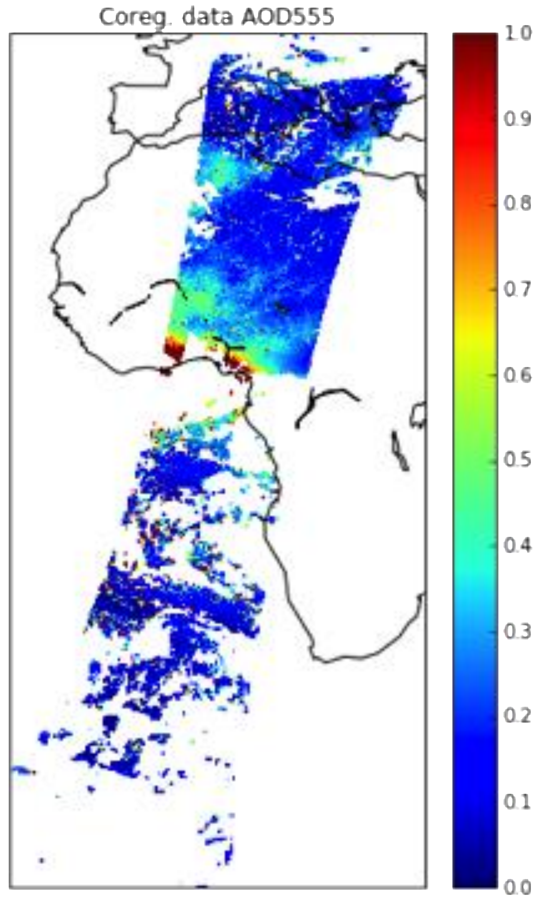
Inversion results of the 1C Level data co-registered by EUMETSAT compared to results from ”ideal” 1C Level data :

AOD (555)

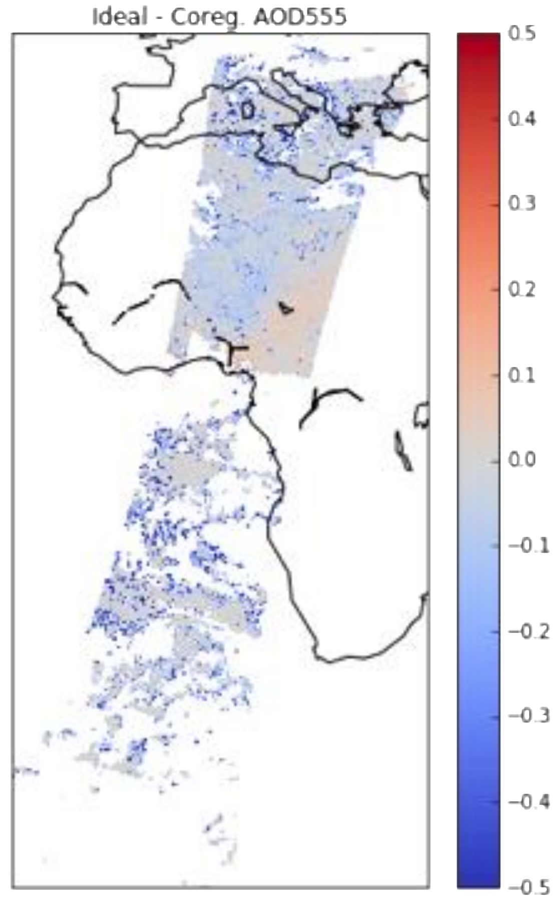
Retrieved



Assumed



Difference



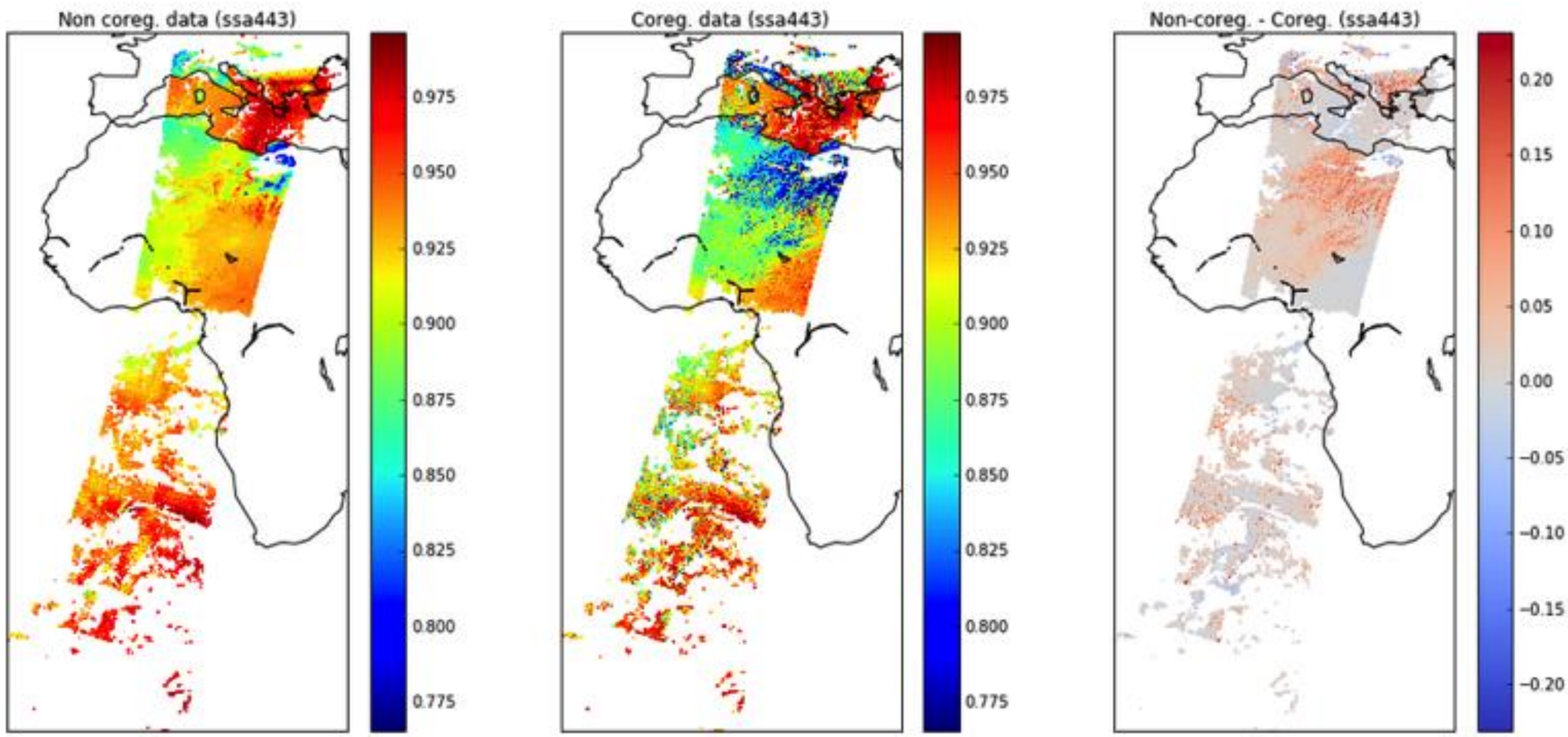
Inversion results of the 1C Level data co-registered by EUMETSAT compared to results from "ideal" 1C Level data :

SSA (440)

Retrieved

Assumed

Difference



Comparison approach

- ## How to compare two 3MI L1C datasets?

Geometric quality assessment

Is the location of a given pixel (characterized by its reflectance value) of one acquisition in a L1C dataset the same in another dataset ?

