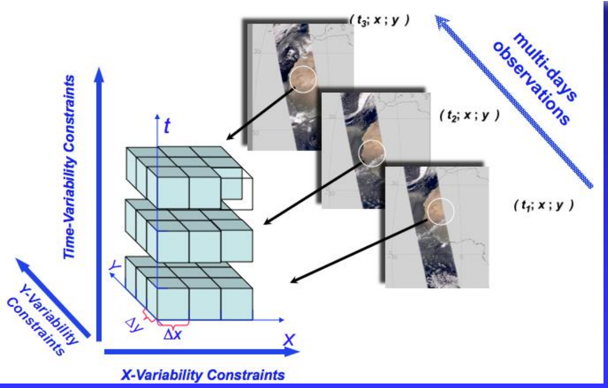
Aerosol retrieval using polarimetric observations: *THEORY and PRACTICE*

What users should expect from polarization?

O. Dubovik[1], P. Litvinov[1], D. Tanré[1], T. Lapyonok[1], A. Fedorenko[1], A. Lopatin[1], F. Ducos[1],
M. Spetsberger[2], A. Coman[2], W. Planer[2], C. Federspiel[2]

1- University of Lille 1, CNRS, France
2 - Catalysts GmbH, High Performance Computing, Linz, Austria



- ✓ Sensitivity of polarization to aerosol;
- ✓ Advantages and possible challenges;
- ✓ GRASP algorithm;
- ✓ PARASOL retrievals – reality, potential

ICAP working group meeting, 5-8 November, 2013, Tsukuba, Japan

Available measurements of polarization:

POLDER

GLOBAL: every 2 days SPATIAL RESOLUTION: 5.3km × 6.2km

VIEWS: $N_{\Theta} = 16$: $(80^0 \leq \Theta \leq 180^0)$

INTENSITY: $N^t_{\lambda} = 6$: *(0.44, 0.49, 0.56, 0.67, 0.865, 1.02 μm)*

POLARIZATION: $N^P_{\lambda} = 3$: *(0.49, 0.67, 0.865 μm)*

AERONET

New generation of Cimel multi-spectral polarimeters

VIEWS: $N_{\Theta} = \sim 30$: $(2^0 \leq \Theta \leq 150^0)$

INTENSITY + POLARIZATION:
$N_{\lambda} = 8$: (0.34, 0.38, 0.44, 0.50, 0.67, 0.87, 1.02, 1.64 μm)

lidar

Multi-spectral backscattering and depolarization profiles

VIEWS: $N_{\Theta} = 1$: $(\Theta = 180^0)$

INTENSITY backscattering profiles : $N^t_{\lambda} = \sim 3$: *(0.355, 0.532, 1.064 μm)*

DEPOLARIZATION profiles : $N^P_{\lambda} = 1$: *(0.532 μm)*

What polarization may add ?

SINDLE SCATTERING

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

OPTIMISTIC view

P_{11} *- characterizes* ***intensity****,*
P_{12} , P_{22} , P_{33} , P_{34} , P_{44} *- characterize state of* ***polarization***

⇩ ⇩ ⇩

add sensitivity to all aerosol properties (size, shape, absorption, refraction)

MULTIPLE SCATTERING

1.Polarization of land surface is very weak, spectrally neutral and quite homogeneous;

⇩ ⇩ ⇩

add sensitivity to aerosol over bright land surfaces

2. Molecular scattering strongly polarizes scatted light and it vertically very stable;

⇩ ⇩ ⇩

add sensitivity to aerosol vertical distribution (in passive observations)

Accounting for polarization in radiation transmitted through the atmospheric

$\mathbf{L}_1; \mathbf{L}_2$ - rotation matrices

Total:

$$\mathbf{I}(\Theta;\lambda)=\frac{\mu_0\left(\exp(-\mu_0\tau)-\exp(-\mu_1\tau)\right)}{\mu_0+\mu_1}\left(\omega_0\tau\,\mathbf{L}_2\mathbf{P}(\Theta;\lambda)\mathbf{L}_1\mathbf{I}_0+\mathit{mult.\ scat.}\right)$$

$$\mathbf{I}=\begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix}$$

- **Stokes vector**

$$\mathbf{F}(\Theta;\lambda)=\begin{bmatrix} \mathbf{F}_{11} & \mathbf{F}_{12} & 0 & 0 \\ \mathbf{F}_{12} & \mathbf{F}_{22} & 0 & 0 \\ 0 & 0 & \mathbf{F}_{33} & \mathbf{F}_{34} \\ 0 & 0 & -\mathbf{F}_{34} & \mathbf{F}_{44} \end{bmatrix}$$

phase matrix !!!

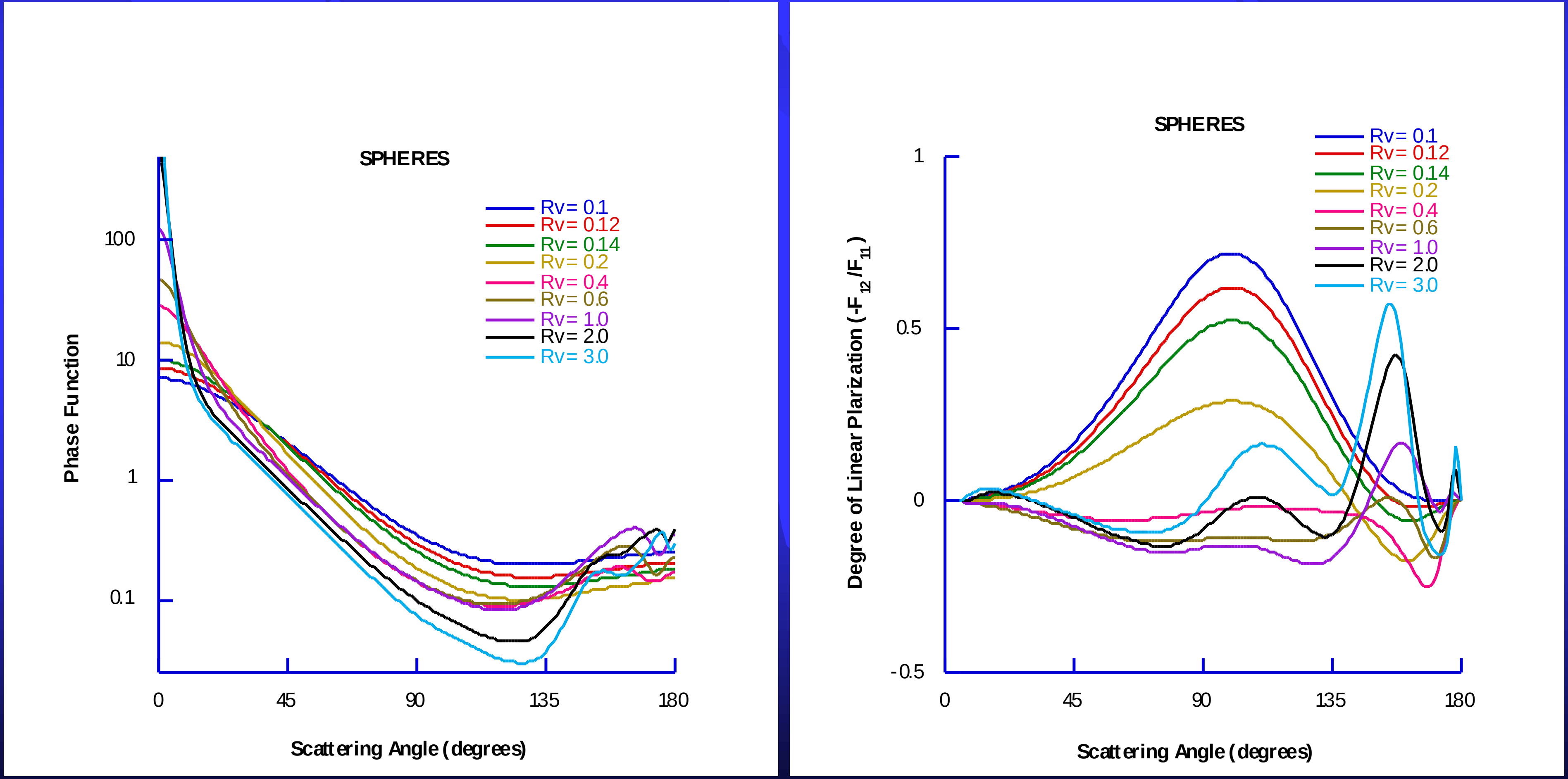
$$\mathbf{I}_0=\begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$I(\Theta;\lambda)\sim\left(\omega_0\tau\,\mathbf{F}_{1\,1}(\Theta;\lambda)+\mathit{mult.\ scat.}\right)$$ - Intensity

$$P(\Theta;\lambda)\sim\left(-\,\mathbf{F}_{1\,2}(\Theta;\lambda)/\mathbf{F}_{1\,1}(\Theta;\lambda)+\mathit{mult.\ scat.}\right)$$ -Linear Polarization

Sensitivity of to particle size

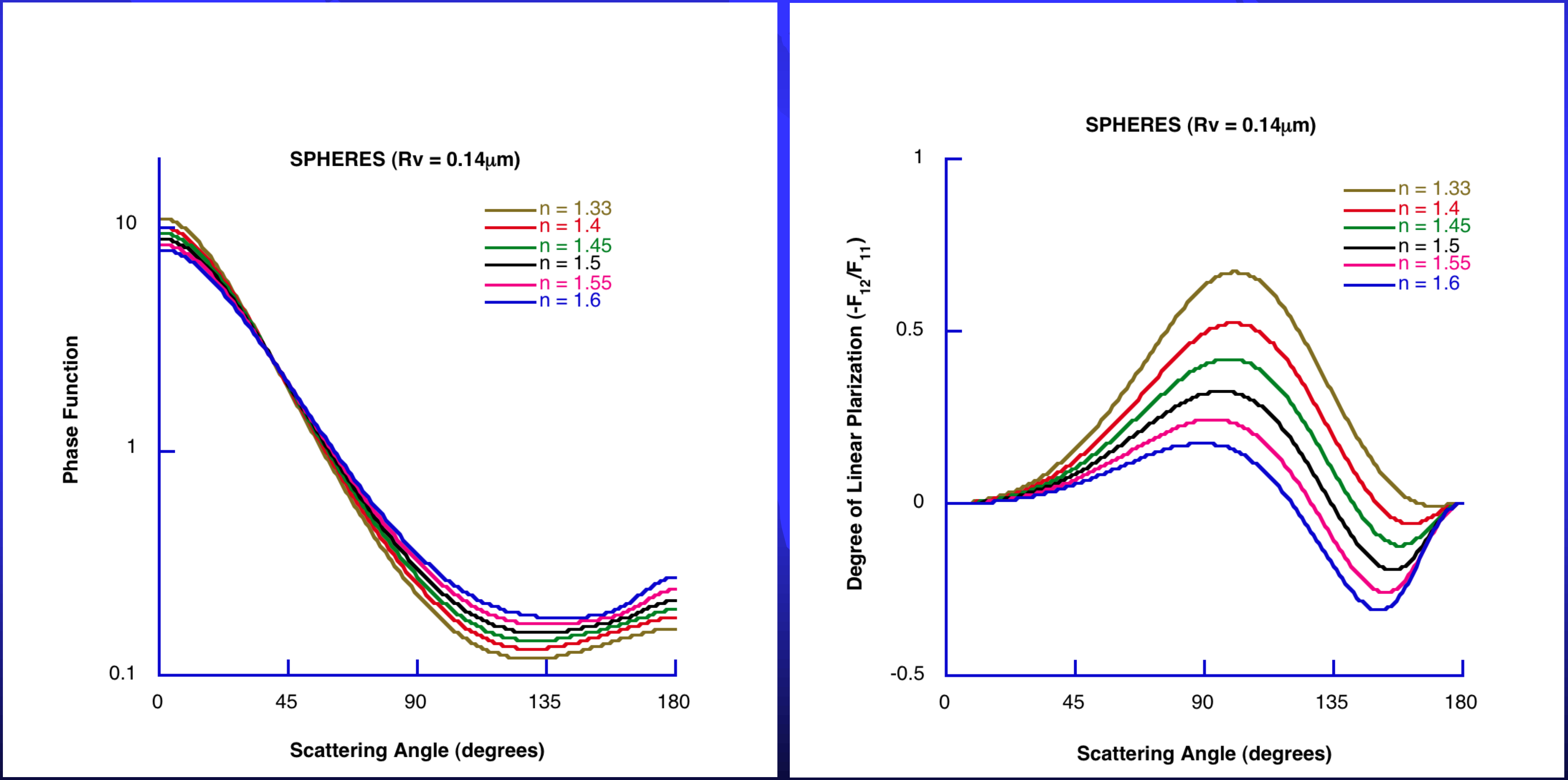
Log-normal monomodal dV(r)/dlnr : $\sigma_v = 0.5$, $\mu = 0.44\ \mu m$, n = 1.4, k = 0.005



Sensitivity to real part of refractive index for fine mode aerosol

Spheres

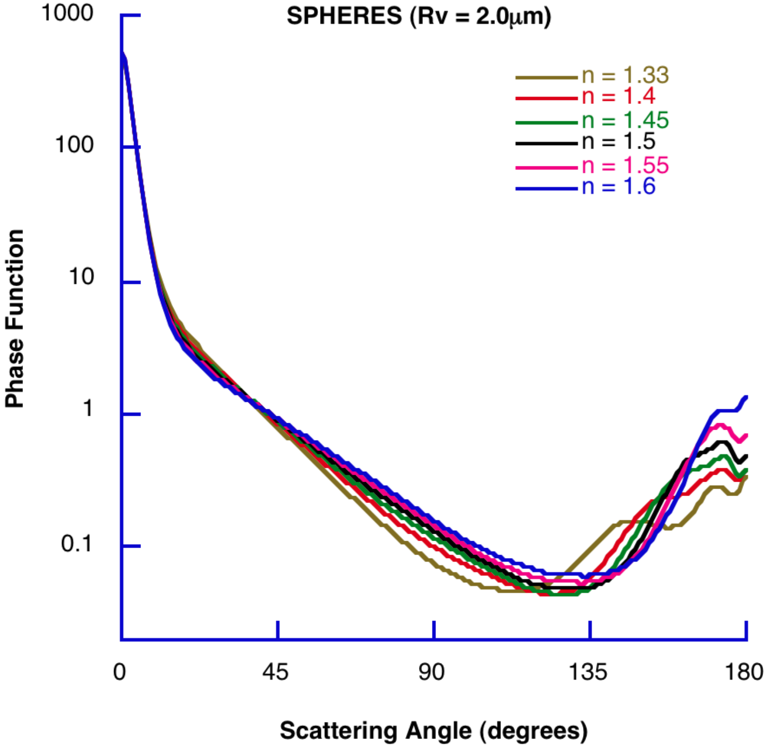
Log-normal monomodal dV(r)/dlnr : σ_v = 0.5, μ = 0.44 μm, k = 0.005

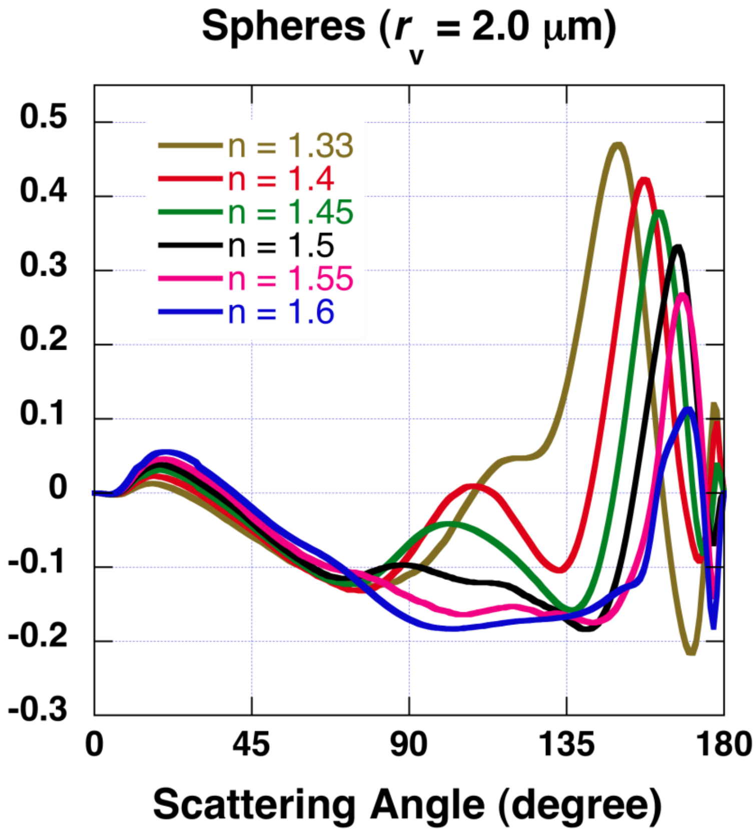


Sensitivity to to real part of refractive index for coarse mode aerosol

Spheres

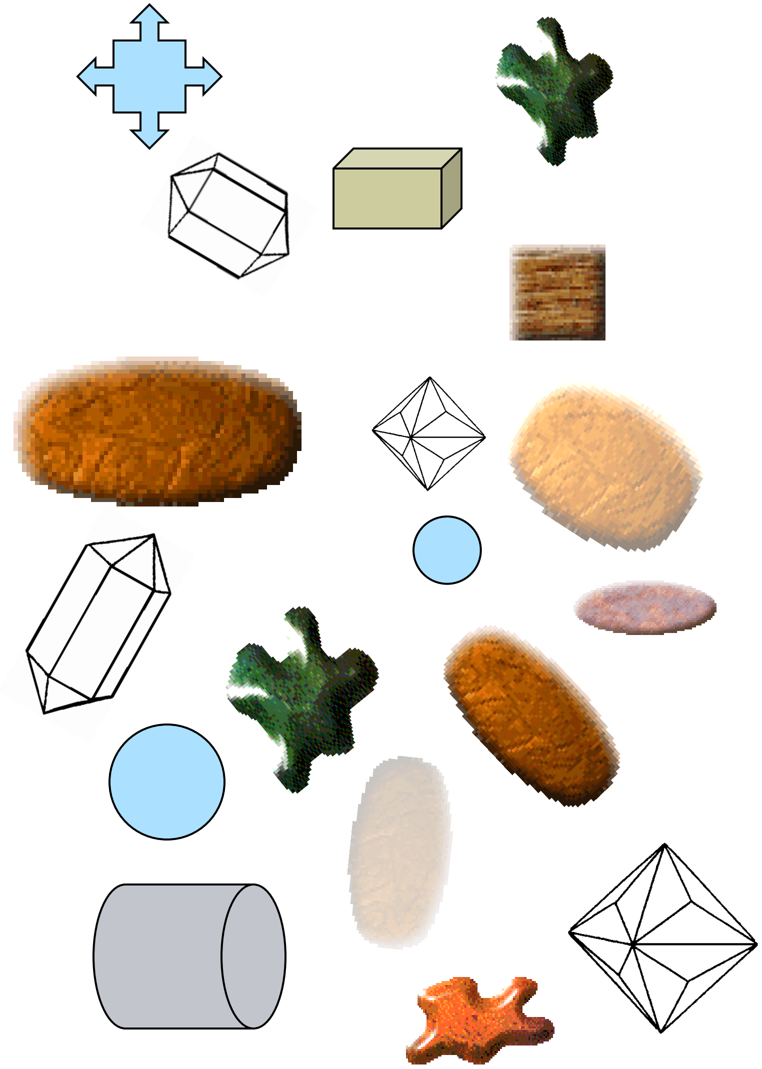
Log-normal monomodal dV(r)/dlnr : $\sigma_v = 0.5$, $\mu = 0.44\ \mu m$, $k = 0.005$

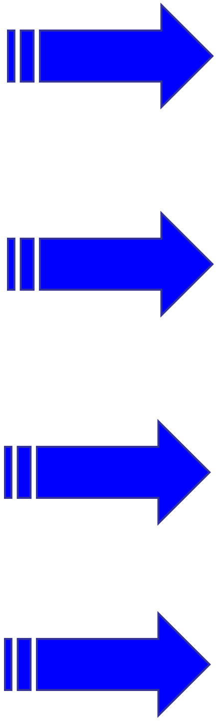

SPHERES (Rv = 2.0μm)


Spheres (r_v = 2.0 μm)

aerosol

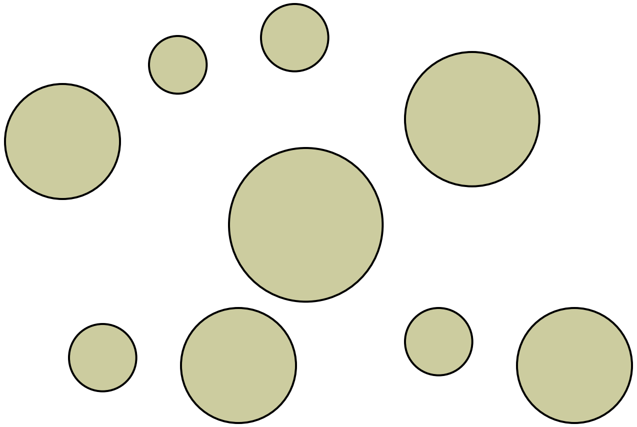
Real





Modeled

spherical:

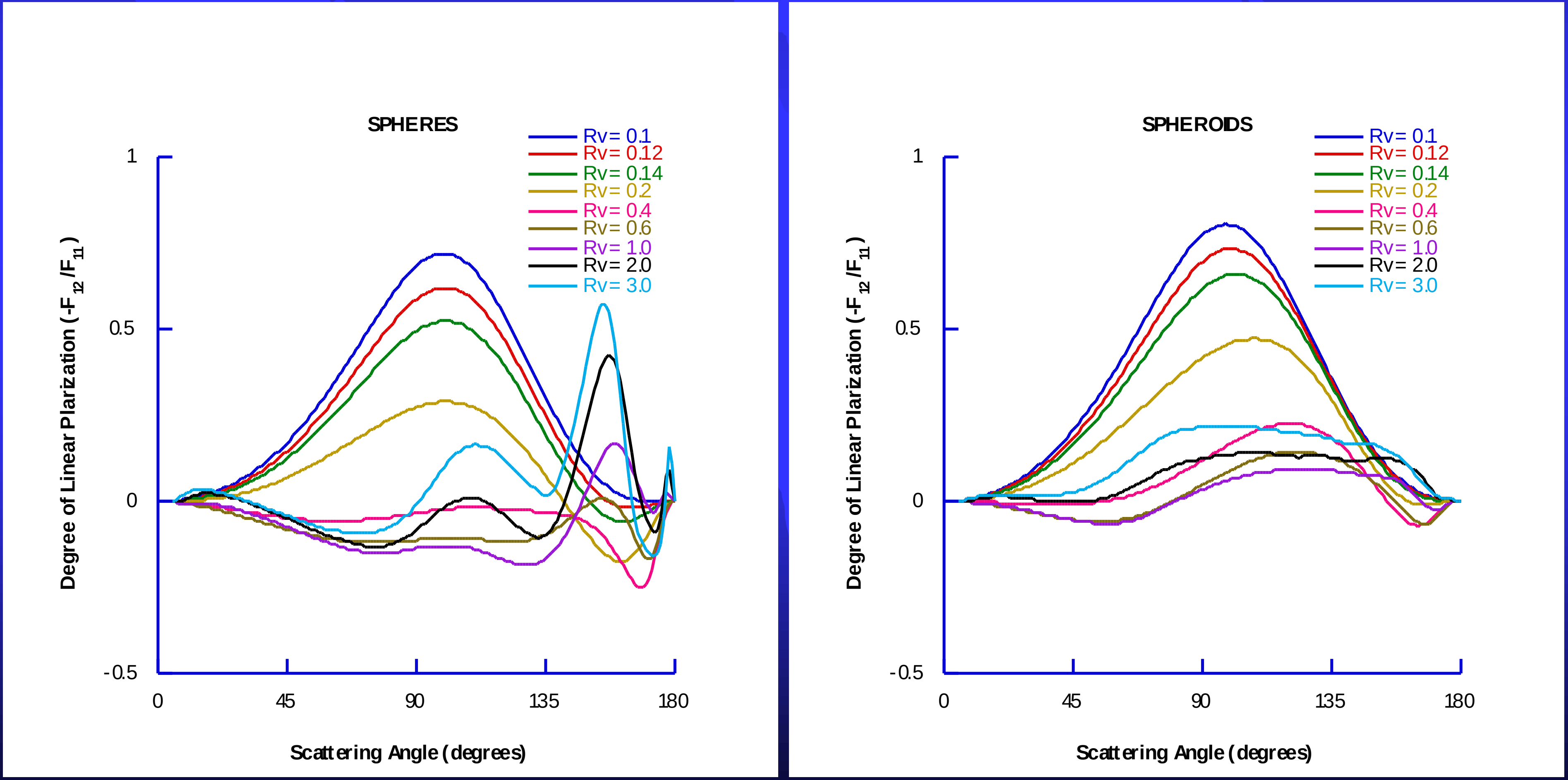


Randomly oriented spheroids :

AERONET model

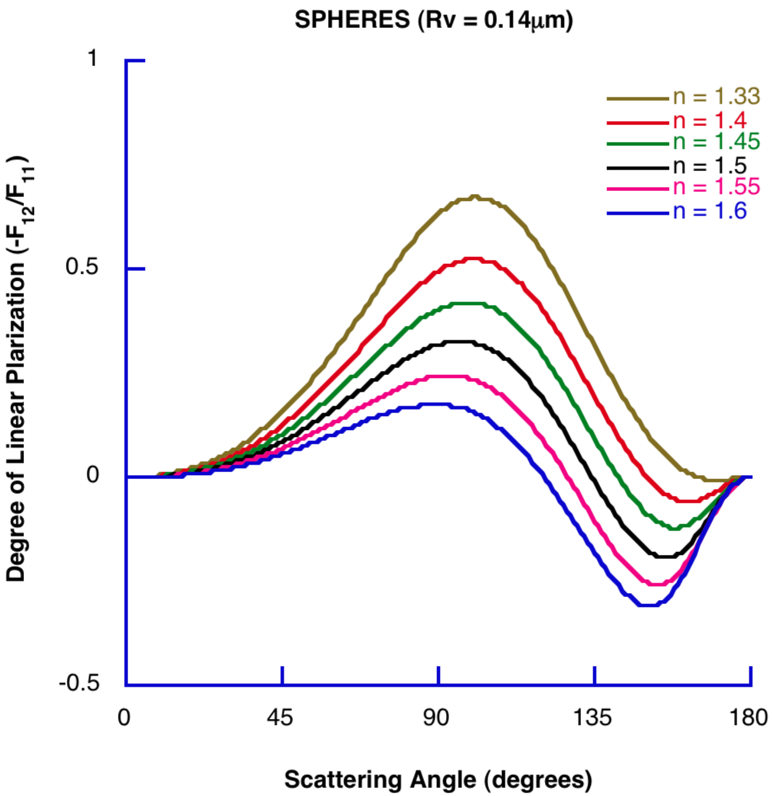
Sensitivity of Linear Polarization to particle size

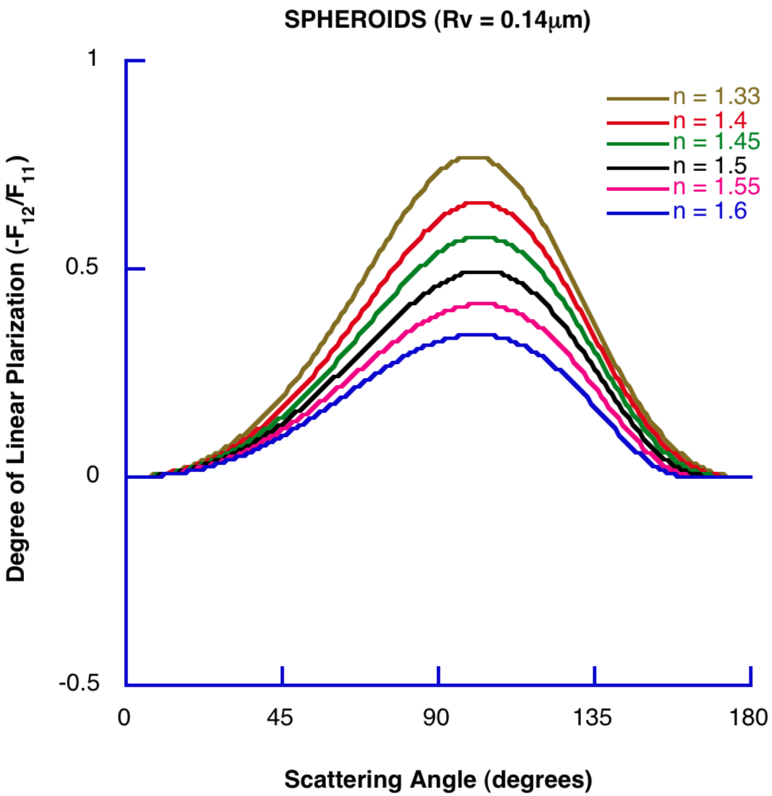
Log-normal monomodal dV(r)/dlnr : $\sigma_v = 0.5$, $\mu = 0.44\ \mu m$, n = 1.4, k = 0.005



Sensitivity of Linear Polarization of fine mode aerosol to real part of refractive index

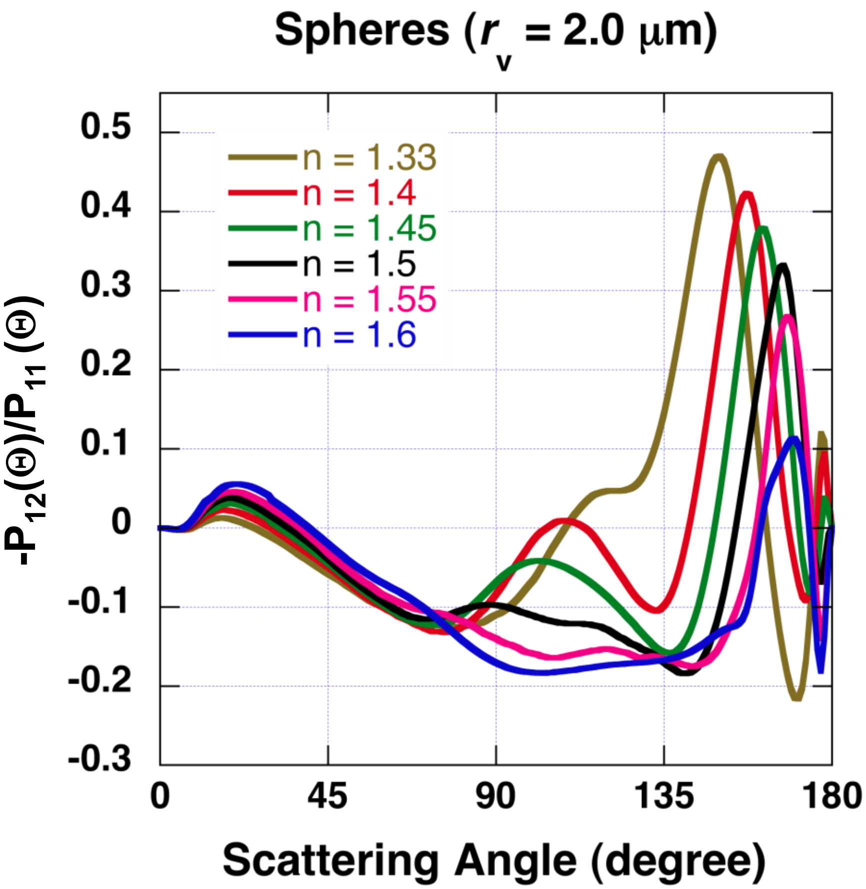
Log-normal monomodal dV(r)/dlnr : σ_v = 0.5, μ = 0.44 μm, k = 0.005

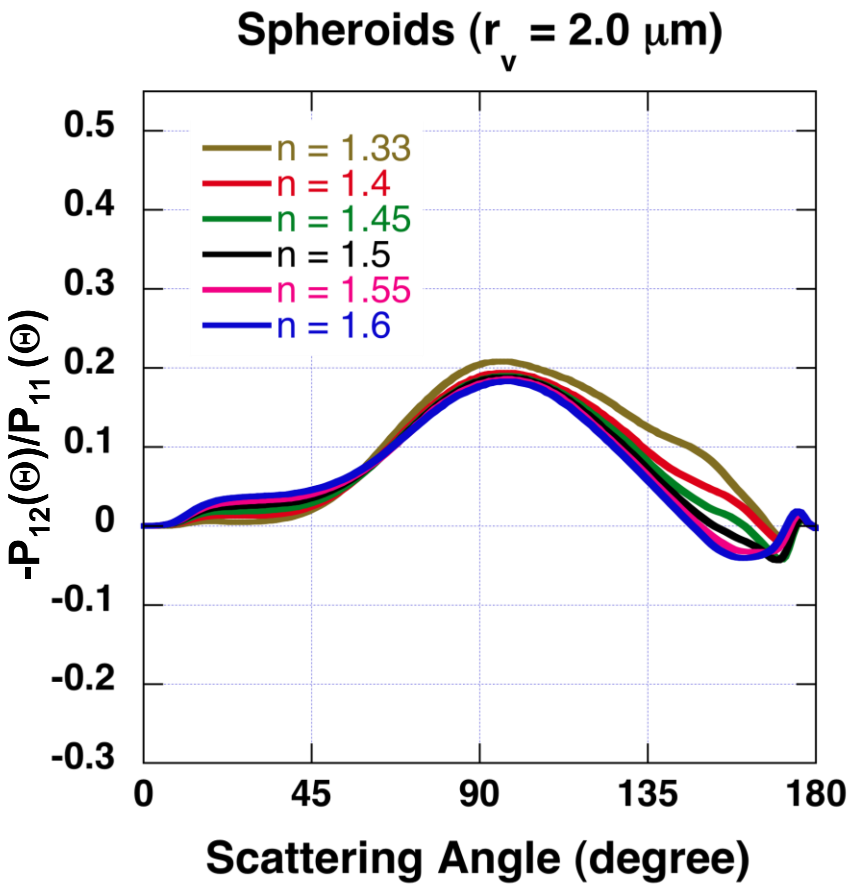




Sensitivity of polarization to particle shape

Coarse aerosol


Spheres (r_v = 2.0 μm)


Spheroids (r_v = 2.0 μm)

What polarization may add ?

SINDLE SCATTERING

REALISTIC view

P_{12} *- important for passive observation of **polarization***

add sensitivity to

- particle shape and

- size distribution and real ref. index of small and large spherical particles

COMPLICATIONS:

particles can be inhomogeneous, and have very complex shape

MULTIPLE SCATTERING

1.Polarization of land surface is very weak, spectrally neutral and quite homogeneous;

add sensitivity to aerosol over bright land surfaces

COMPLICATIONS: accurate modeling of surface polarization is complicated

2. Molecular scattering strongly polarizes scatted light and it vertically very stable;

add sensitivity to aerosol vertical distribution (in passive observations)

COMPLICATIONS: accurate assumption of aerosol vertical properties is complicated

“independent” POLDER/PARASOL measurements :

GLOBAL: every 2 days SPATIAL RESOLUTION: 5.3km × 6.2km

VIEWS: $N_{\Theta} = 16$: $(80^0 \leq \Theta \leq 180^0)$

INTENSITY: $N^t_{\lambda} = 6$: *(0.44, 0.49, 0.56, 0.67, 0.865, 1.02 μm)*

POLARIZATION: $N^P_{\lambda} = 3$: *(0.49, 0.67, 0.865 μm)*

<u>SINGLE OBSERVATION:</u>

a lot !!! – as much as AERONET

$$(N^t_{\lambda} + N^P_{\lambda}) \times N_{\Theta} = (6+3) \times 16 = 144$$

Present aerosol retrieval from PARASOL:

Over Ocean (Herman et al., 2005):

- *Uses look-up tables*

- *Fits both intensity and polarizations at 0.67 and 0.87 μm*

-*Retrieves:* AOT of fine and coarse mode, size information, non-sphericity, some height information.

-*Issues: does not always provide consistency with other channels*

Over Land (Deuzé et al., 2001):

- *Uses look-up tables*

- *Fits only polarizations at 0.67 and 0.87 μm using look-up tables*

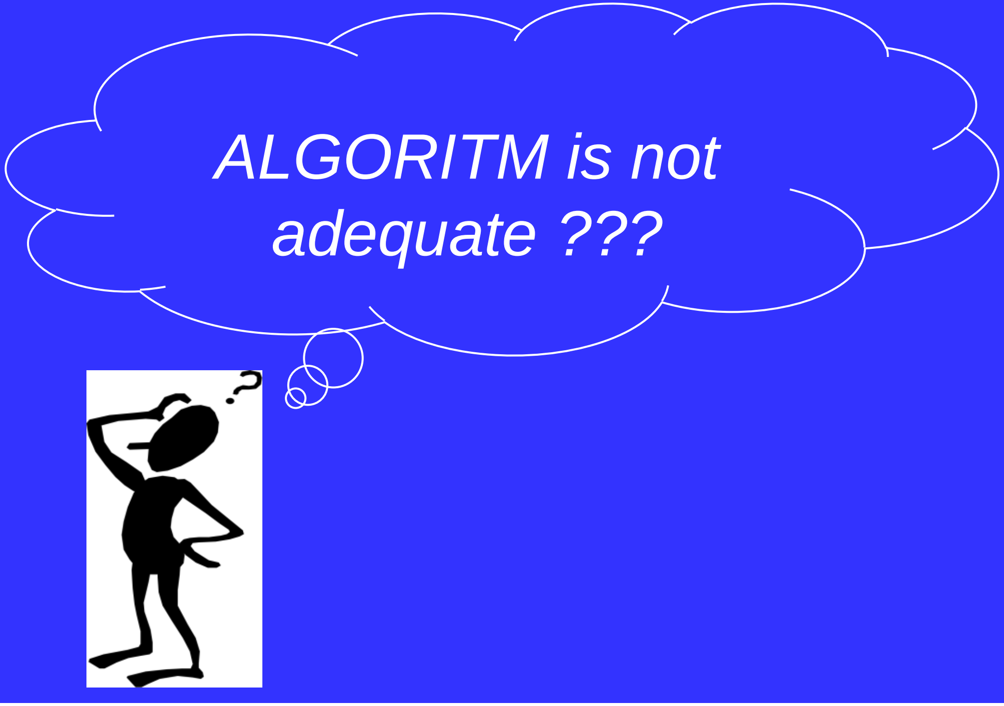
- *Retrieves:*

AOT of fine mode only , some size information

- *Issues: quite limited*

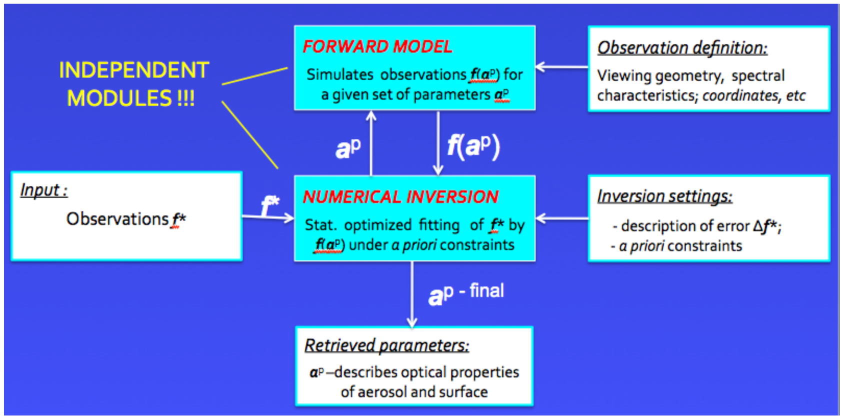
QUESTION:

Why the PARASOL (2004 - …) polarimeter data did not result in a great aerosol product until now?



ALGORITM is not adequate ???

GRASP objectives:
Accurate, Versetile and Fast



INDEPENDENT MODULES !!!