Matching of the enhanced acquisitions of two datasets: computation of the normalized cross correlation

→ **geometric precision** → **geometric accuracy**

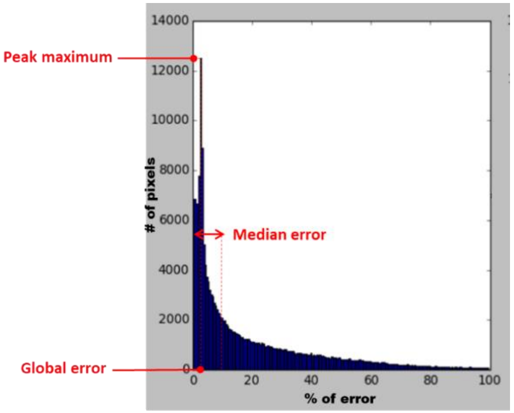
Radiometric quality assessment

What is the error on the reflectance values (due to geometric error or interpolation method)?

Computation of percentage of error for each 3MI L1C pixel

$$\%_{error} = 100 \frac{reflectance_{REF} - reflectance_{EUM/NOV}}{(reflectance_{REF} + reflectance_{EUM/NOV})/2}$$

→ **radiometric precision** → **radiometric accuracy**



Comparison results

- **Global radiometric result, for all pixels, and with cloud free pixels only**
  - 2008 orbit
  - Perfect L1C dataset as reference
  - No parallax correction

Dataset	Radiometric assessment	
	Global error (%) (accuracy)	Peak maximum (%) (precision)
EUMETSAT	0,67	10,30
NOVELTIS	0,72	7,70

Dataset	Radiometric assessment	
	Global error (%) (accuracy)	Peak maximum (%) precision)
EUMETSAT	0,67	19,30
NOVELTIS	0,68	15,90

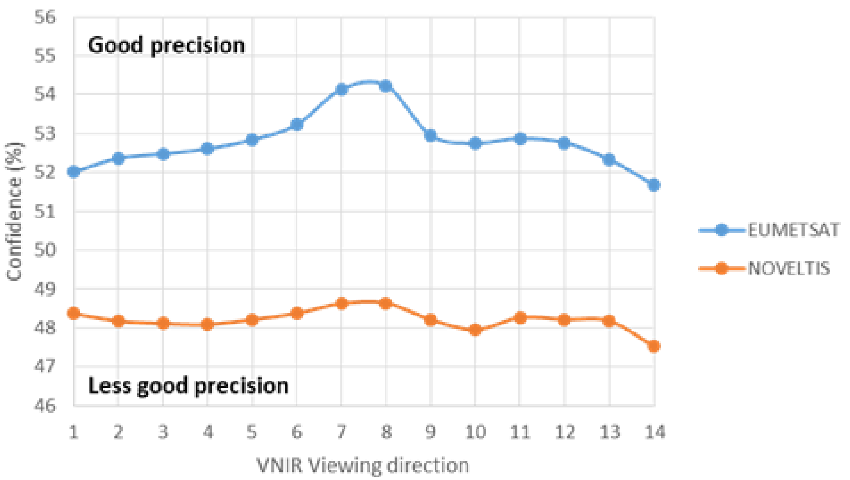
Cloud free

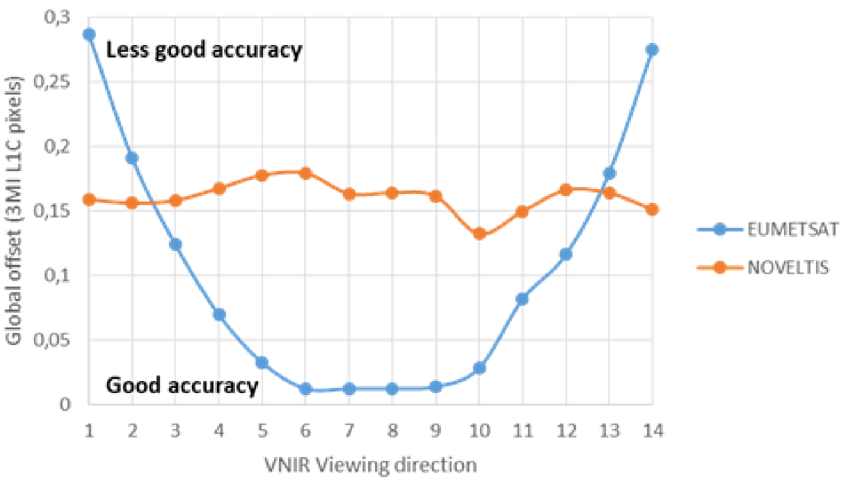
→ Results of the 2 methods are closer from each other considering cloud free pixels only

→ The radiometry of the cloud free pixels is closer from the "reference" radiometry, than the one of the cloudy pixels

Comparison results

- **Geometric quality according to the viewing directions**
  - 2008 orbit
  - Comparison intra-dataset: central acquisition of the considered dataset used as reference
  - No parallax correction





→ Global offset lower

→ Reduction of parallax effect with NOVELTIS co-registration method

Conclusion

- **Two co-registration methods really different**
- **EUMETSAT method gives better global results**
- **Hypothesis of correct L1B geolocation values for NOVELTIS technique: no correction of the absolute geolocation**
- **No specific correction of the parallax effect in the NOVELTIS technique but the chosen co-registration method reduces its impact**
- **Two methods providing satisfactory global results**

Inversion results of the 1C Level data co-registered by EUMETSAT and NOVELTIS compared to results from "ideal" 1C Level data :

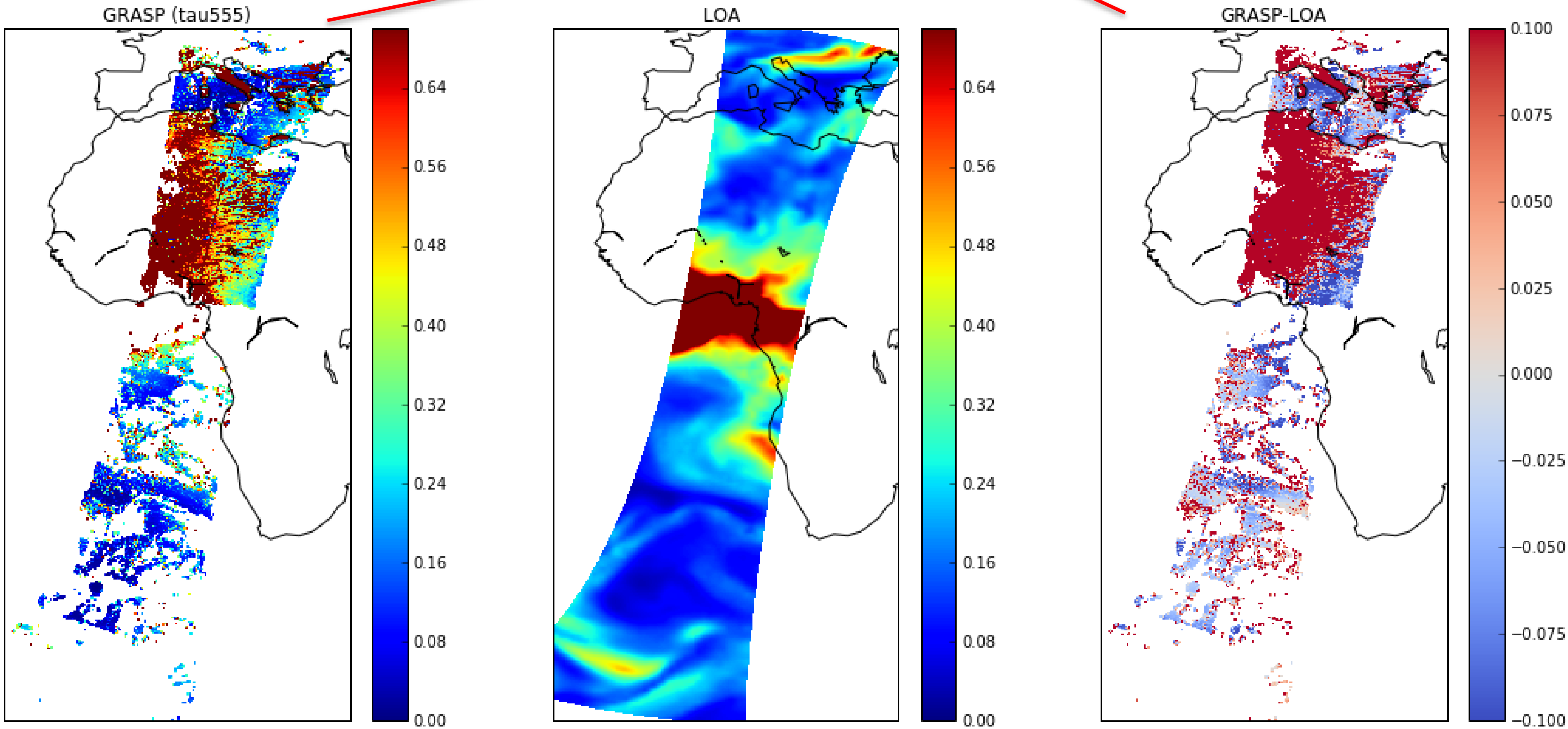
Problems in the retrievals - ???