FORWARD MODEL
Simulates observations $f(a^p)$ for a given set of parameters a^p

Observation definition:
Viewing geometry, spectral characteristics; *coordinates, etc*

a^p

$f(a^p)$

Input :
Observations f^*

f^*

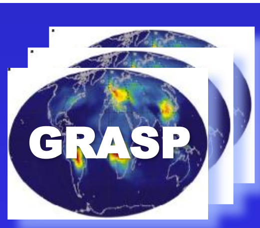
NUMERICAL INVERSION
Stat. optimized fitting of f^* by $f(a^p)$ under *a priori* constraints

Inversion settings:
- description of error Δf^*;
- *a priori* constraints

a^p - final

Retrieved parameters:
a^p –describes optical properties of aerosol and surface

✓ Inversion scheme:
- search in continues space of solution;
- optimization as Multi-term LSM;
- simultaneous multi-pixel retrieval;



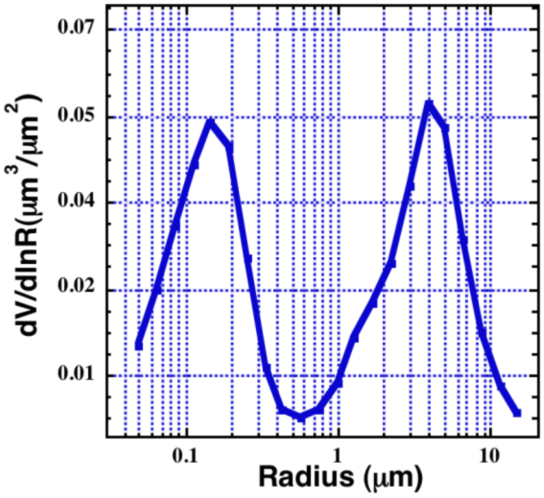
✓ Forward model:
- applicable to diverse remote sensing observations;
- accurate modeling using direct “on-line” computations;

✓ Software implementation:
- advanced highly parralized CPU and GPU programinng;
- public, open source aerosol retrieval code; _

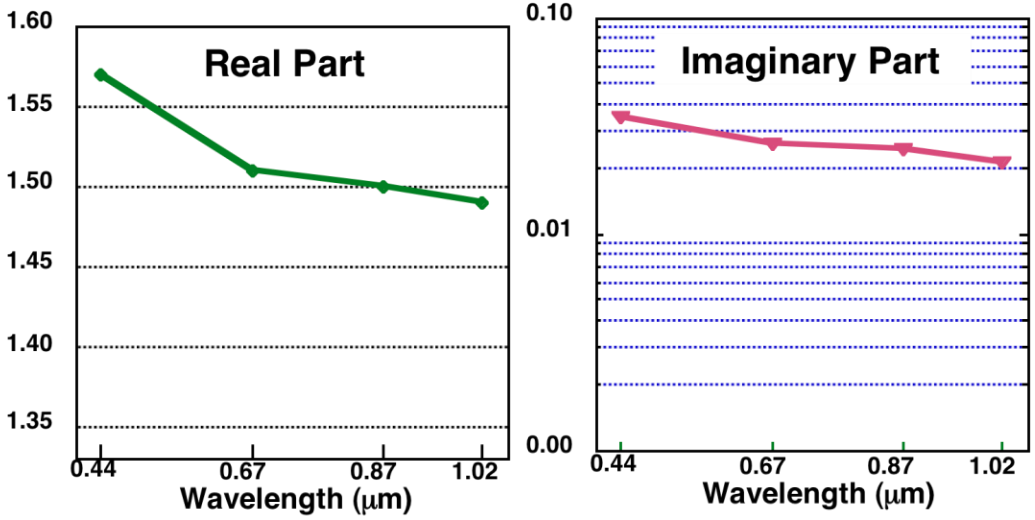
AERONET retrievals are driven by 31 variables : PARASOL: + surface BRDF+ aerosol height

dV/lnr - size distribution (22 values);
n(λ) and k(λ) - ref. index (4 +4 values)
C_{spher} (%) - spherical fraction (1 value)

Particle Size Distribution:
0.05 μm ≤ R (22 bins) ≤ 15 μm



Complex Refractive Index at
λ = 0.44; 0.67; 0.87; 1.02 μm



Forward Model

GRASP

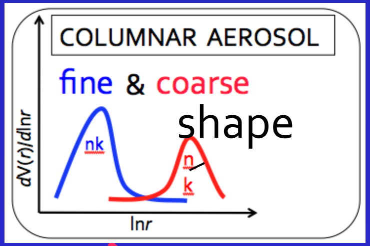
Vector of retrieved parameters :

a^{aer} *- aerosol properties*

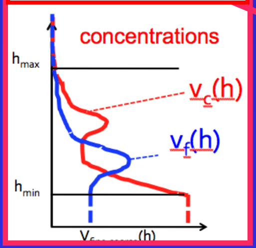
a^{surf} *- surface properties*

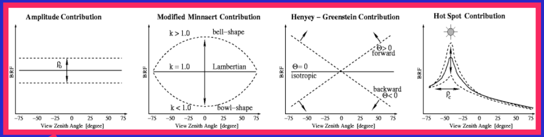
a^{aer}

a^{surf}



Vertical distribution





Aerosol single scattering

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

Surface reflectance

BRDF

BPDF

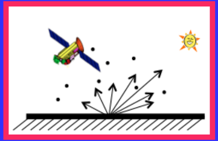
Multiple scattering effects

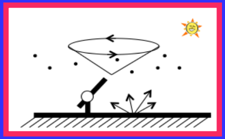
Radiative Transfer:

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

All calculations are on line !!!

Simulated observations:





statistically Optimized Minimization – Multi-Term LSM

Dubovik and King 2000, Dubovik 2004, Dubovik et a. 2011

Measurements:

***A priori** restrictions*

consistency Indicator

$$\sum_{(\lambda,\theta)_i} \frac{\varepsilon_0^2}{\varepsilon_i^2}\left(f_i^* - f_i(\mathbf{x})\right)^2 + \sum_i \frac{\varepsilon_0^2}{\varepsilon_i^2}\left(f_i^a - f_i(\mathbf{x})\right)^2 \to (\mathrm{N}_{\mathrm{total}} - \mathrm{N}_{\mathrm{x}})\hat{\varepsilon}_0^2$$

weighting

***Lagrange** multipliers*

***Radiances** (ground/plane/space);*

- ***Pol. radiances** (ground/plane/space);*
- ***$\tau(\lambda)$** – (e.g. AERONET);*
- ***$\beta(\lambda,h)$** □**lidar backscattering;***

-their covariances

(should depend on λ and Θ)

-lognormal error distributions

Restrictions on derivatives of:

- ***size distr.** **Variability;***
- ***n** **spectral variability;***
- ***k** **spectral variability;***

AERONET

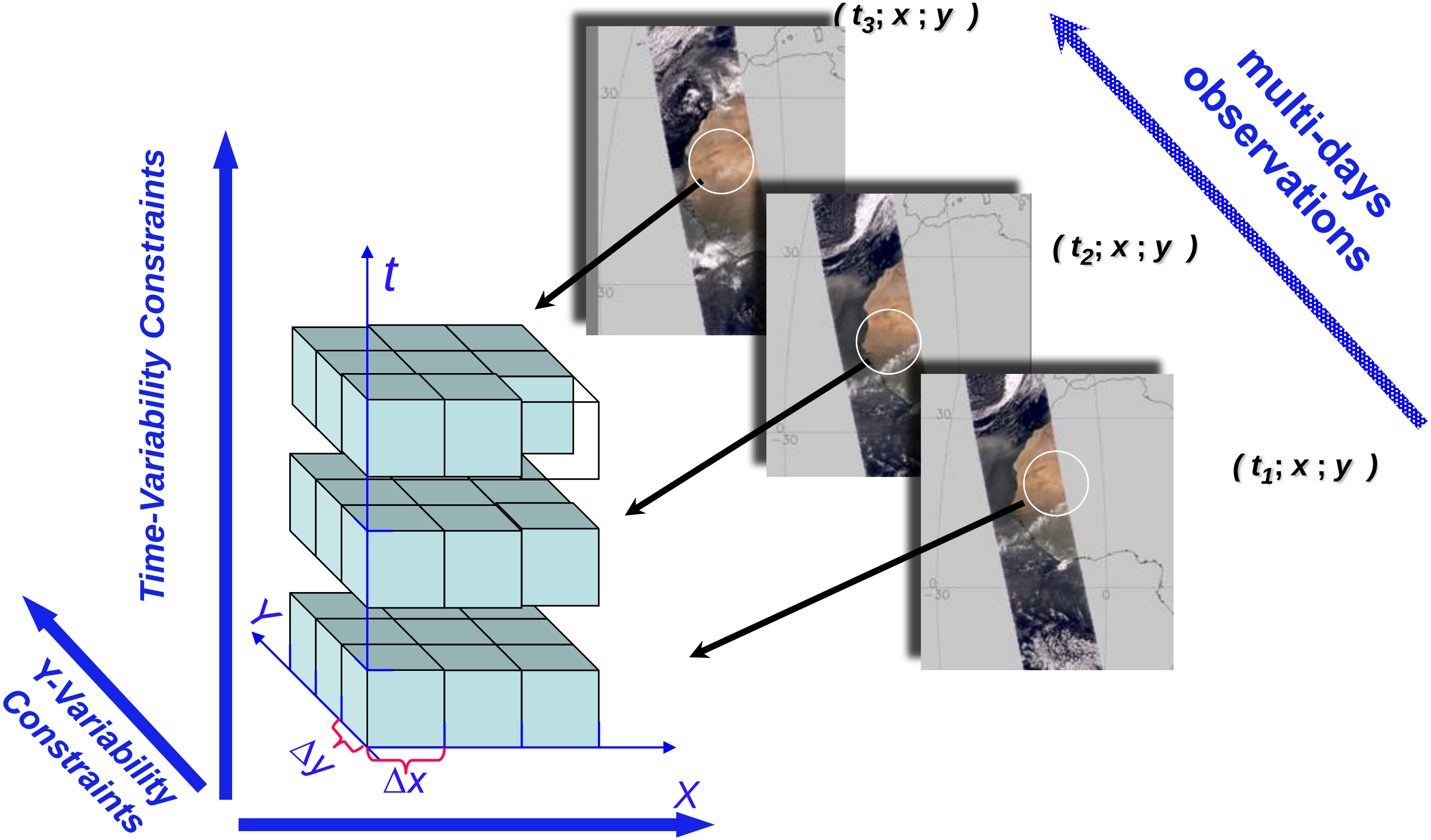
- BRDF and BPDF ***spectral variability;***
- ***C(h)*** ***vertical variability;***

Lidar

Surface

The concept of multi-pixel retrieval

POLDER/PARASOL



$(t_3; x; y)$

$(t_2; x; y)$

$(t_1; x; y)$

multi-days observations

Time-Variability Constraints

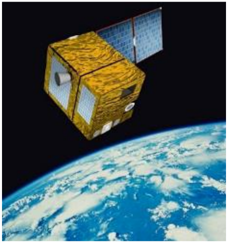
Y-Variability Constraints

X-Variability Constraints

GRASP: Generalized Retrieval of Aerosol and Surface Properties

AERONET

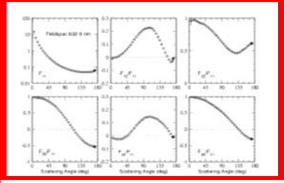
POLDER



lidar

AERONET

laboratory

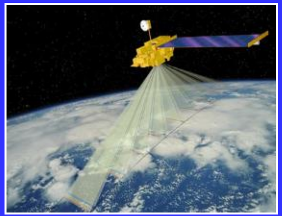


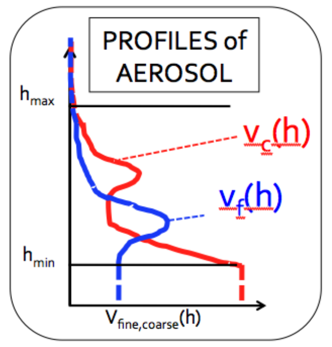
single scattering

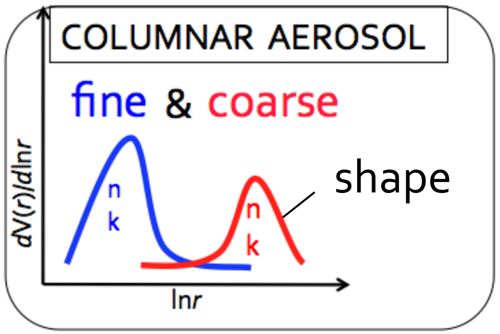
GRASP

???

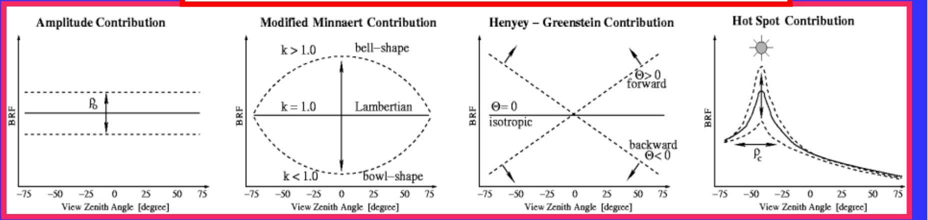
MISR





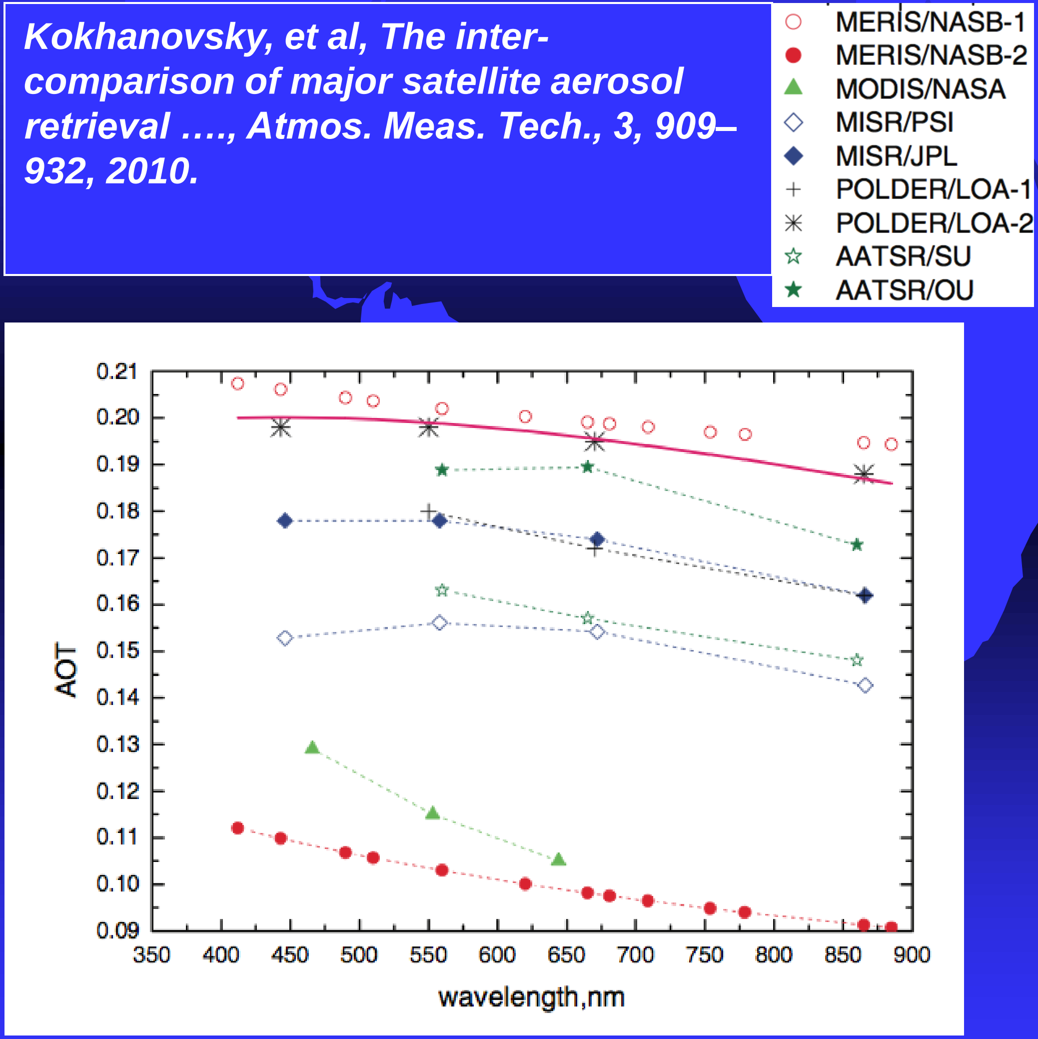


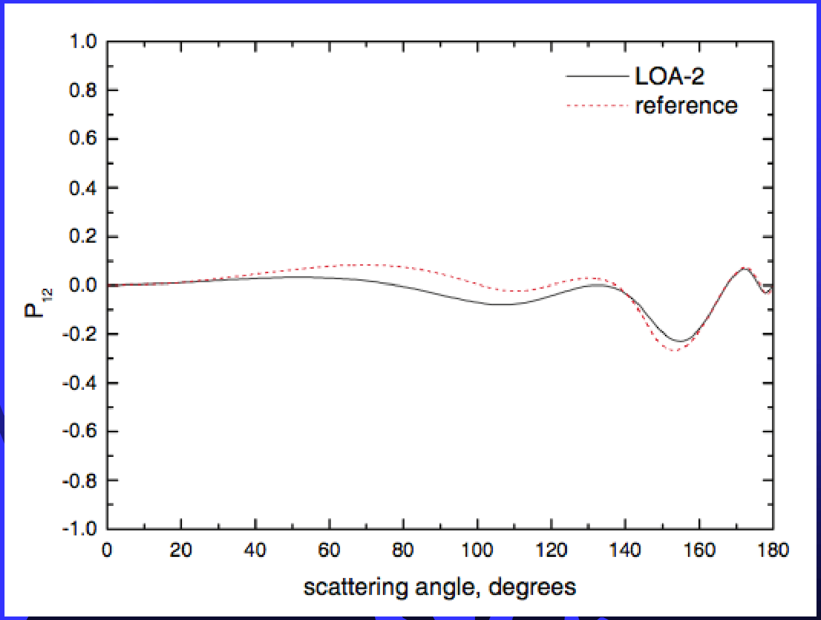
Surface BRDF, BPDF

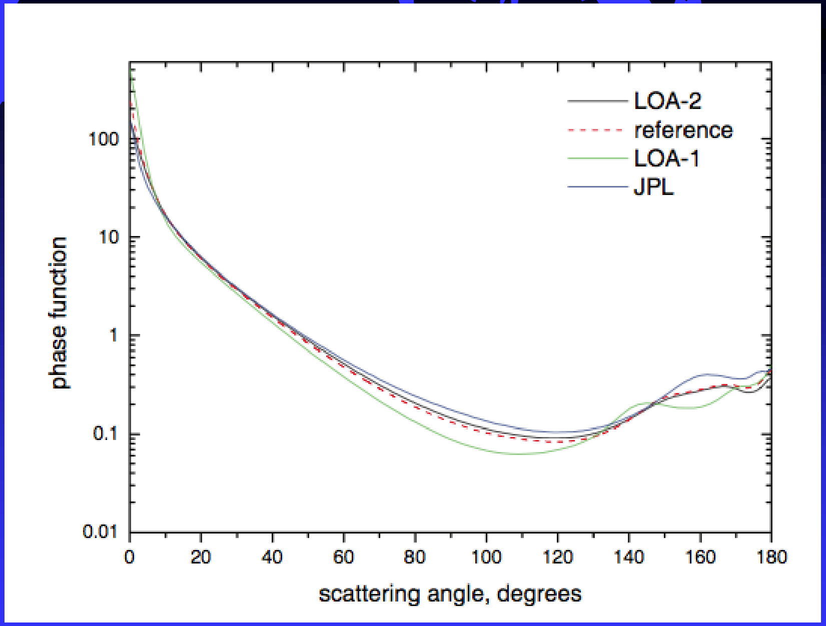


Tests over dark surface (*« Blind » Test*)

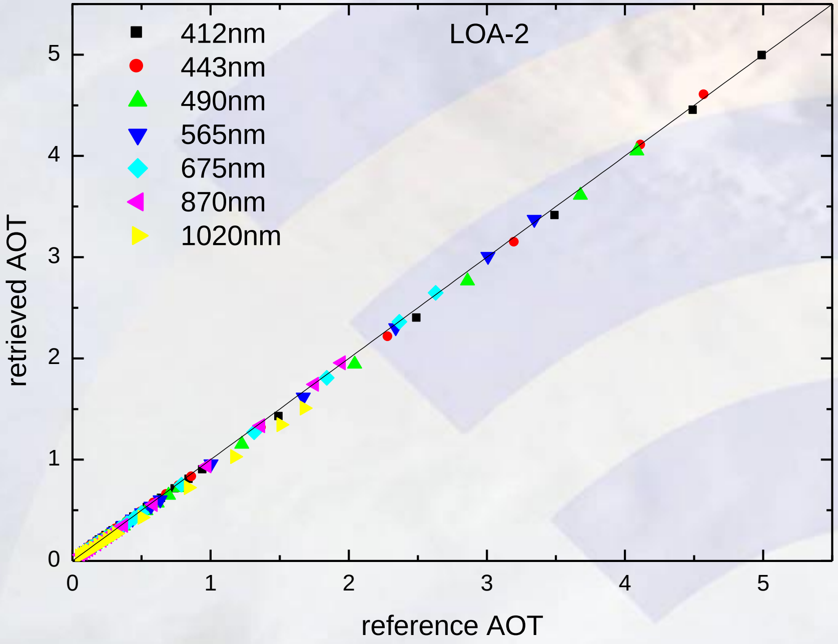
Kokhanovsky, et al, The inter-comparison of major satellite aerosol retrieval …., Atmos. Meas. Tech., 3, 909–932, 2010.