AOD(555)

Retrieved

Assumed

Difference

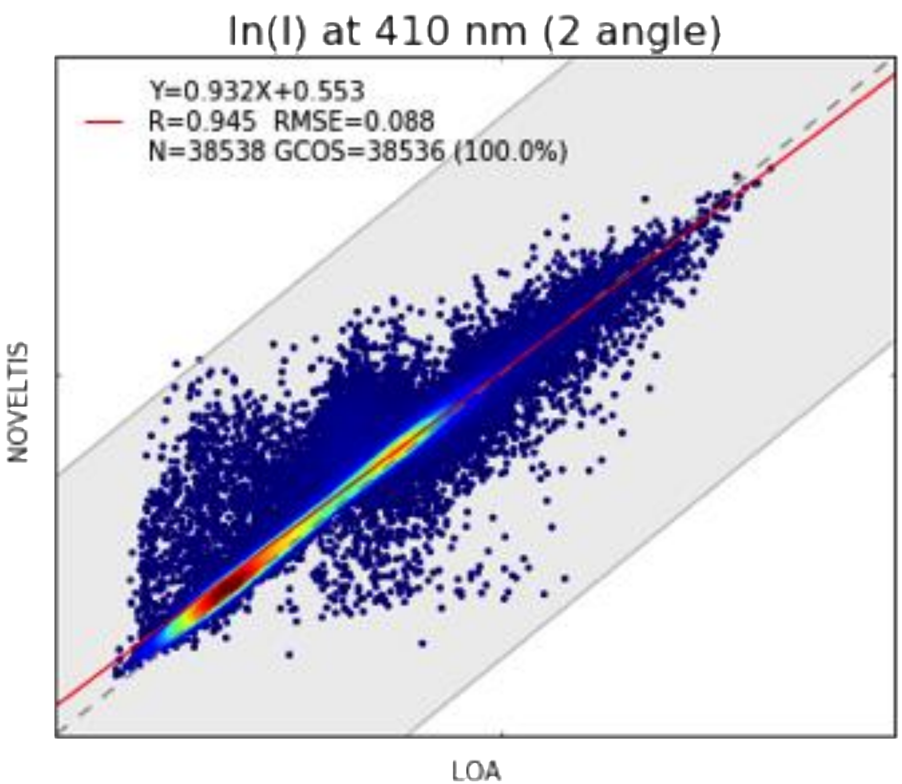


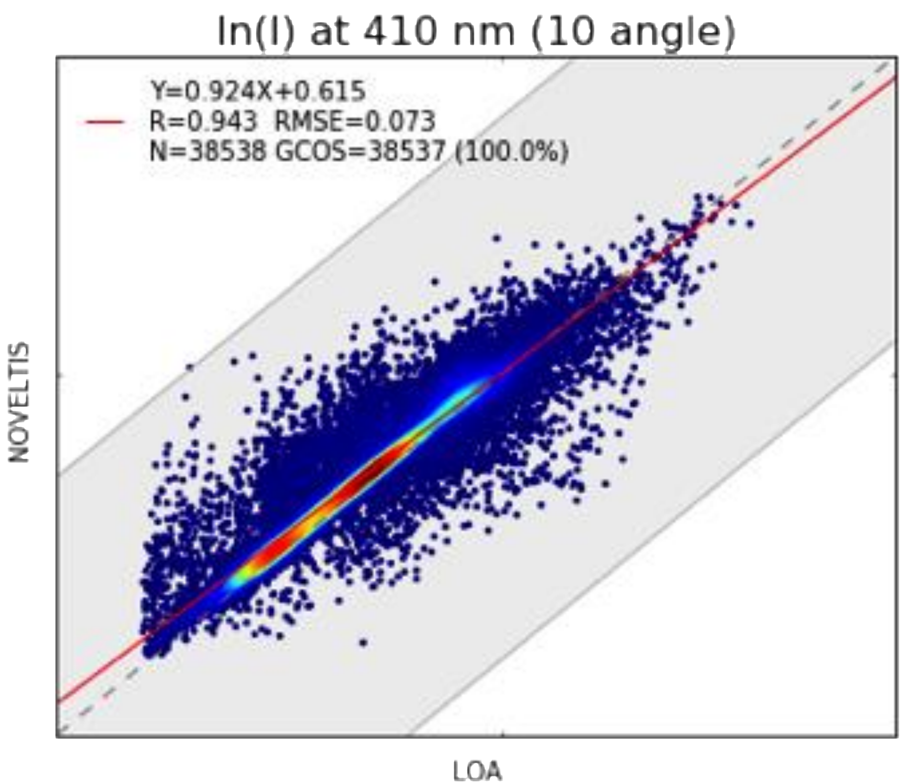
Comparison of "ideal" 1C Level data with 1C Level co-registered by NOVELTIS:

Radiances in logarithmic scale

RMSE= ~ 9%

RMSE= ~7%



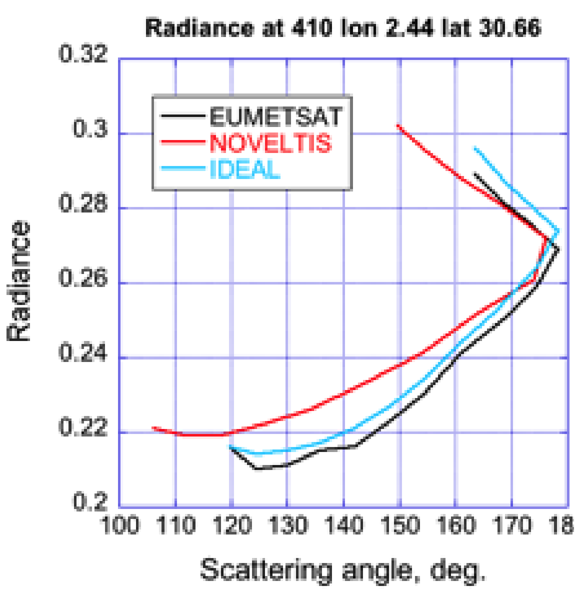


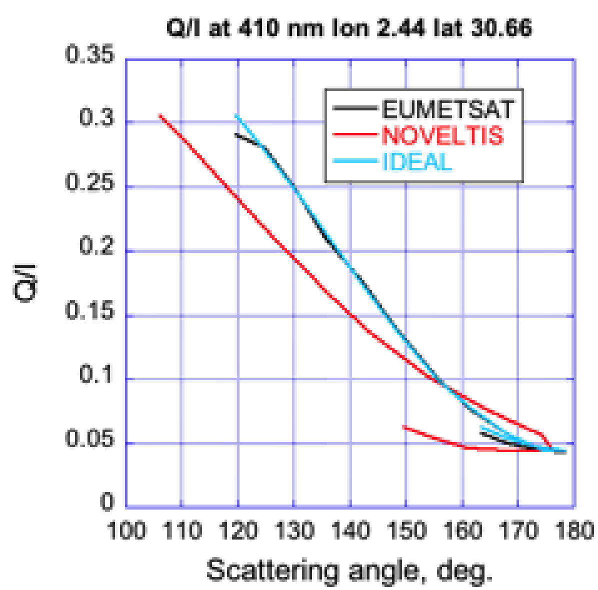
Comparison of "ideal" 1C Level data with 1C Level co-registered by NOVELTIS:

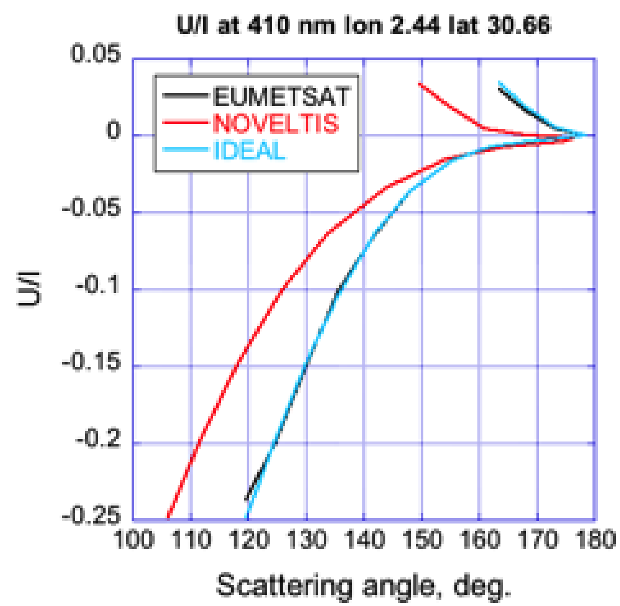
I (Θ, 410)

Q/I (Θ, 410)

U/I (Θ, 410)







Angles by NOVELTIS are very different

Number of iterations and fitting errors :

	niterations	residual_relative_noise0	residual_absolute_noise1
count	24676.000000	24676.000000	24676.000000
mean	9.612579	0.004609	0.002075
std	2.517298	0.002215	0.000958
min	2.000000	0.001853	0.001220
25%	8.000000	0.003538	0.001781
50%	9.000000	0.004310	0.001982
75%	11.000000	0.005167	0.002280
max	15.000000	0.193616	0.106666

« ideal » 1C data

	niterations	residual_relative_noise0	residual_absolute_noise1
count	24566.000000	24566.000000	24566.000000
mean	8.531588	0.010979	0.003538
std	2.158402	0.009434	0.002092
min	2.000000	0.003081	0.001425
25%	7.000000	0.005765	0.002590
50%	8.000000	0.007936	0.003238
75%	10.000000	0.012319	0.003901
max	15.000000	0.170211	0.077280

EUMETSAT co-registered

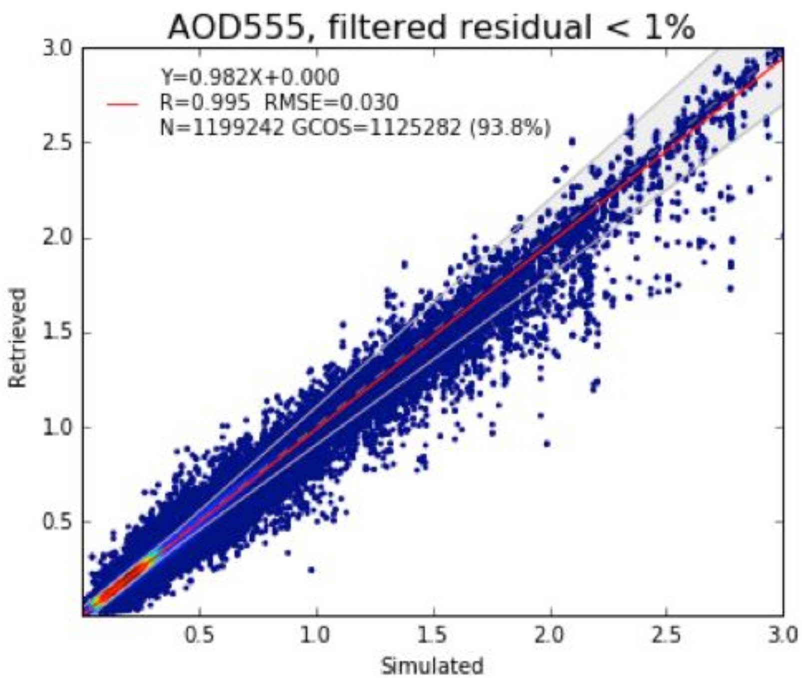
	niterations	residual_relative_noise0	residual_absolute_noise1
count	23500.000000	23500.000000	23500.000000
mean	4.609106	0.058414	0.032606
std	0.994501	0.023654	0.011453
min	2.000000	0.025642	0.014479
25%	4.000000	0.045986	0.027759
50%	4.000000	0.057813	0.032374
75%	5.000000	0.067326	0.035398
max	12.000000	0.421296	0.203867

NOVELTIS co-registered

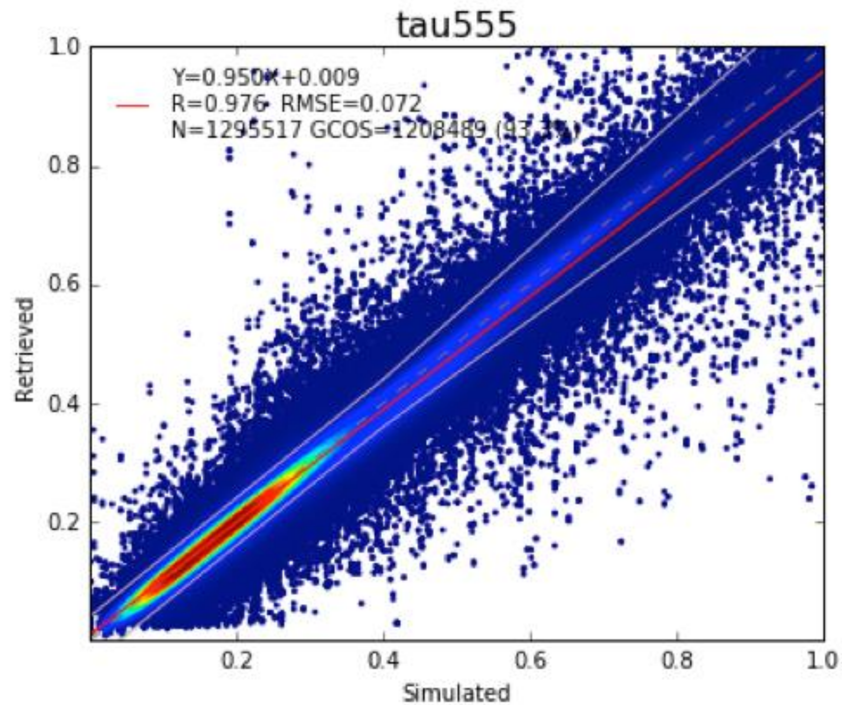
Inversion of the ”ideal” 1C Level data generated by GRASP-SAS:

Optimized

AOD(555) < 3, residual < 1%



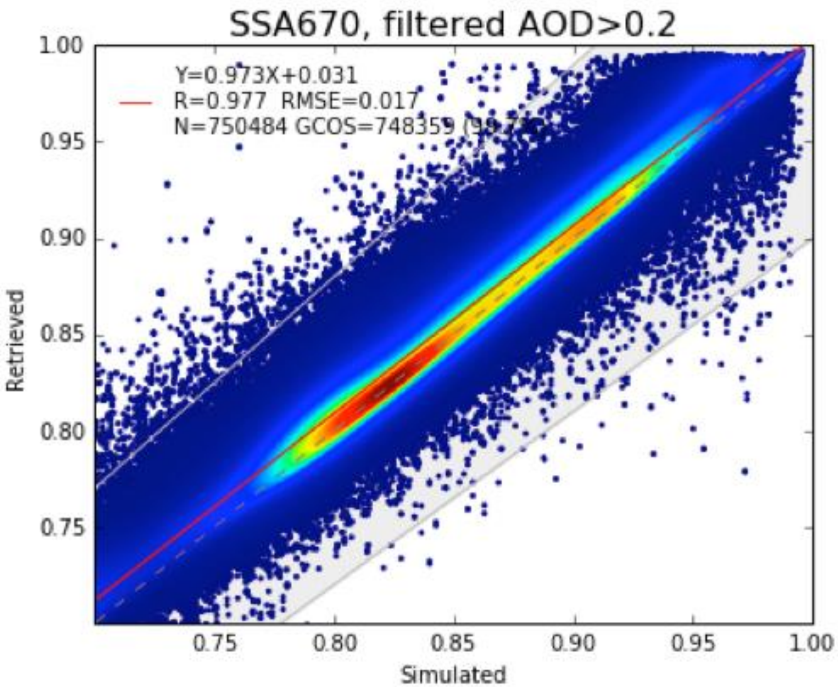
AOD(555) < 1, residual < 3%



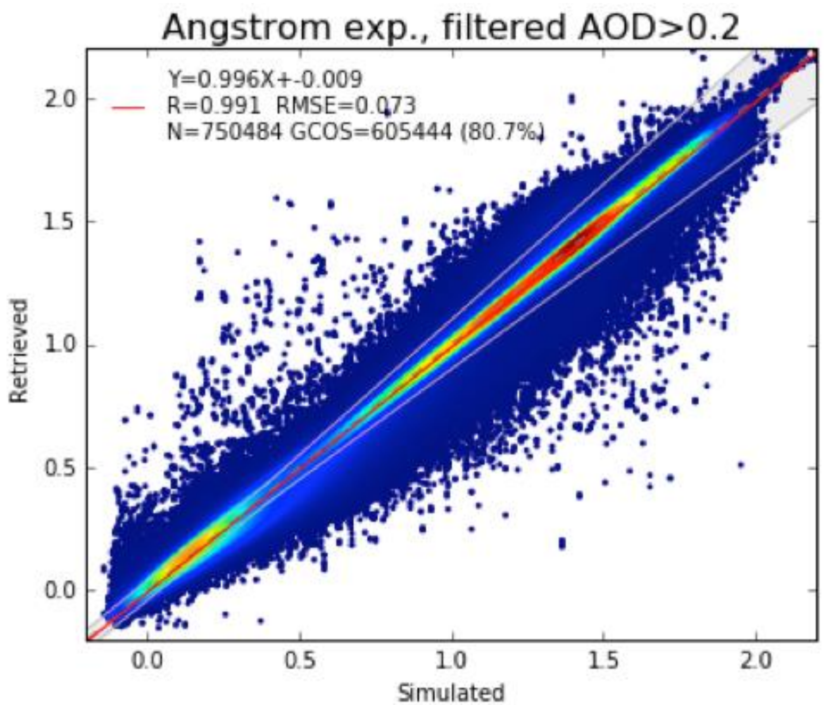
Inversion of the "ideal" 1C Level data generated by GRASP-SAS:

Optimized

SSA(670) for AOD(555) > 0.2



Angstrom for AOD(555) > 0.2

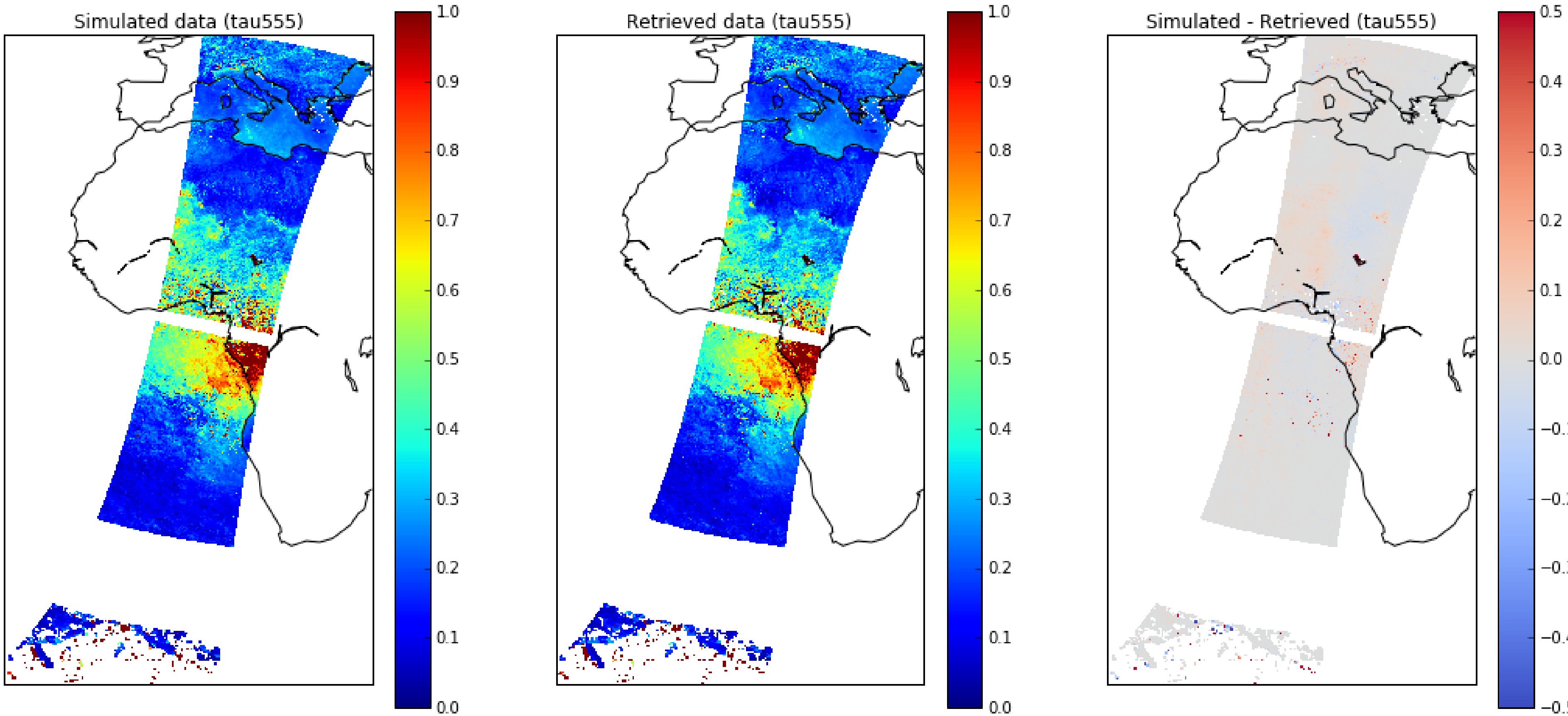


Inversion of the ”ideal” 1C Level data generated by GRASP-SAS:

Optimized

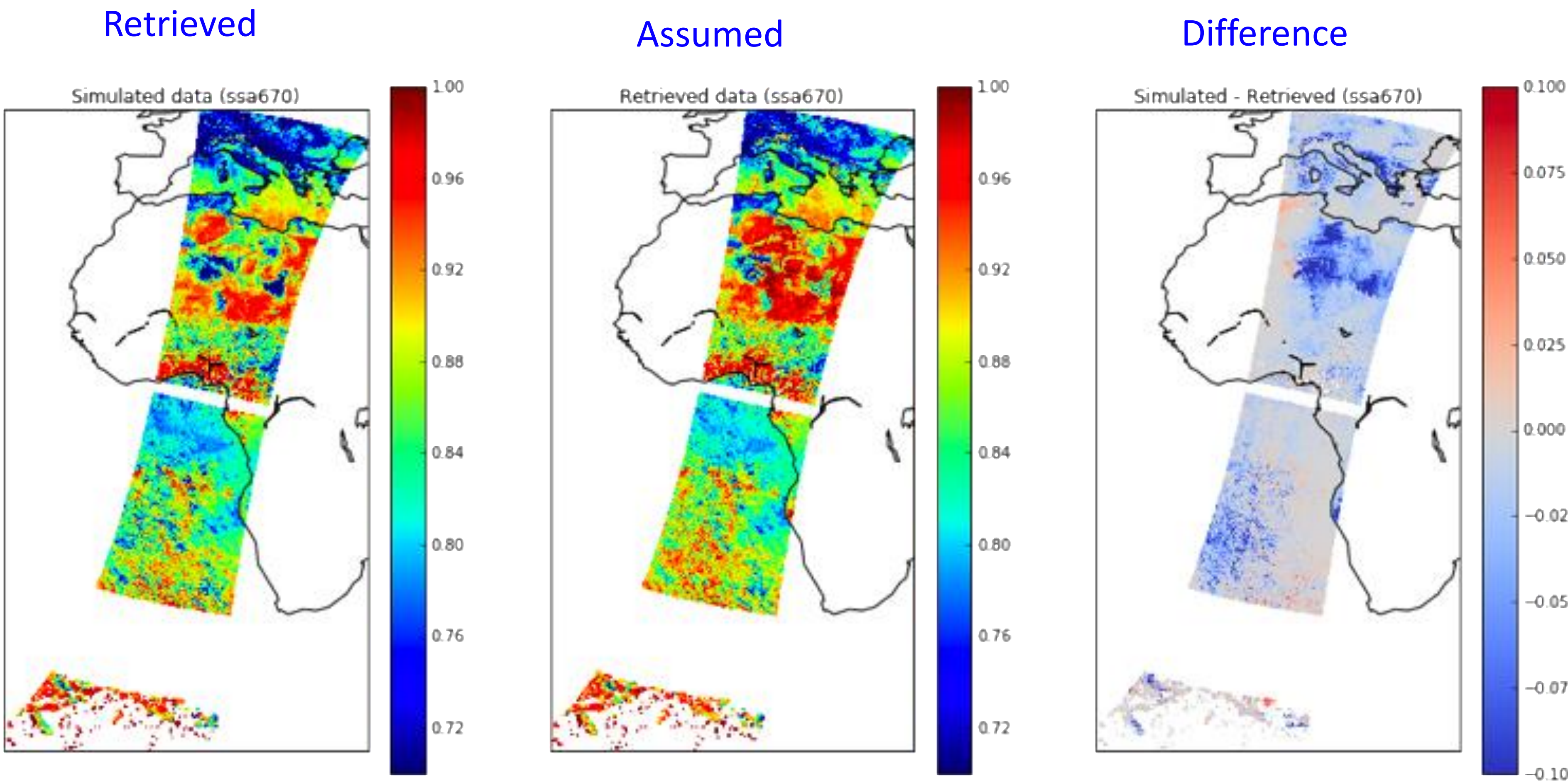
AOD (555)

Retrieved | Assumed | Difference



Inversion of the ”ideal” 1C Level data generated by GRASP-SAS:

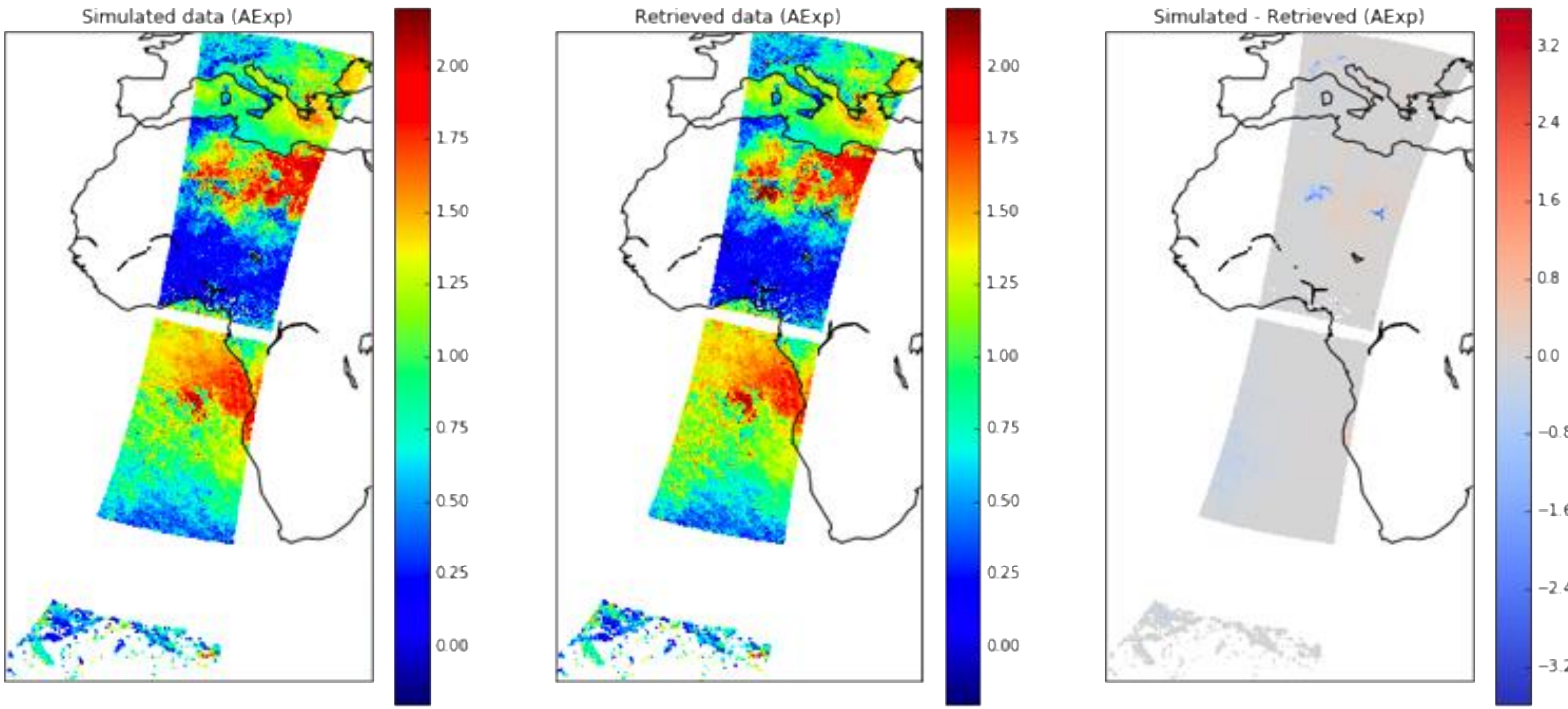
SSA (670) **Optimized**



Inversion of the "ideal" 1C Level data generated by GRASP-SAS:

Angstrom **Optimized**

Retrieved Assumed Difference



Project results/accomplishments:

Task-1: Set of aerosol models for LUT algorithms was reviewed corrected;

Task-2.1: Independent co-registration function was developed, and corresponding 3MI Level 1C were prepared and delivered;

Task-2.2: 3MI Level 1C proxy data based on PARASOL climatology were simulated were generated and delivered: 1 complete orbit + 3 months over selected AERONET sites.