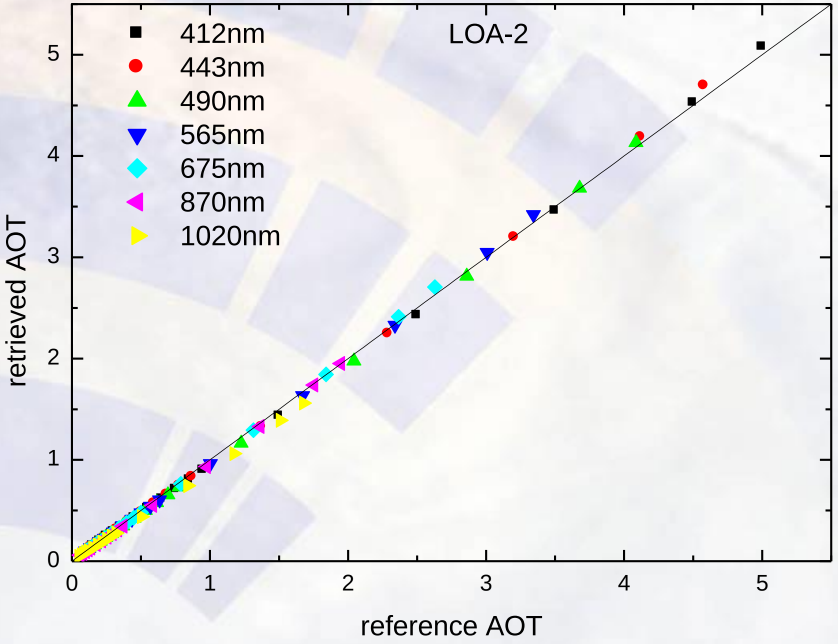




POLDER:
LOA-2(Dubovik) algorithm (BRDF)

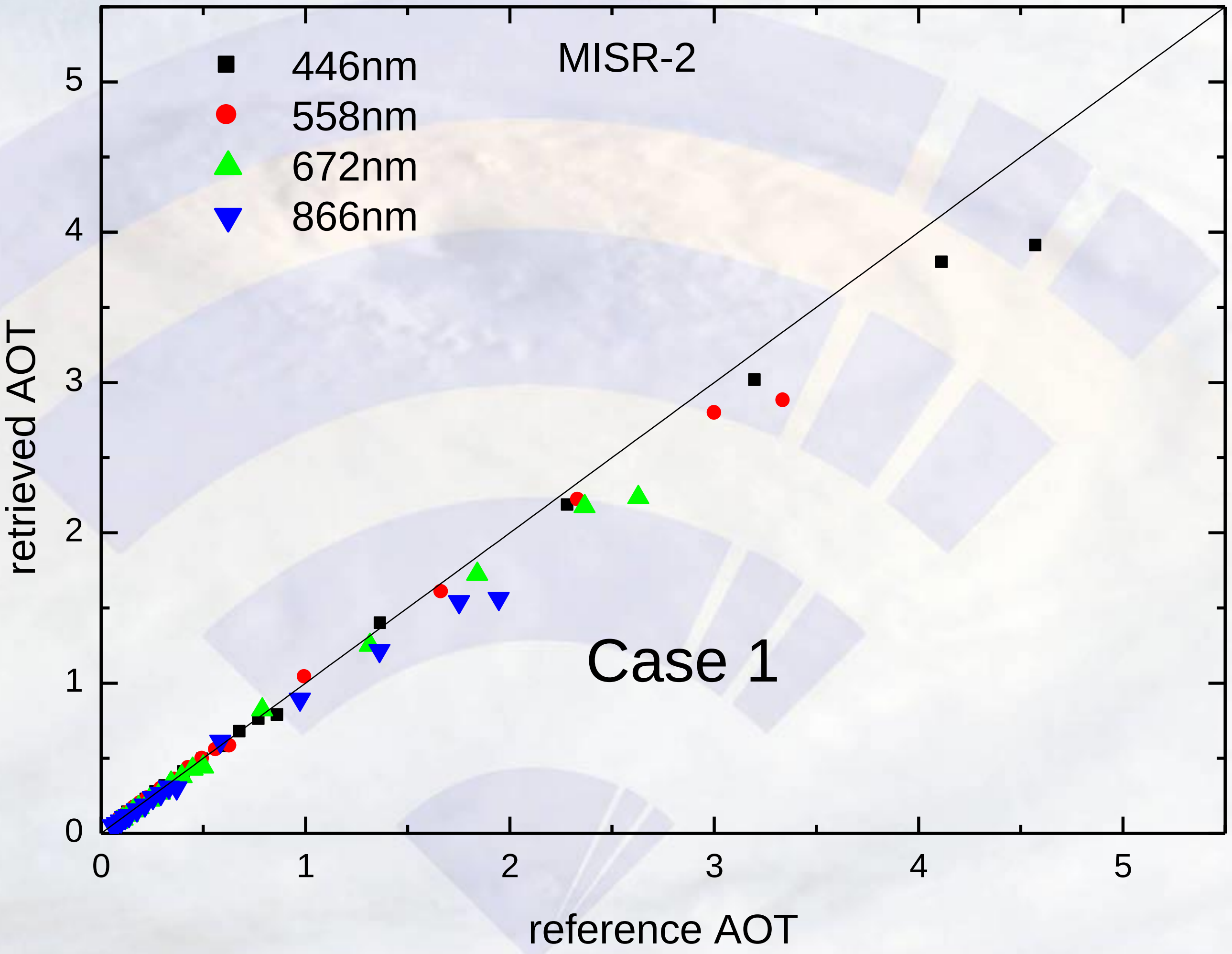


Case 1



Case 2

MSPI (JPL): I+Q
Lambertian unknown surface



Conclusion from the numerical retrieval tests:

Positive: GRASP provides rather accurate aerosol retrievals;

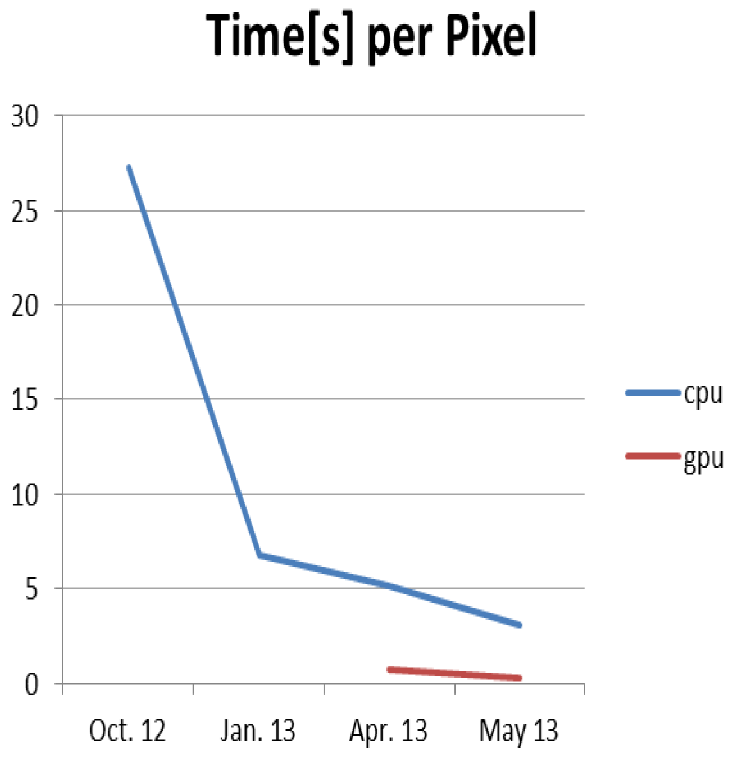
Negative: GRASP is essentially slower than traditional aerosol algorithms;

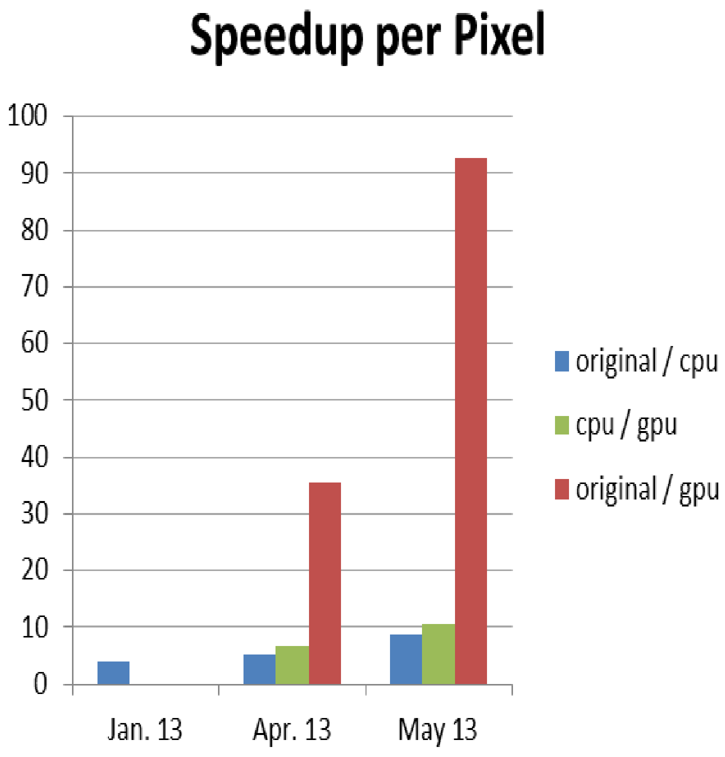
(originally ~ 10 sec per pixel)

GRASP – is too slow ?

Acceleration using GPU

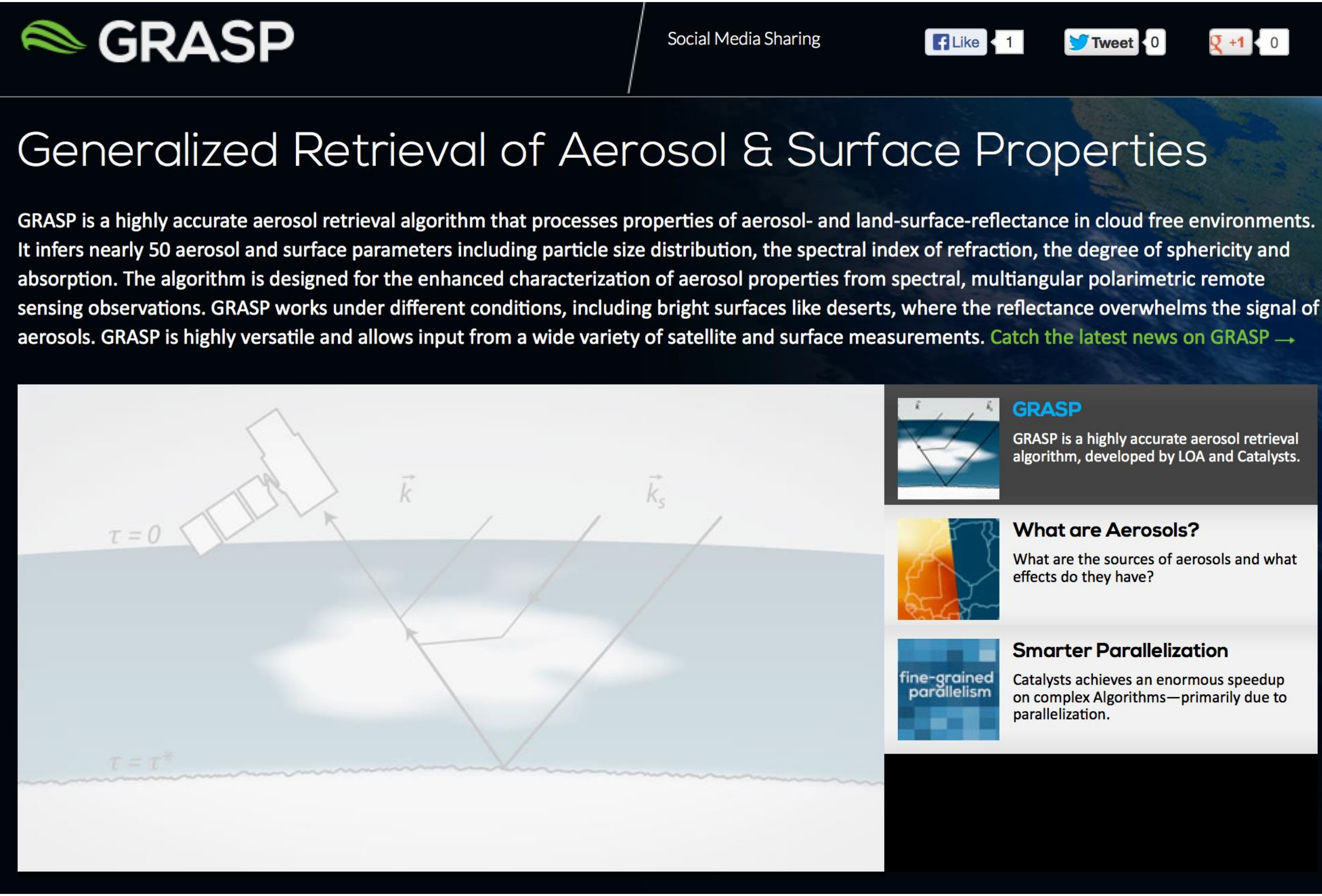
Overall Timing Trends


Time[s] per Pixel


Speedup per Pixel

Now: ~ 0.1 sec per pixel, it is not over…

GRASP – Open Source Code distributed via web



Generalized Retrieval of Aerosol & Surface Properties

GRASP is a highly accurate aerosol retrieval algorithm that processes properties of aerosol- and land-surface-reflectance in cloud free environments. It infers nearly 50 aerosol and surface parameters including particle size distribution, the spectral index of refraction, the degree of sphericity and absorption. The algorithm is designed for the enhanced characterization of aerosol properties from spectral, multiangular polarimetric remote sensing observations. GRASP works under different conditions, including bright surfaces like deserts, where the reflectance overwhelms the signal of aerosols. GRASP is highly versatile and allows input from a wide variety of satellite and surface measurements. Catch the latest news on GRASP →

GRASP

GRASP is a highly accurate aerosol retrieval algorithm, developed by LOA and Catalysts.

What are Aerosols?

What are the sources of aerosols and what effects do they have?

Smarter Parallelization

Catalysts achieves an enormous speedup on complex Algorithms—primarily due to parallelization.

Aerosol Retrieval LEGO ?

Game principles:

- "basic blocs" are solid, easy to use, replaceable, can be connected in different combinations;
- final construction is reliable.

Benefits:

- variety of applications;
- different designs are possible;
- testing of alternative "basic blocks";
- testing various connections

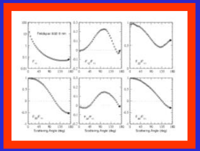
Results are better !!!

Progress is faster !!!

Game is fan !!!

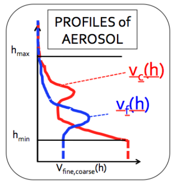
Diverse applications of GRASP

Nephelometer



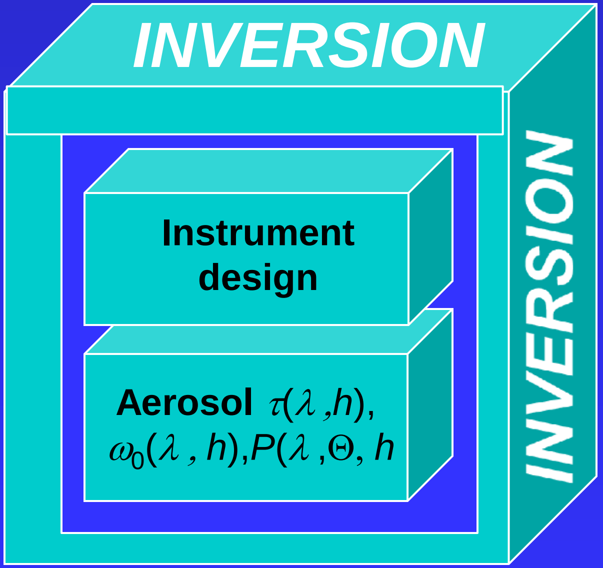
Sun-photometer

Lidar



AERONET

PARASOL

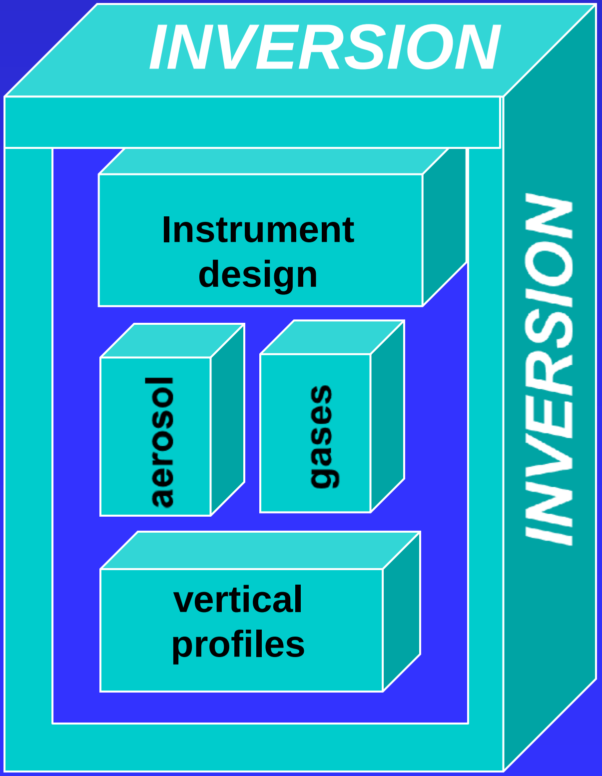


INVERSION

Instrument design

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

INVERSION



INVERSION

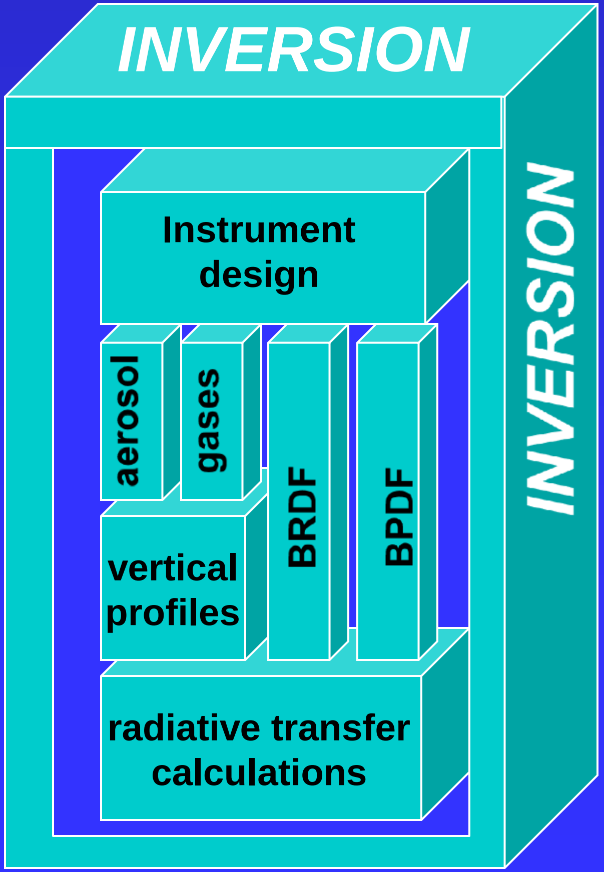
Instrument design

aerosol

gases

vertical profiles

INVERSION



INVERSION

Instrument design

aerosol

gases

BRDF

BPDF

vertical profiles

radiative transfer calculations

INVERSION

All modules are fully consistent !!!

GRASP applications:

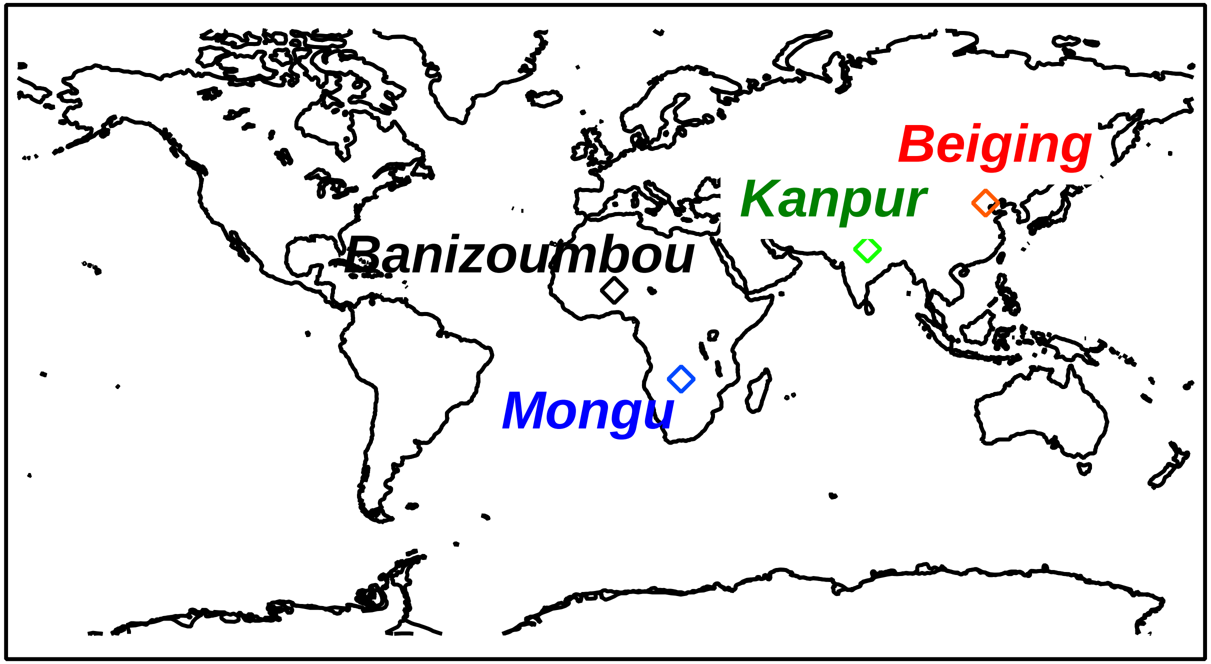
Real Data:

- **PARASOL over land and ocean (CNES, ESA);**	**- polar polarimeter**
- **MERIS over land (ESA);**	**- polar radiometer**
- ***AERONET+ lidar* (FP-7 Europe)**	***- ground-based***
- **airborne nephelometer (UMBC)**	***- airborne***

Numerical test with “perfect” observations:

- **3MI / EPS-SG ;**	**- polar polarimeter**
- ***Sentinel – 4* (GOCI real data – ESA);**	**- geostationary radiometer**
- ***MERIS, AATSR* (ESA);**	**- polar radiometer**
- ***MISR*;**	**- polar radiometer**
- **GICOM project (JAXA);**	**- polar bi-viewing polarimeter**
- **CHINA “GLORY + 3MI” project**	**- polar polarimeter**

Comparison of PARASOL with AERONET



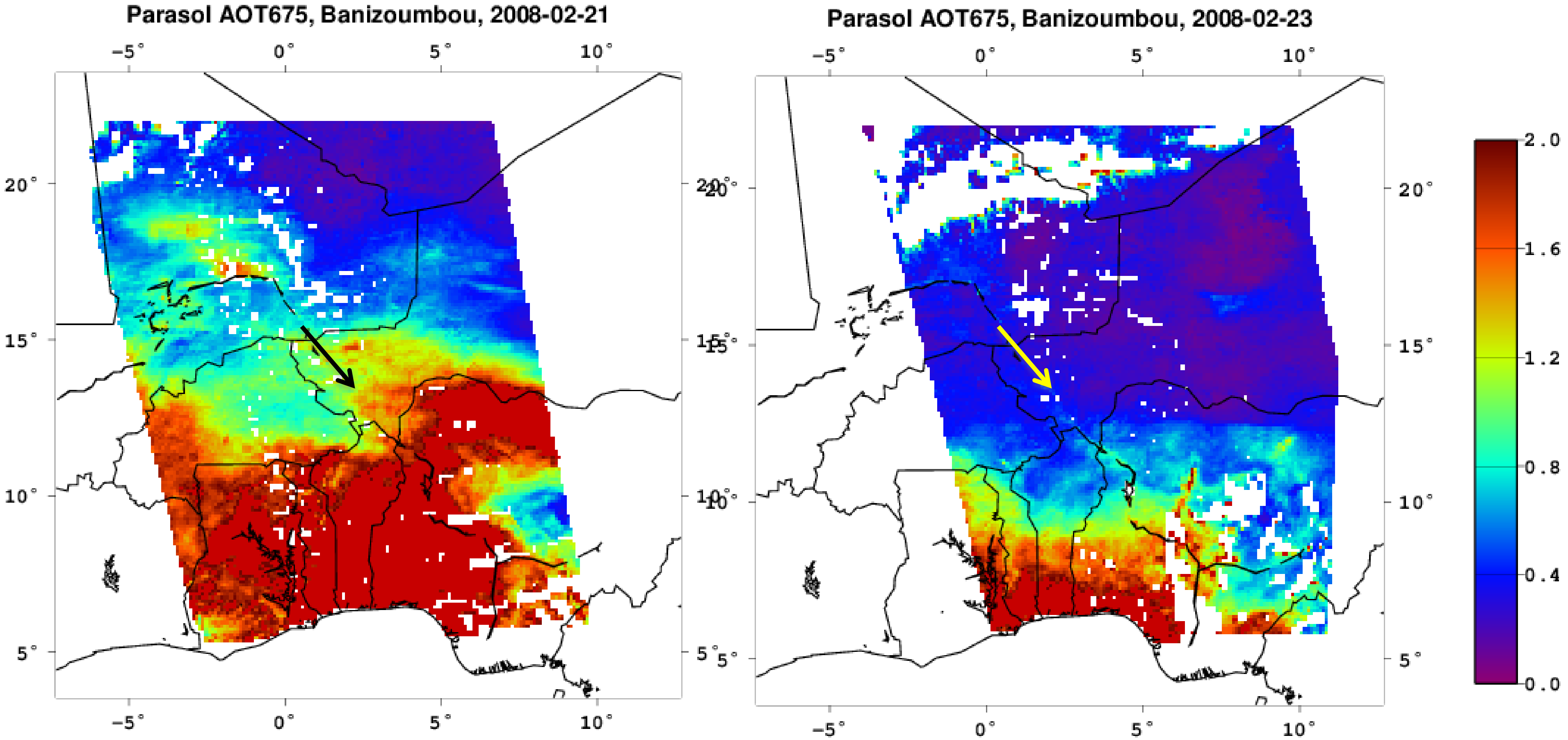
In cooperation with

ESA - CCI

Banizoumbou: *January, February, 2008*
Surface: Grassland. **Aerosol**: Coarse mode is dominated.
Mongu: *August, September, 2008*
Surface*:* Savanna. **Aerosol**: Fine mode is dominated.
Beijing: *April, December, 2008*
Surface: Urban. **Aerosol:** Mixture of Fine and Coarse
Kanpur: *October-December, 2008*
Surface: Urban. **Aerosol:** Mixture of Fine and Coarse

The IGBP (International Geosphere Biosphere Program) land type specification was used

Regional maps (1800 x 1800 km). Banizoumbou, AOD 670 nm

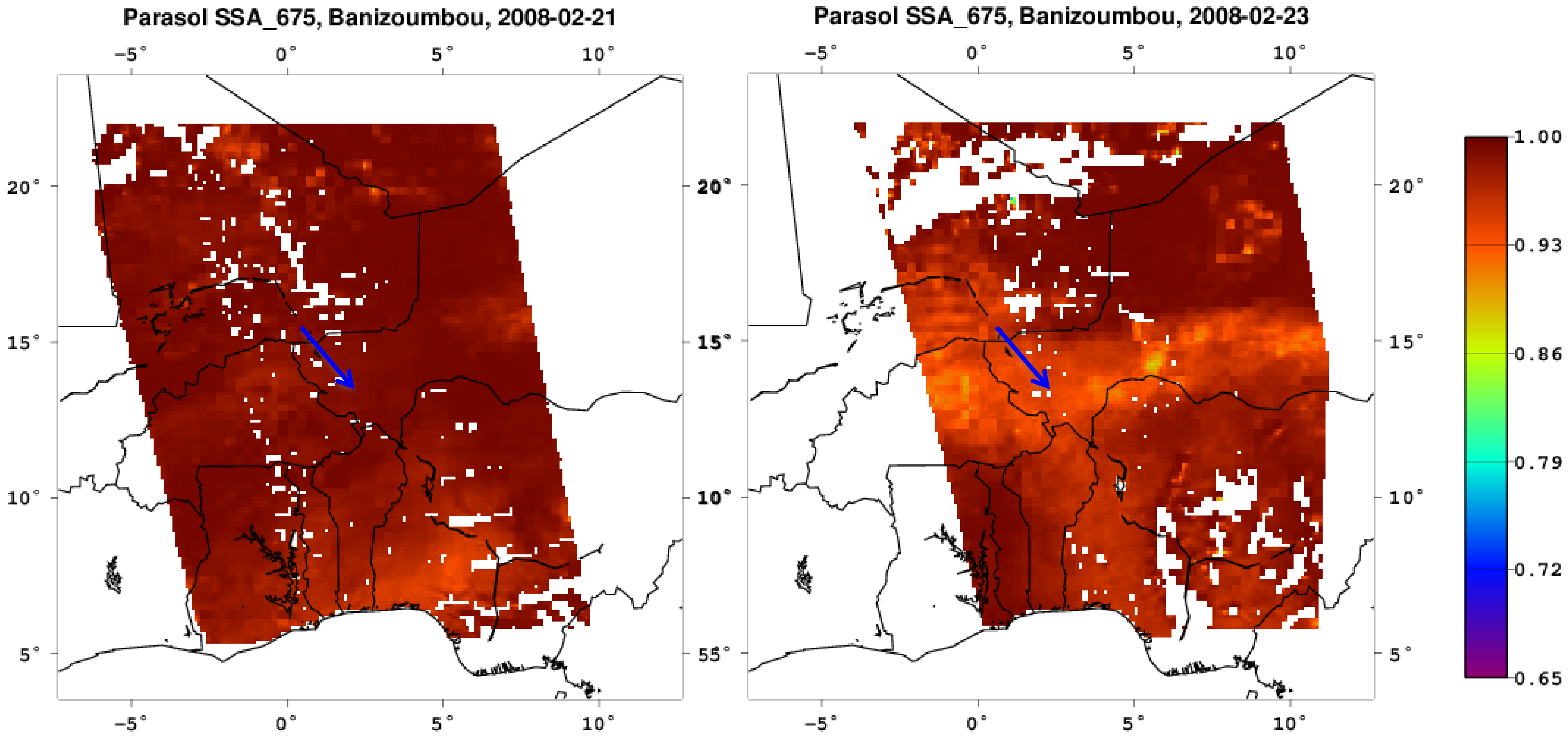


Parasol AOT675, Banizoumbou, 2008-02-21

Parasol AOT675, Banizoumbou, 2008-02-23

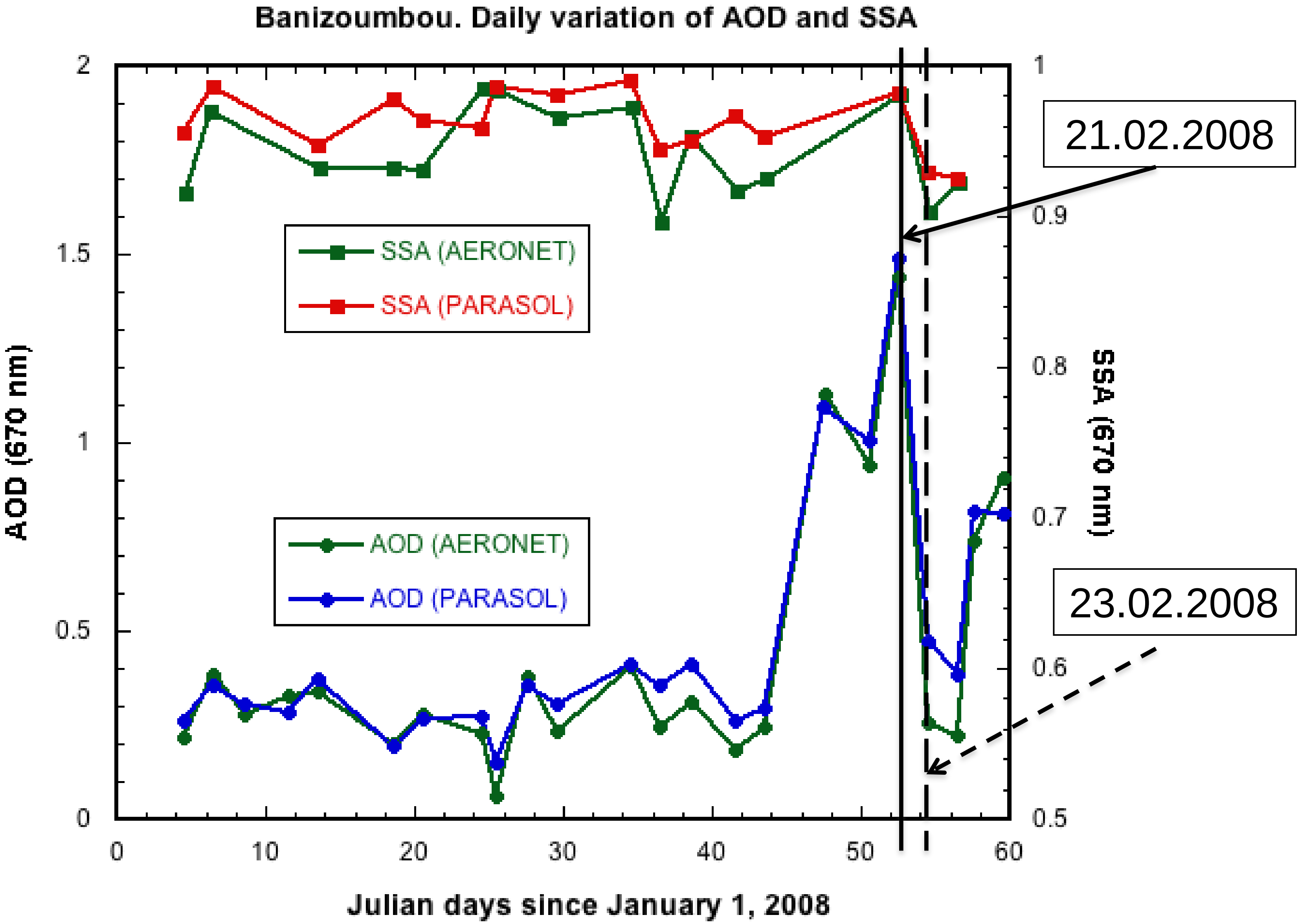
Strong spatial and temporal variation of AOD

Regional maps (1800 x 1800 km).
Banizoumbou, SSA 670 nm



Essential temporal variation of SSA

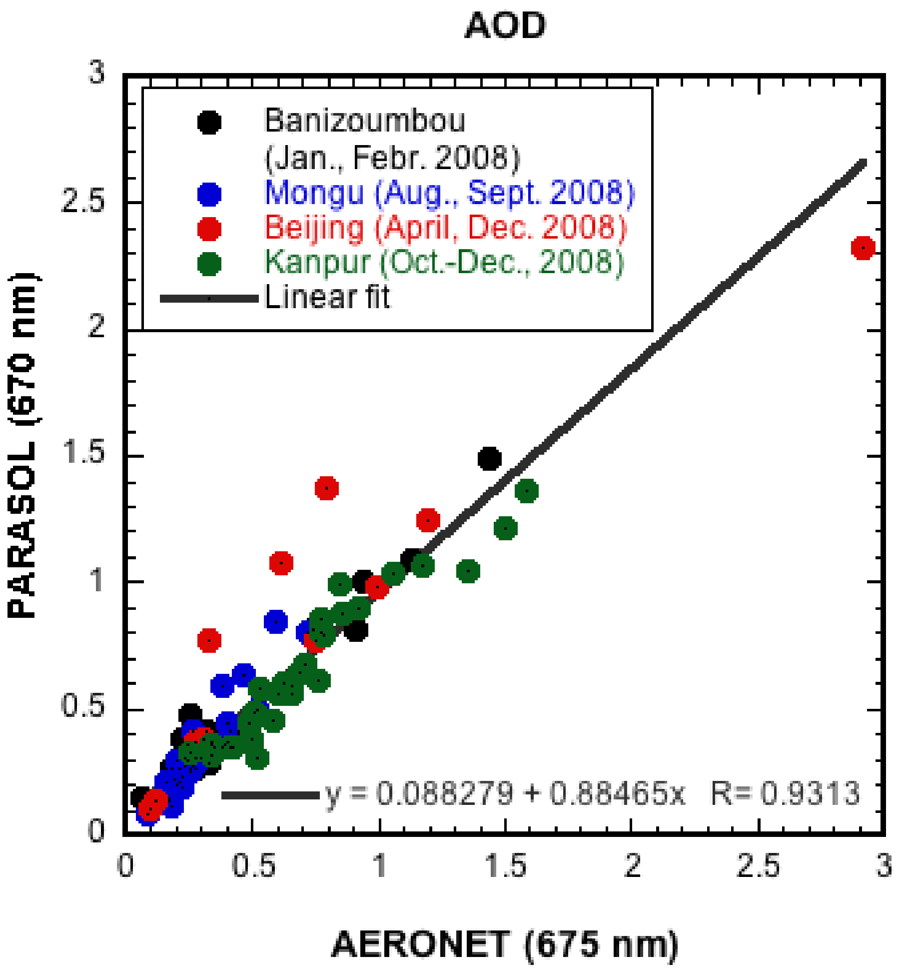
Daily variation of AOD and SSA at 670 nm. Banizoumbou (Jan., Febr. 2008).