Task-3: The performance of 3MI LUT algorithm was evaluated. Based on the results the development of LUT algorithm was stopped due to its immaturity.

Task-4: The enhanced NRT 3MI algorithm has been proposed

Task-5: The enhanced NRT Aerosol Retrieval Algorithm has been extensively tested for accuracy and speed. Recommendations have been made.

Task-6: The EUMETSAT Co-registration Function has been evaluated in two different ways:

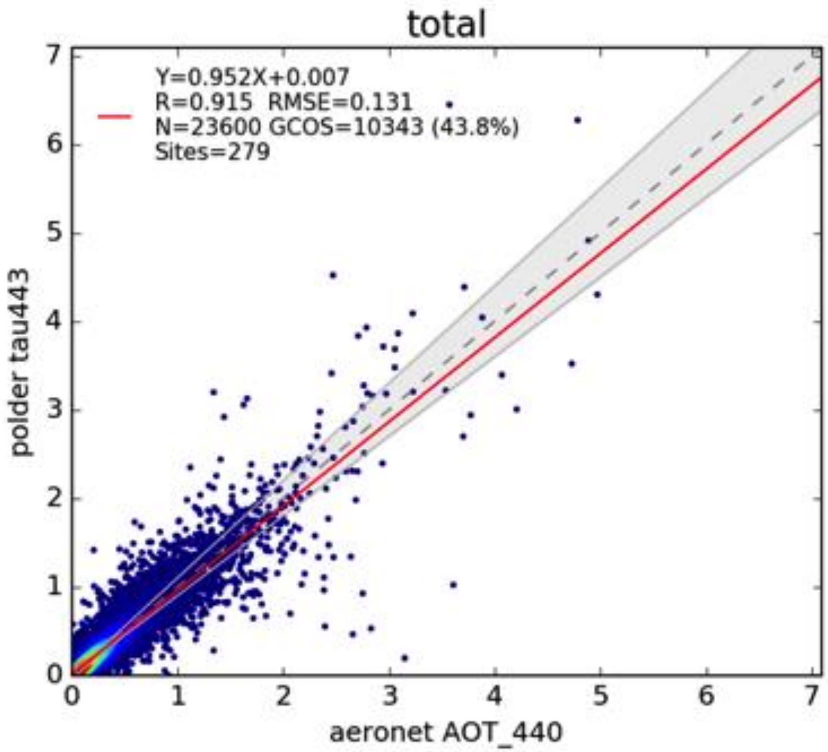
Task 6.1: Direct comparison with NOVELTIS co-registered data has been done;
Task 6. 2: The effect of co-registration errors on aerosol retrieval has been accessed;

GRASP NOVELTIS

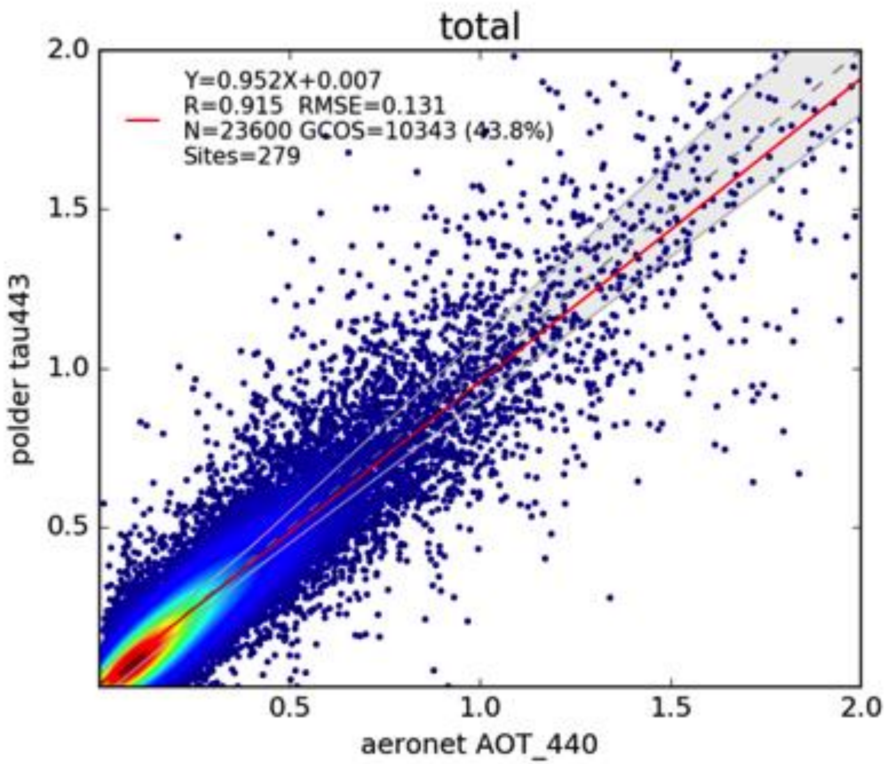
Inversion of real PARASOL data 2004 - 2013