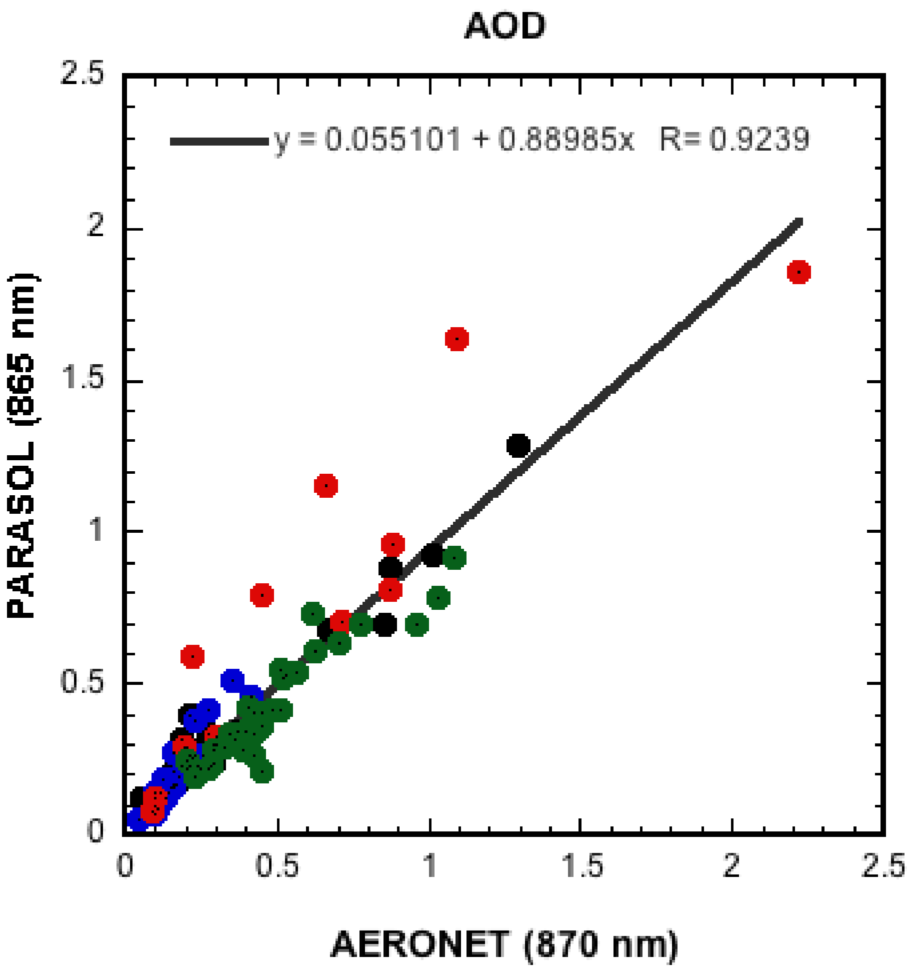
21.02.2008

23.02.2008

AOD. POLDER/AERONET

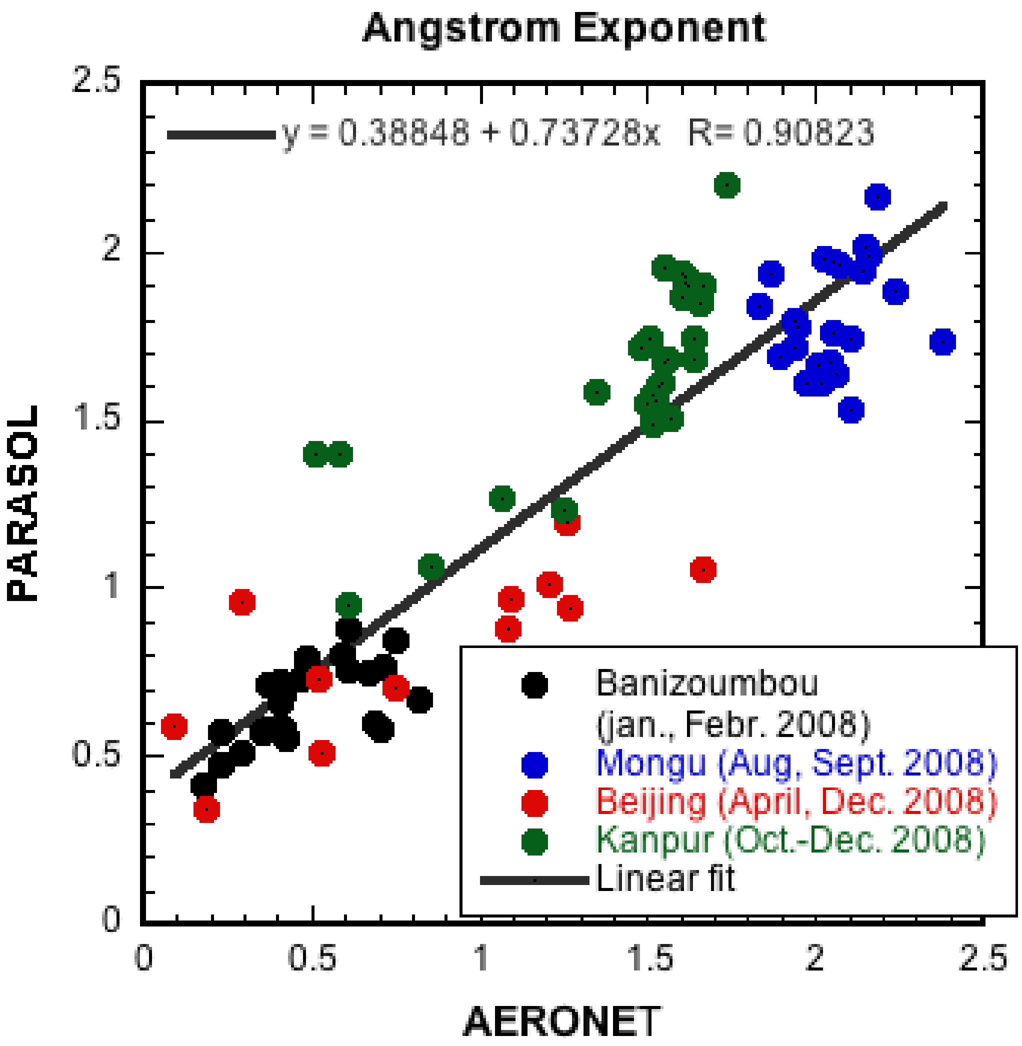


AOD

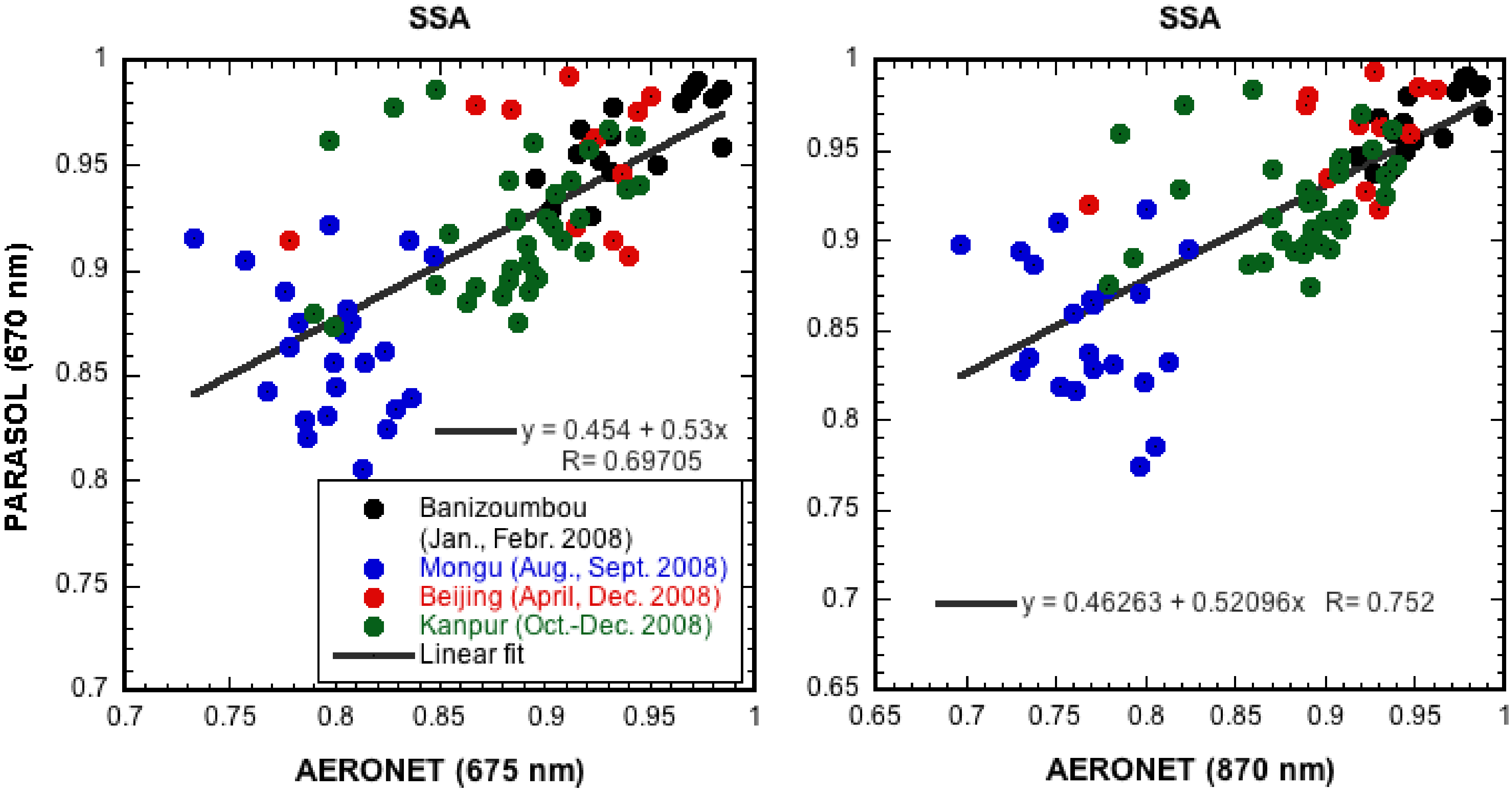


AOD

Angstrom Exponent.
POLDER/AERONET



SSA. POLDER/AERONET



Importance of Polarization ?

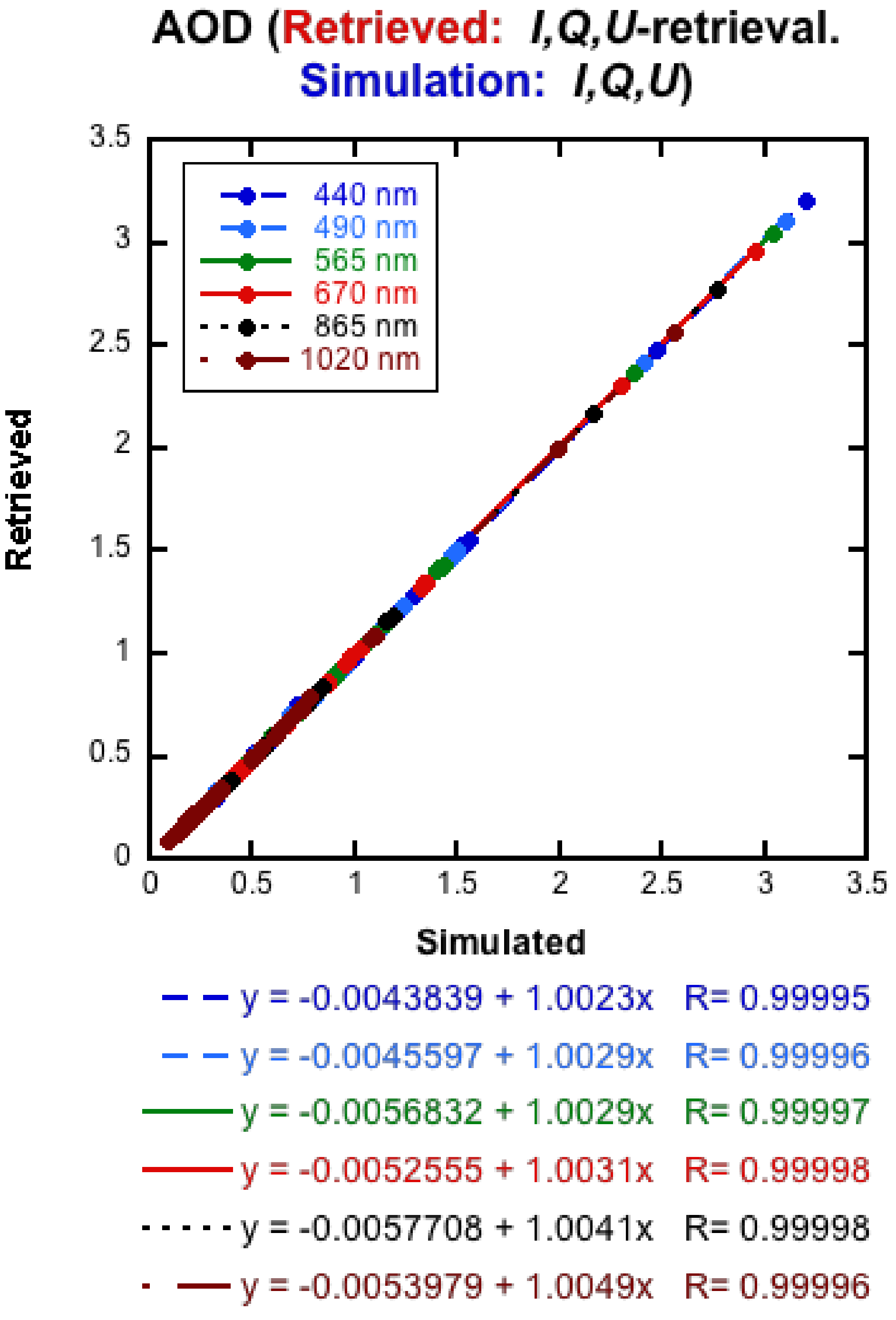
Synthetic measurements simulation

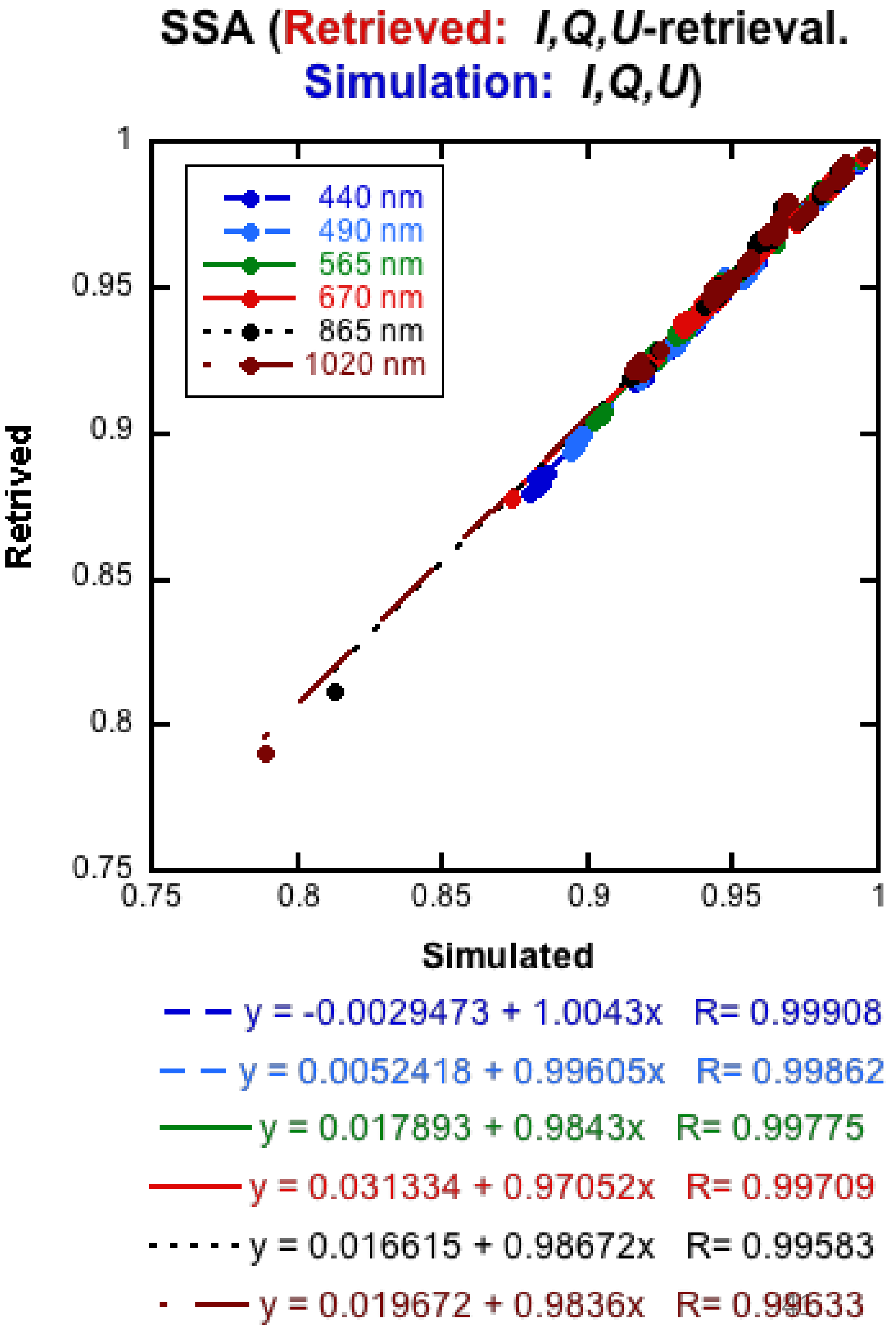
- We simulated **2 months of PARASOL measurements**

- **Aerosol and surface** properties and **aerosol concentration** are taken from the retrieval of PARASOL measurements over Banizoumbou in January, February 2008.

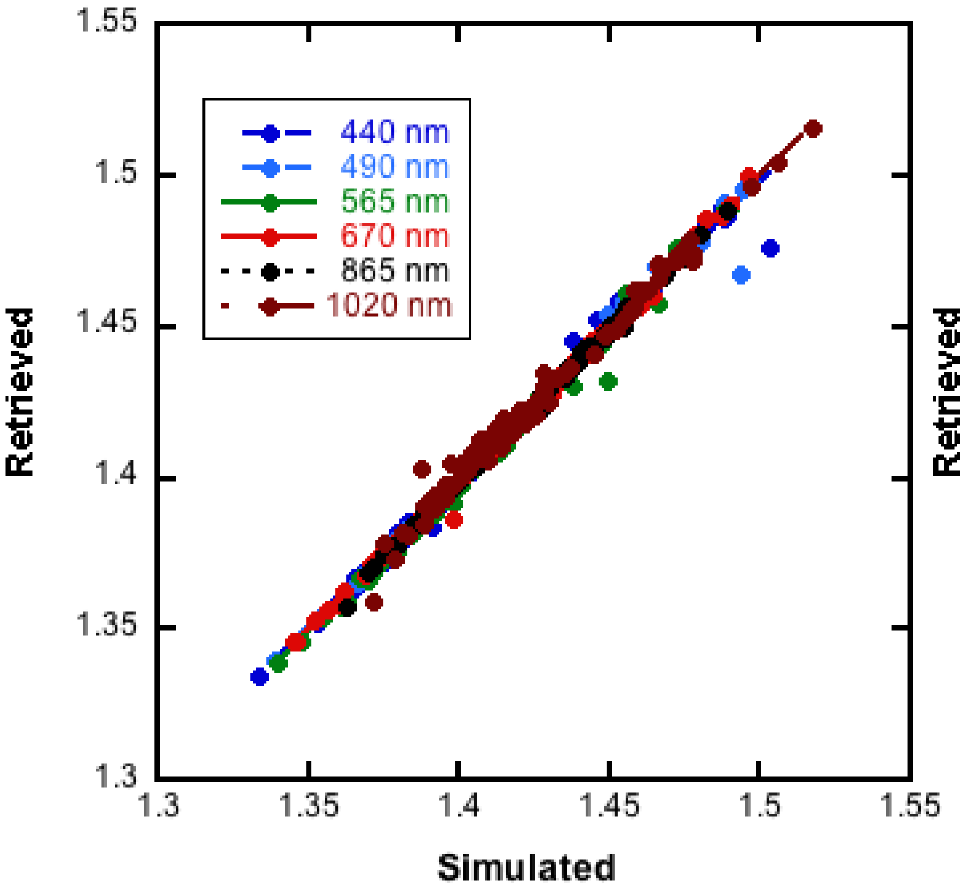
Inversion of synthetic measurements

Intensity + Polarization
(I , Q , U)


AOD (Retrieved: I,Q,U-retrieval.
Simulation: I,Q,U)
Retrieved
Simulated
0
0.5
1
1.5
2
2.5
3
3.5
440 nm
490 nm
565 nm
670 nm
865 nm
1020 nm
y = -0.0043839 + 1.0023x R= 0.99995
y = -0.0045597 + 1.0029x R= 0.99996
y = -0.0056832 + 1.0029x R= 0.99997
y = -0.0052555 + 1.0031x R= 0.99998
y = -0.0057708 + 1.0041x R= 0.99998
y = -0.0053979 + 1.0049x R= 0.99996

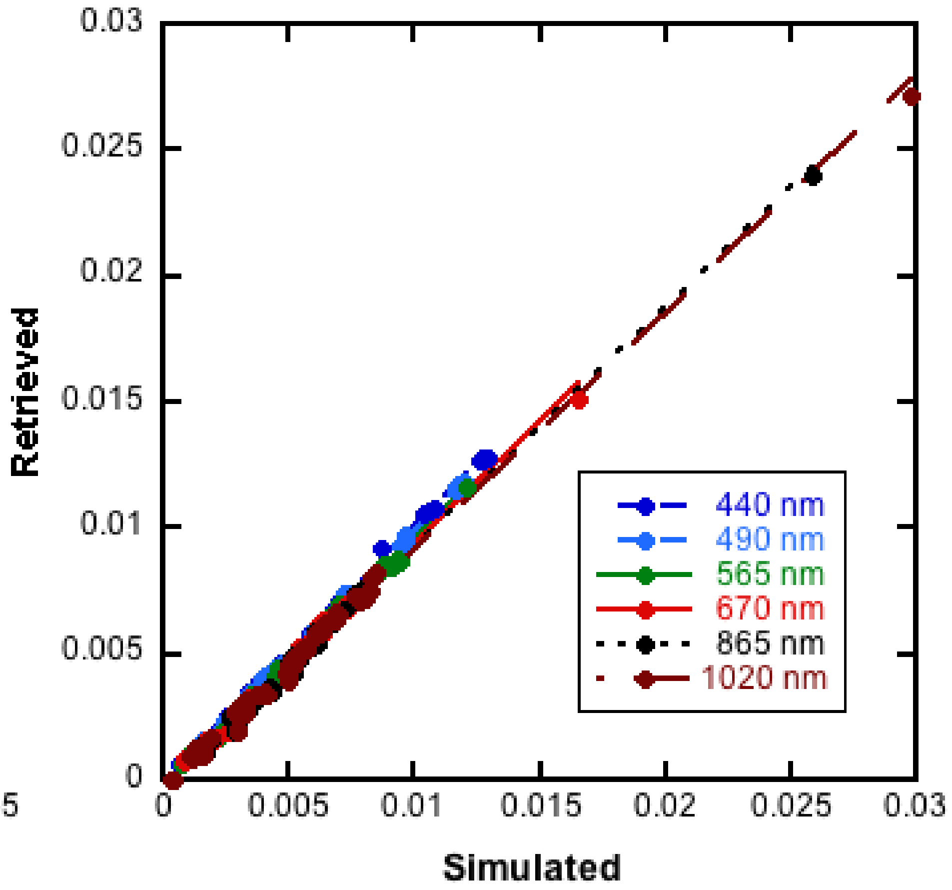

SSA (Retrieved: I,Q,U-retrieval.
Simulation: I,Q,U)
Retrieved
Simulated
0.75
0.8
0.85
0.9
0.95
1
440 nm
490 nm
565 nm
670 nm
865 nm
1020 nm
y = -0.0029473 + 1.0043x R= 0.99908
y = 0.0052418 + 0.99605x R= 0.99862
y = 0.017893 + 0.9843x R= 0.99775
y = 0.031334 + 0.97052x R= 0.99709
y = 0.016615 + 0.98672x R= 0.99583
y = 0.019672 + 0.9836x R= 0.99633

Re(*m*) (Retrieved: *I,Q,U*-retrieval.
Simulation: *I,Q,U*)



y = 0.02697 + 0.98023x R= 0.99402
y = 0.014274 + 0.98951x R= 0.99594
y = -0.010894 + 1.0066x R= 0.99717
y = -0.010484 + 1.0072x R= 0.99895
y = -0.0038963 + 1.0023x R= 0.99925
y = 0.014557 + 0.99005x R= 0.99476

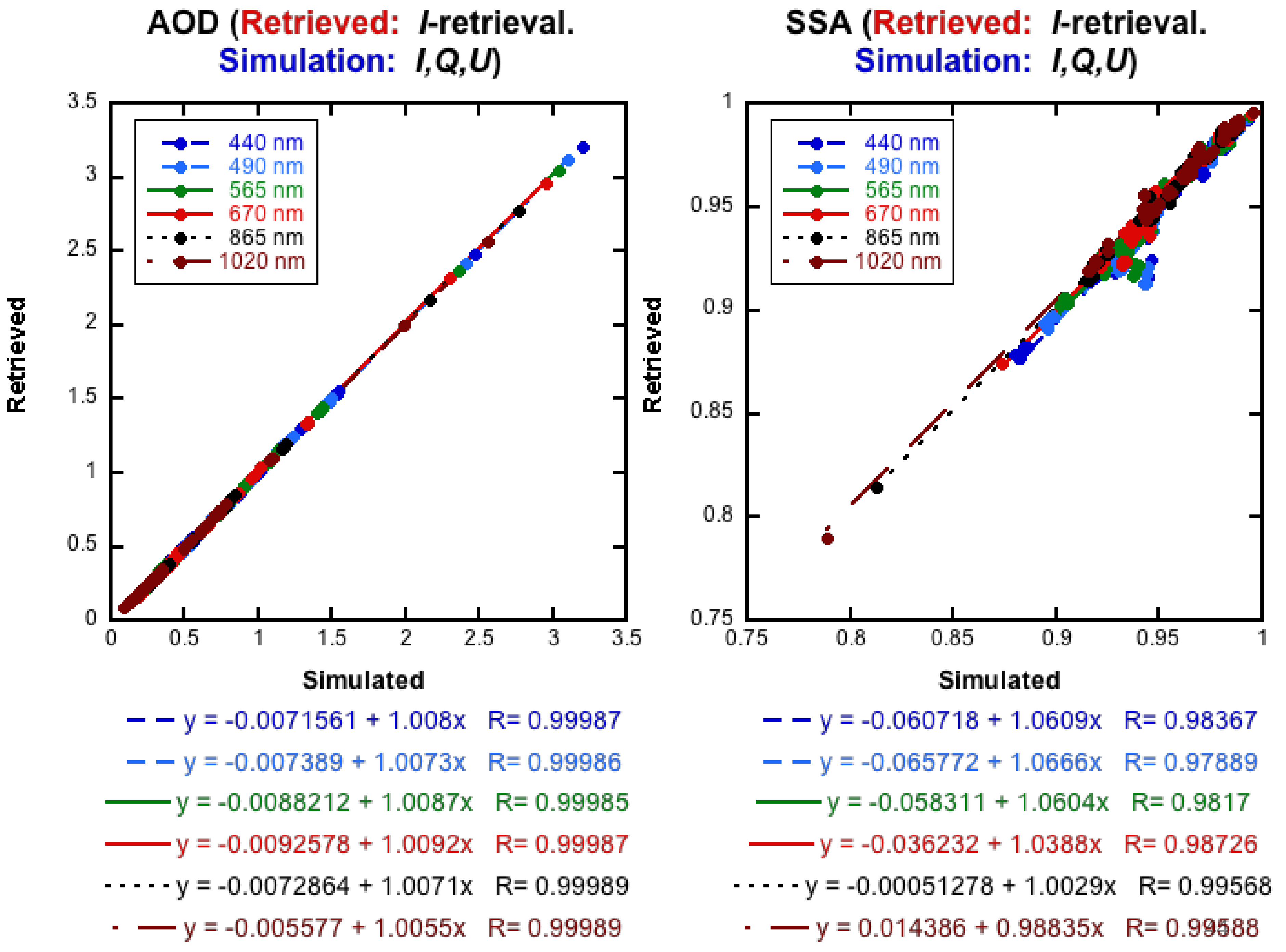
Im(*m*) (Retrieved: *I,Q,U*-retrieval.
Simulation: *I,Q,U*)

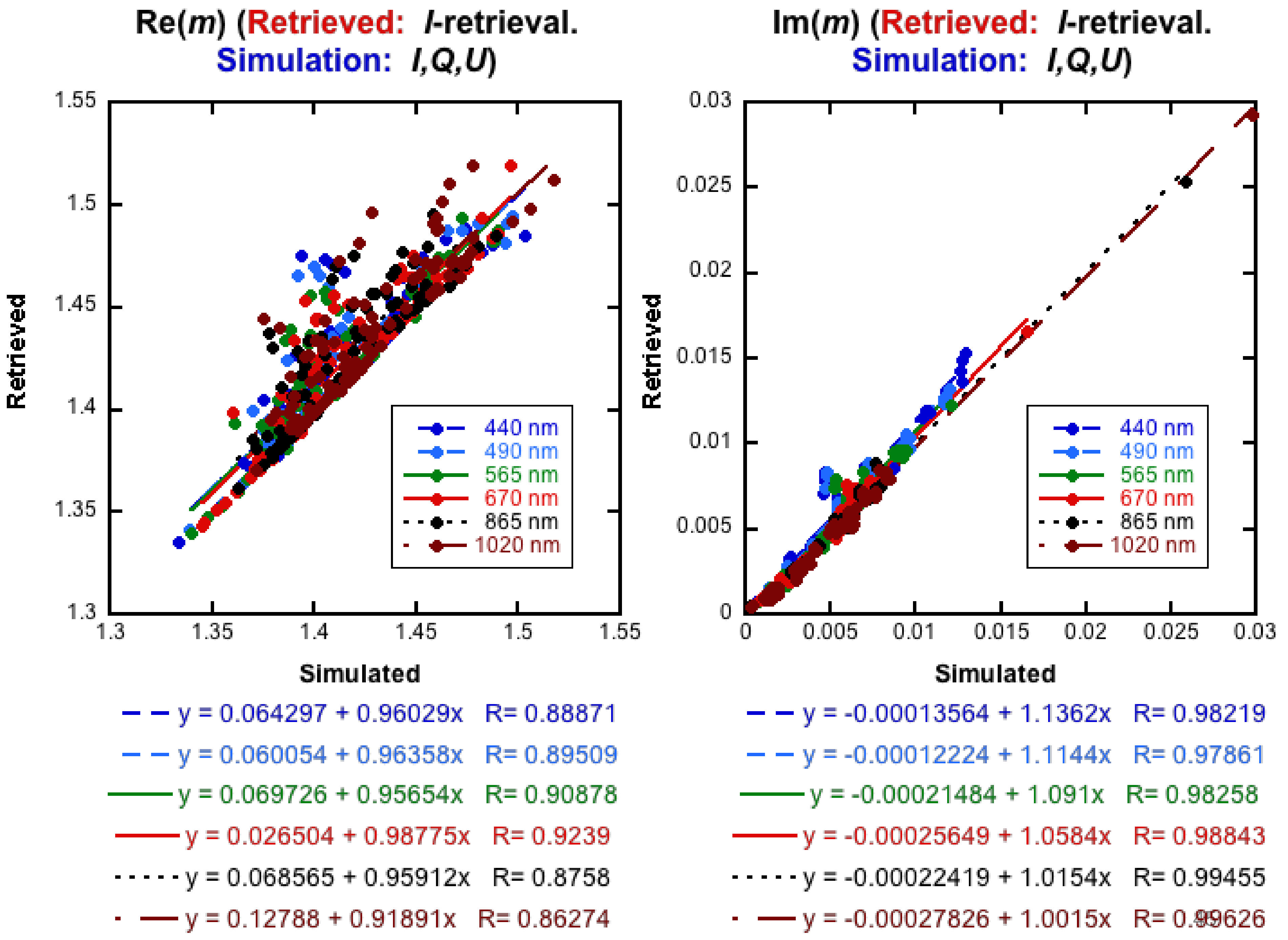


y = -0.00011281 + 1.0118x R= 0.99928
y = -0.00010855 + 1.0028x R= 0.99909
y = -0.00017203 + 0.97747x R= 0.99852
y = -0.00013111 + 0.96086x R= 0.99782
y = -0.00021565 + 0.95096x R= 0.99732
y = -0.0001892 + 0.93962x R= 0.99711

Inversion of synthetic measurements

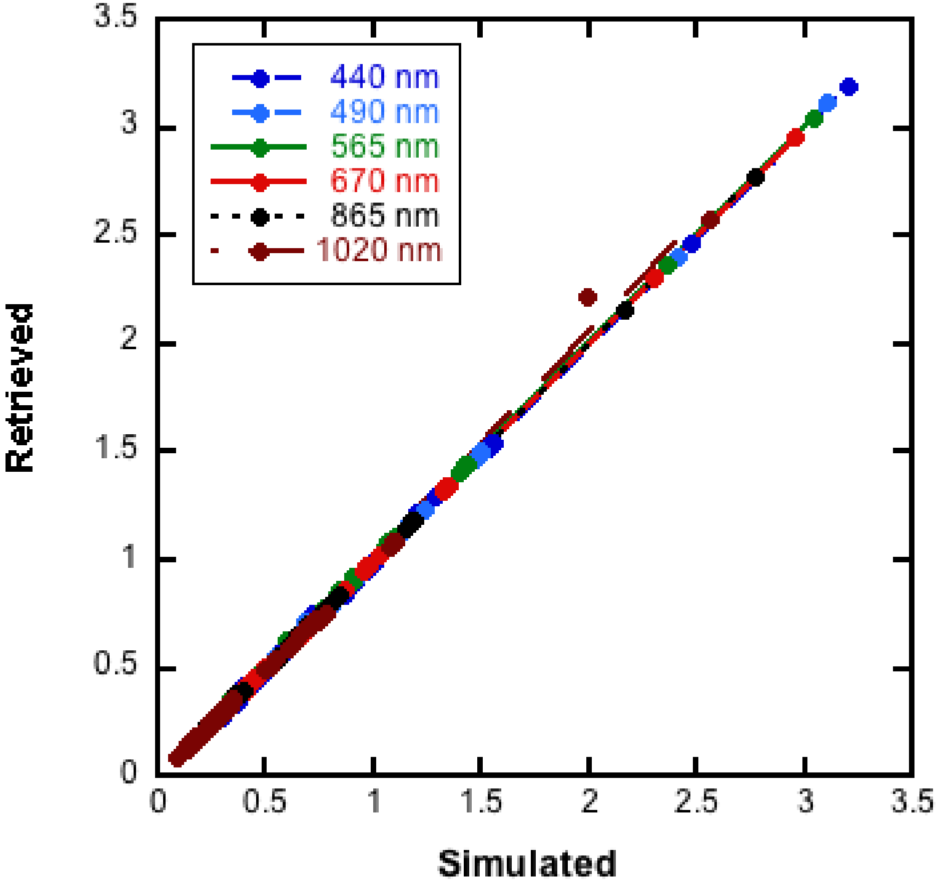
Intensity only (*I*)


AOD (Retrieved: I-retrieval.
Simulation: I,Q,U)
440 nm
490 nm
565 nm
670 nm
865 nm
1020 nm
Retrieved
Simulated
0
0.5
1
1.5
2
2.5
3
3.5
y = -0.0071561 + 1.008x R= 0.99987
y = -0.007389 + 1.0073x R= 0.99986
y = -0.0088212 + 1.0087x R= 0.99985
y = -0.0092578 + 1.0092x R= 0.99987
y = -0.0072864 + 1.0071x R= 0.99989
y = -0.005577 + 1.0055x R= 0.99989
SSA (Retrieved: I-retrieval.
Simulation: I,Q,U)
440 nm
490 nm
565 nm
670 nm
865 nm
1020 nm
Retrieved
Simulated
0.75
0.8
0.85
0.9
0.95
1
y = -0.060718 + 1.0609x R= 0.98367
y = -0.065772 + 1.0666x R= 0.97889
y = -0.058311 + 1.0604x R= 0.9817
y = -0.036232 + 1.0388x R= 0.98726
y = -0.00051278 + 1.0029x R= 0.99568
y = 0.014386 + 0.98835x R= 0.99588


Re(m) (Retrieved: I-retrieval.
Simulation: I,Q,U)
Retrieved
Simulated
1.3
1.35
1.4
1.45
1.5
1.55
440 nm
490 nm
565 nm
670 nm
865 nm
1020 nm
y = 0.064297 + 0.96029x R= 0.88871
y = 0.060054 + 0.96358x R= 0.89509
y = 0.069726 + 0.95654x R= 0.90878
y = 0.026504 + 0.98775x R= 0.9239
y = 0.068565 + 0.95912x R= 0.8758
y = 0.12788 + 0.91891x R= 0.86274
Im(m) (Retrieved: I-retrieval.
Simulation: I,Q,U)
Retrieved
Simulated
0
0.005
0.01
0.015
0.02
0.025
0.03
440 nm
490 nm
565 nm
670 nm
865 nm
1020 nm
y = -0.00013564 + 1.1362x R= 0.98219
y = -0.00012224 + 1.1144x R= 0.97861
y = -0.00021484 + 1.091x R= 0.98258
y = -0.00025649 + 1.0584x R= 0.98843
y = -0.00022419 + 1.0154x R= 0.99455
y = -0.00027826 + 1.0015x R= 0.99626

Inversion of synthetic measurements

Polarization only (Q , U)



AOD (Retrieved: *Q,U*-retrieval. Simulation: *I,Q,U*)

y = -0.0052906 + 1.0007x R= 0.99986

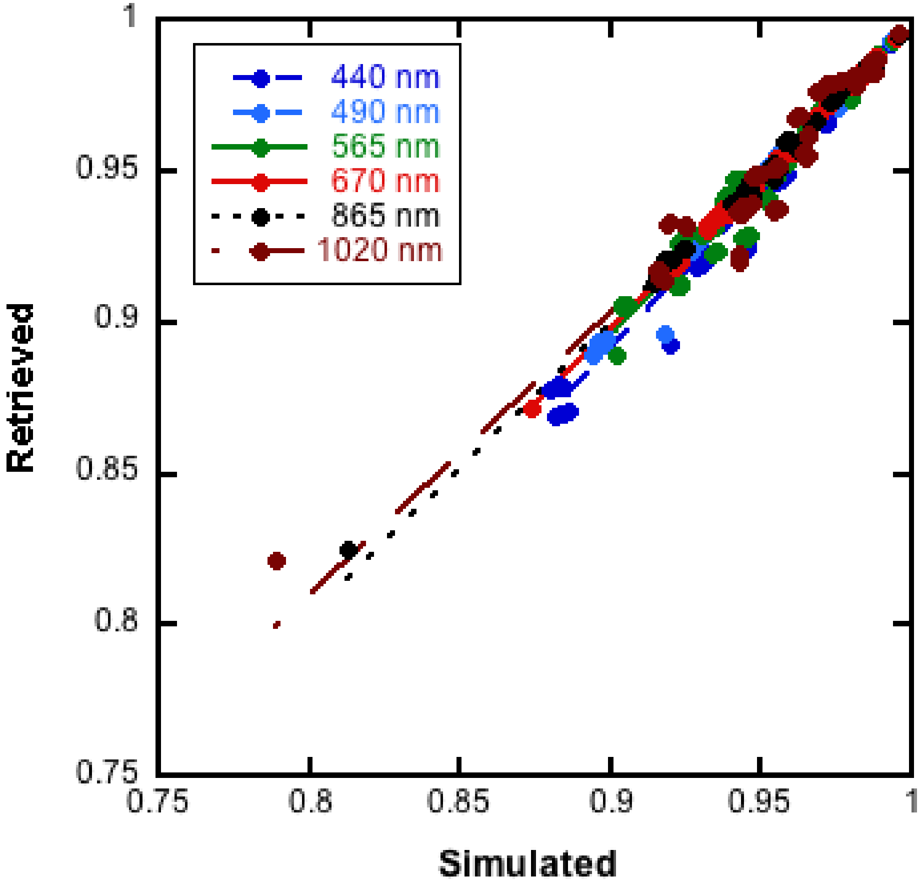
y = 0.0010661 + 1.0003x R= 0.99995

y = 0.00096879 + 1.0044x R= 0.99991

y = 0.0012797 + 0.99963x R= 0.99997

y = 0.0016497 + 0.99921x R= 0.99997

y = -0.011559 + 1.0302x R= 0.99806



SSA (Retrieved: *Q,U*-retrieval. Simulation: *I,Q,U*)

y = -0.084303 + 1.0834x R= 0.98944

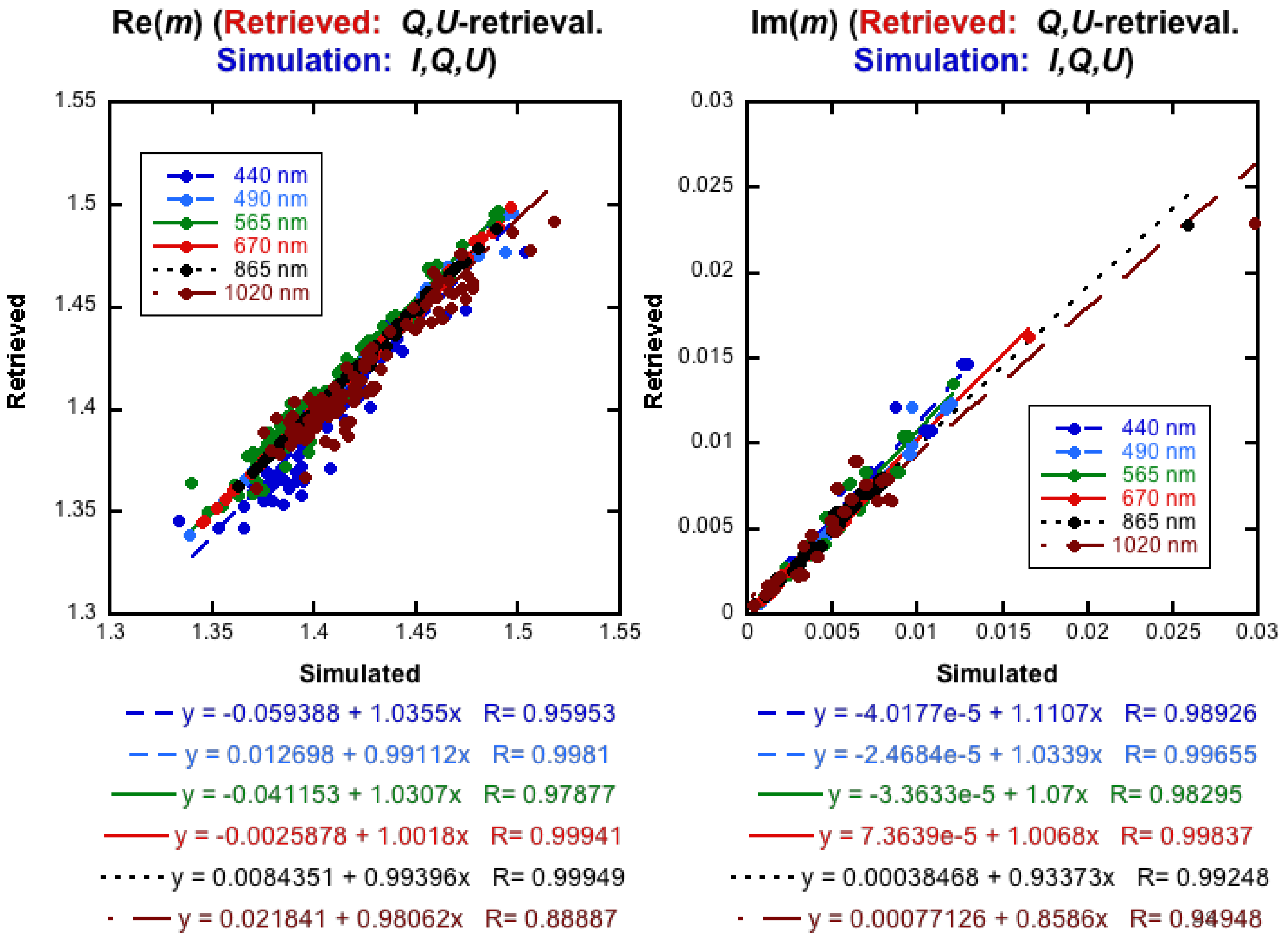
y = -0.035547 + 1.0356x R= 0.99707

y = -0.040899 + 1.04x R= 0.98086

y = -0.022387 + 1.0219x R= 0.9984

y = 0.023316 + 0.9743x R= 0.99565

y = 0.067708 + 0.92724x R= 0.95841



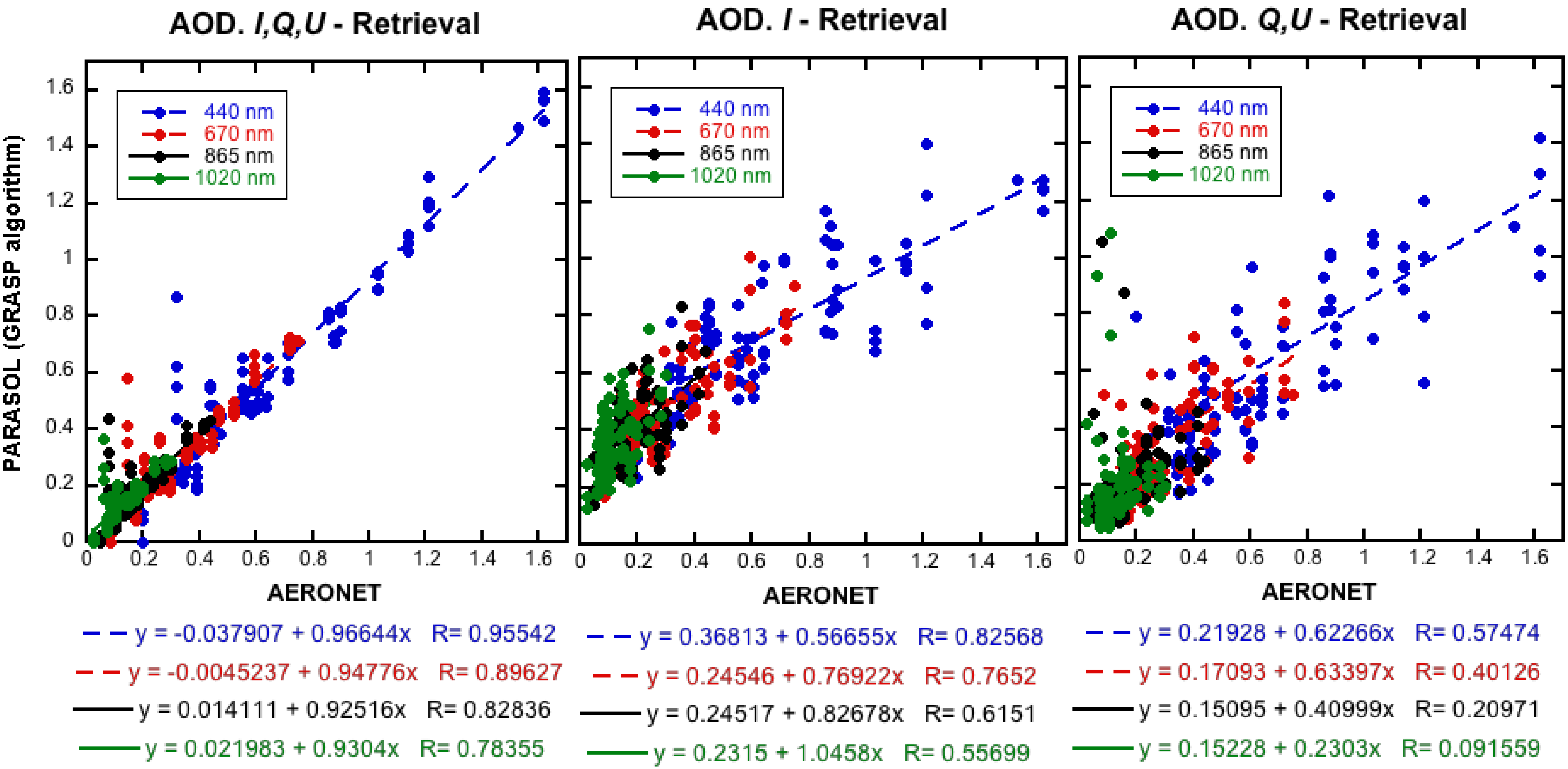
Re(*m*) (Retrieved: *Q,U*-retrieval. Simulation: *I,Q,U*)