Comparison with entire AERONET archive

AOD (443) < 7

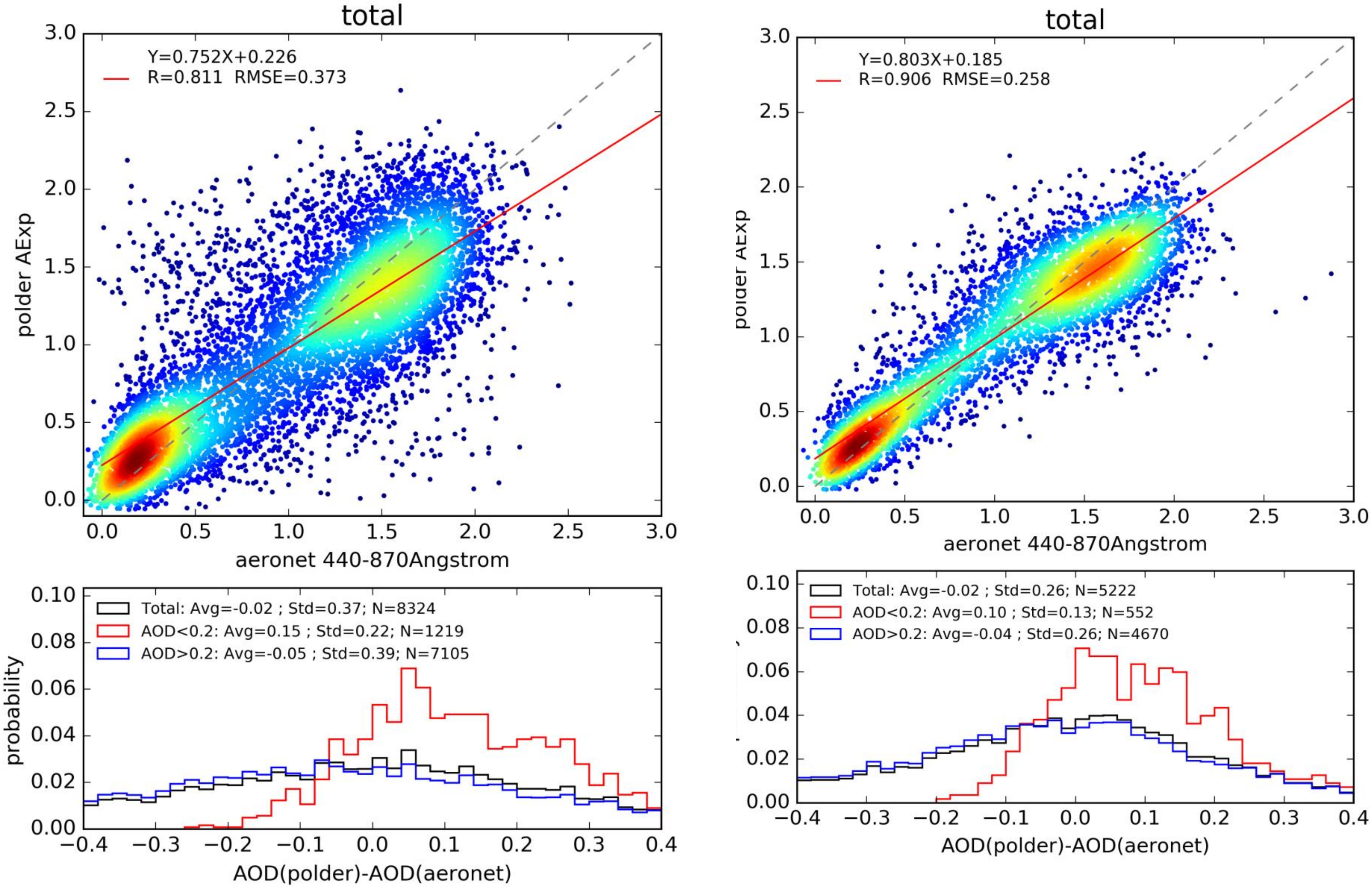


AOD (443) < 2



PARASOL Validation vs AERONET 2004 - 2013

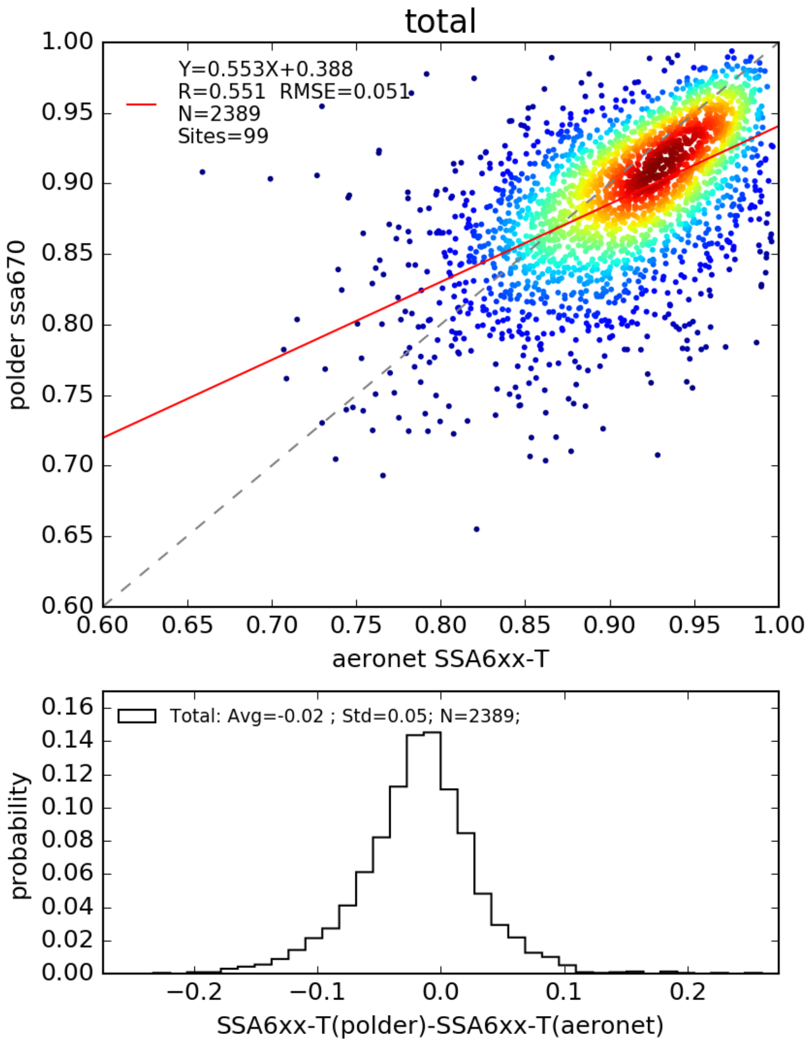
Ocean Angstrom



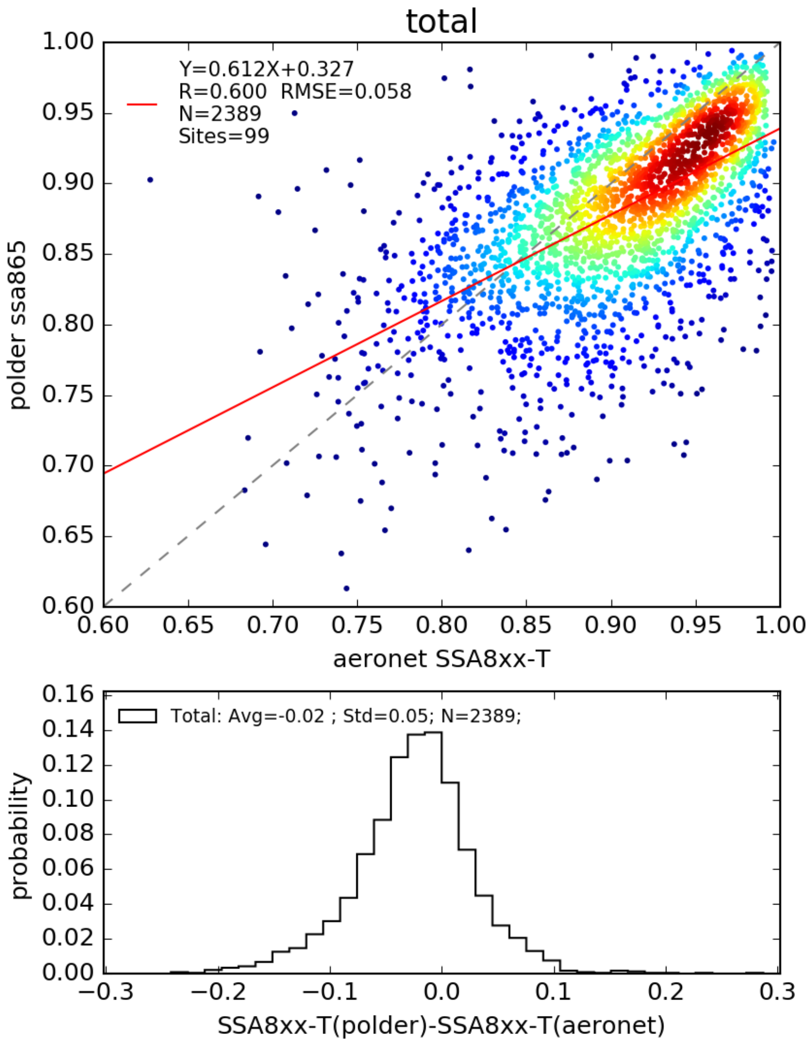
PARASOL Validation vs AERONET 2004 - 2013

Land + Ocean

SSA(670) R=0.55



SSA(870) R=0.6



Conclusions:

- ✓ Inversion of co-registered EMETSAT data :
  - retrieval results for AOD are acceptable ;
  - the results are expected to improve once inconsistencies between ideal simulations and GRASP are resolved;
- ✓ Inversion of co-registered NOVLETIS data :
  - retrieval results for AOD were questionable due to uncertainties in the given observational geometry;

Suggestions:

- ✓ Dedicated study could be desirable for proper evaluation of retrieval uncertainty:
  - inconsistencies need to be understood and addressed;
  - evaluation of full retrieval potential (for SSA, Angstrom, aerosol height, etc. requires using dedicated simulations;