Im(*m*) (Retrieved: *Q,U*-retrieval. Simulation: *I,Q,U*)

Inversion of REAL PARASOL measurements

Different Scenarios:
I+Q+U;
I;
Q+U

I,Q,U retrieval vs *I*-retrieval and *Q,U*-retrieval: AOD (Mongu. August, September 2008)

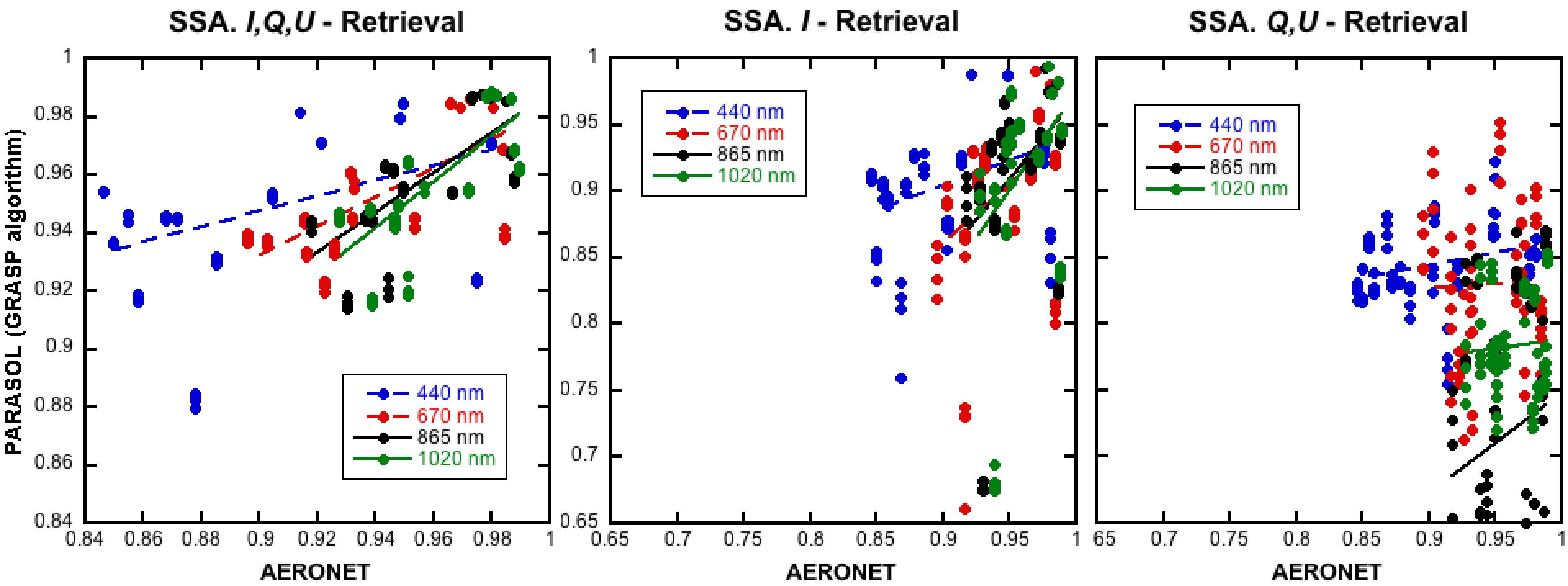


y = -0.037907 + 0.96644x R= 0.95542
y = -0.0045237 + 0.94776x R= 0.89627
y = 0.014111 + 0.92516x R= 0.82836
y = 0.021983 + 0.9304x R= 0.78355

y = 0.36813 + 0.56655x R= 0.82568
y = 0.24546 + 0.76922x R= 0.7652
y = 0.24517 + 0.82678x R= 0.6151
y = 0.2315 + 1.0458x R= 0.55699

y = 0.21928 + 0.62266x R= 0.57474
y = 0.17093 + 0.63397x R= 0.40126
y = 0.15095 + 0.40999x R= 0.20971
y = 0.15228 + 0.2303x R= 0.091559

I,Q,U retrieval vs *I*-retrieval and *Q,U*-retrieval: SSA (Banizoumbou)



y = 0.70542 + 0.26876x R= 0.43754

y = 0.48299 + 0.49932x R= 0.69482

y = 0.29752 + 0.69079x R= 0.73451

y = 0.19564 + 0.79387x R= 0.73262

y = 0.5662 + 0.37595x R= 0.33855

y = 0.066682 + 0.88263x R= 0.38326

y = -0.27308 + 1.2429x R= 0.3699

y = -0.50576 + 1.48x R= 0.40026

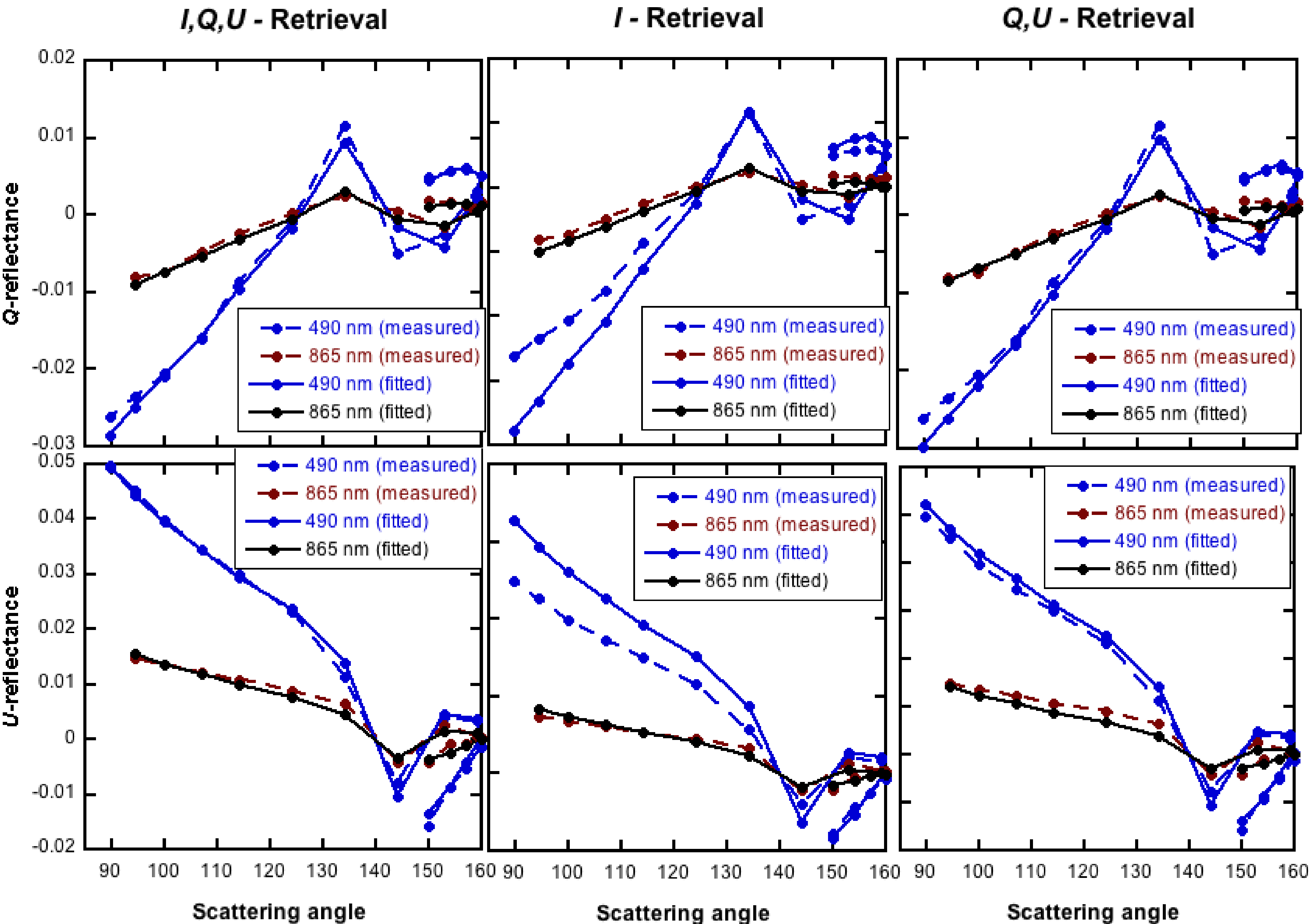
y = 0.67505 + 0.18747x R= 0.26615

y = 0.7699 + 0.06359x R= 0.032866

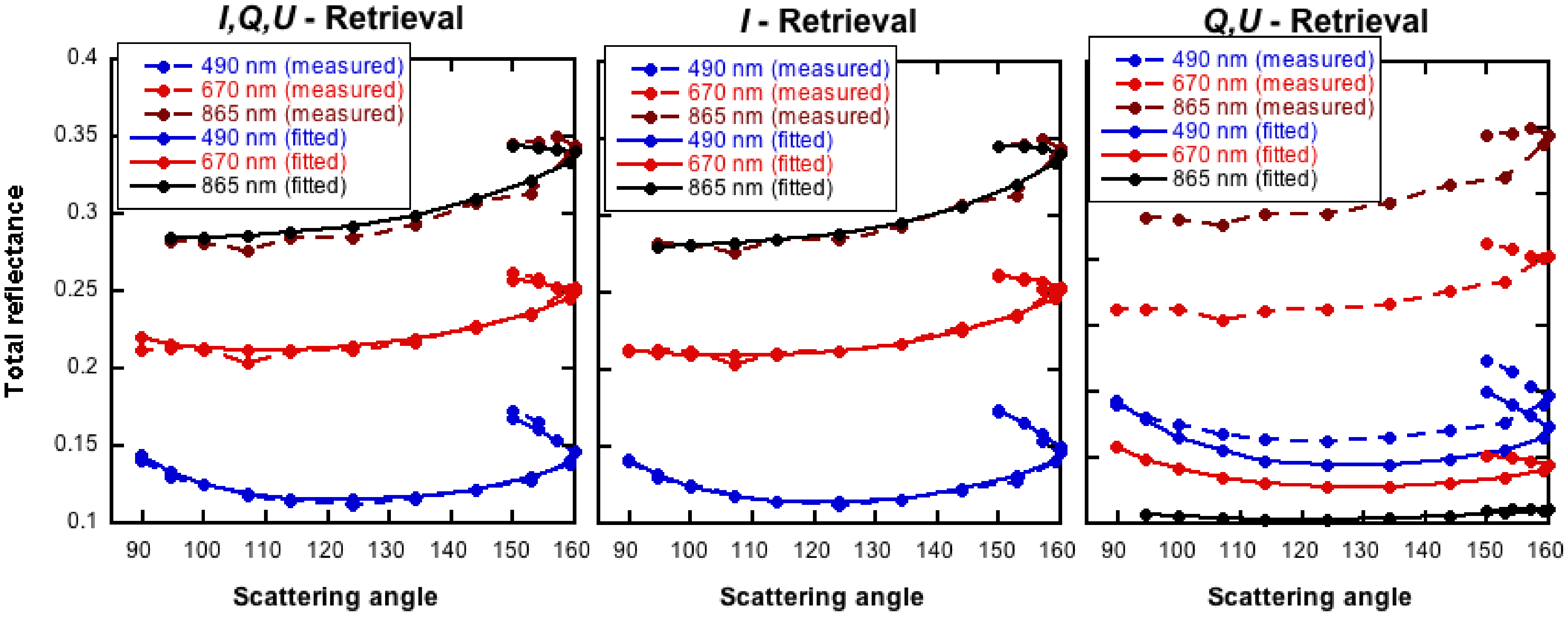
y = -0.0053611 + 0.75325x R= 0.17484

y = 0.64161 + 0.1472x R= 0.079932

I,Q,U retrieval vs *I*-retrieval and *Q,U*-retrieval



I,Q,U retrieval vs *I*-retrieval and *Q,U*-retrieval: total reflectance fits



Conclusion from the tests:

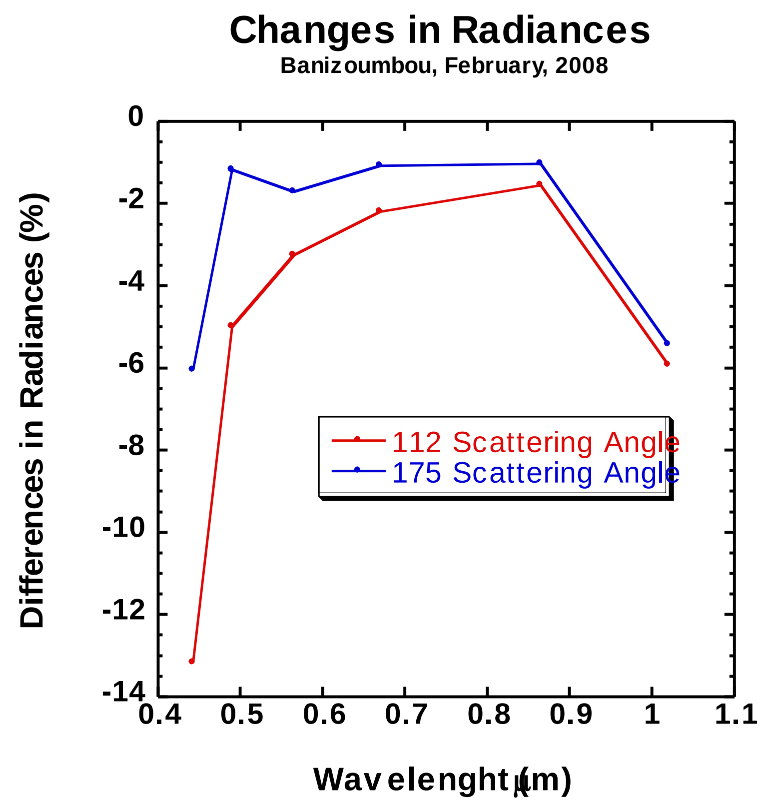
Polarization is a great addition to multi-angular intensity observations

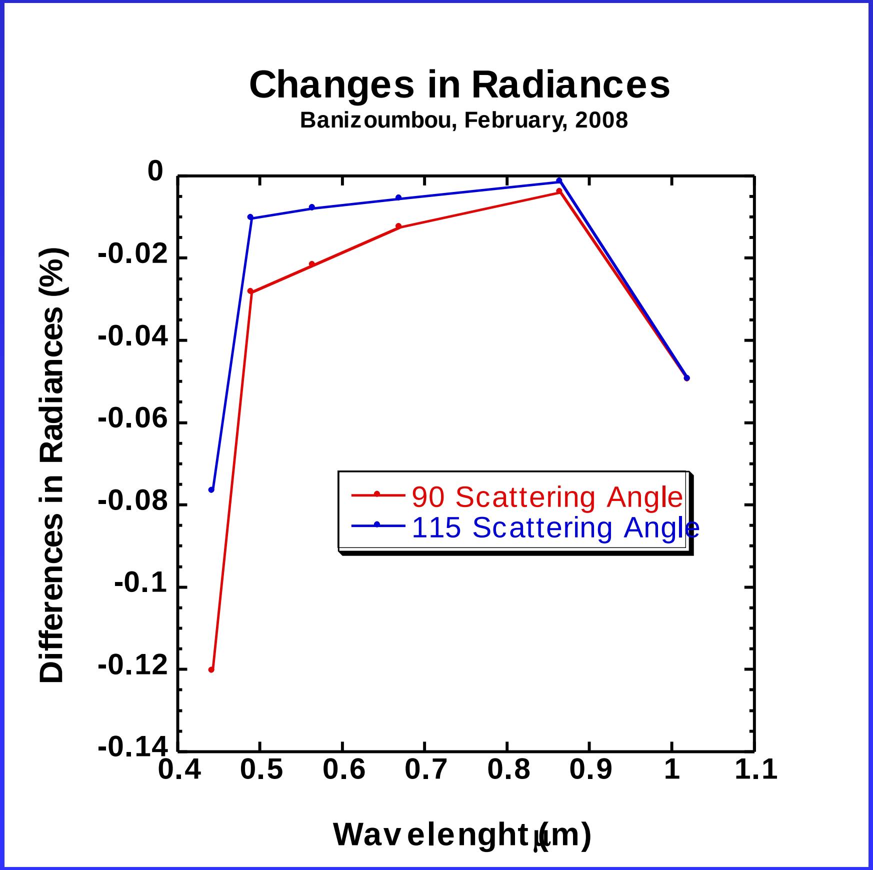
PARASOL observations under correction by CNES now

Spectral changes in radiances

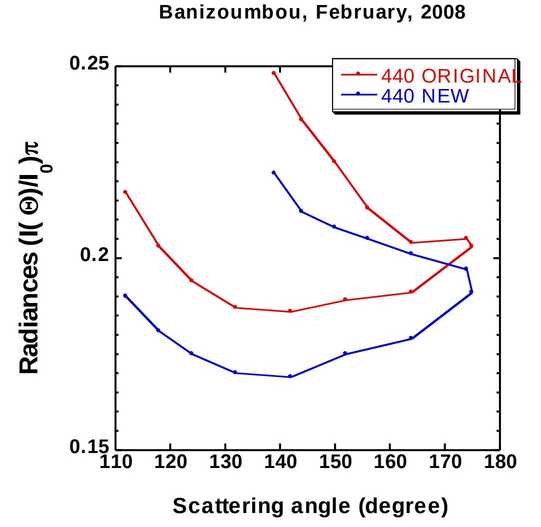
Banizoumbou

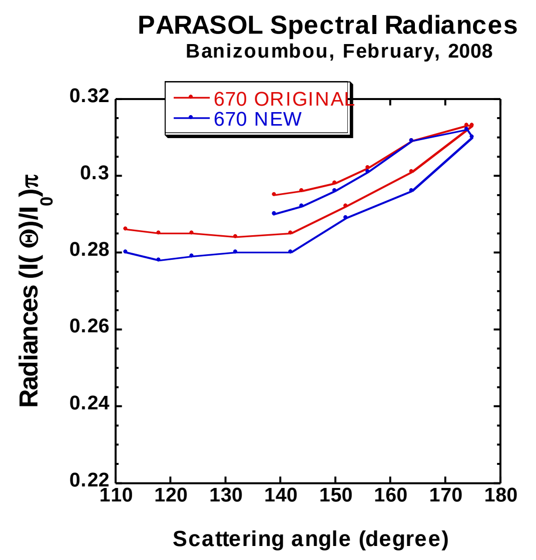
Mongu

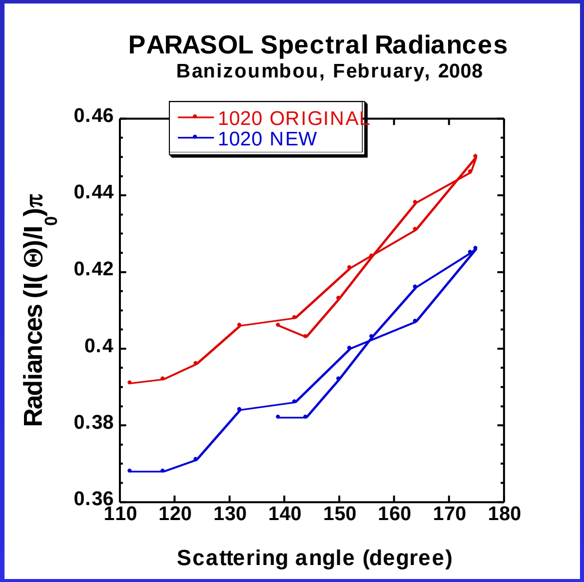




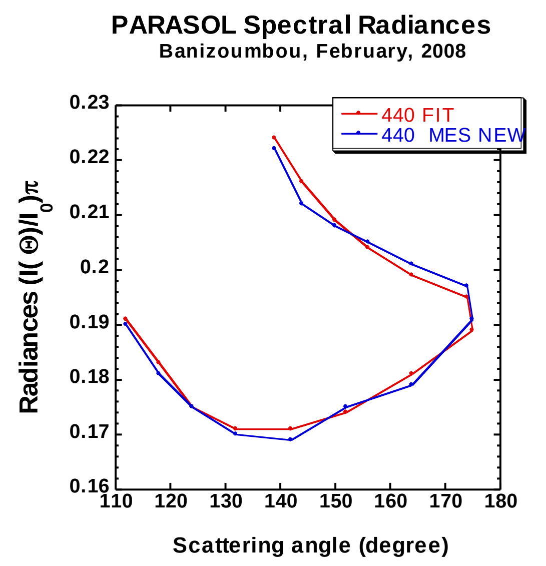
Changes in radiances

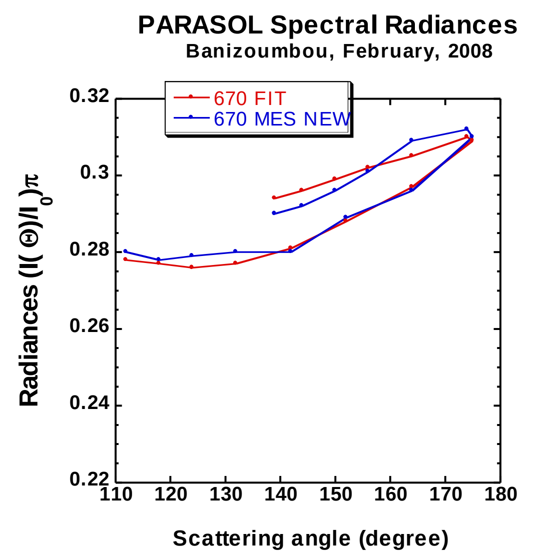


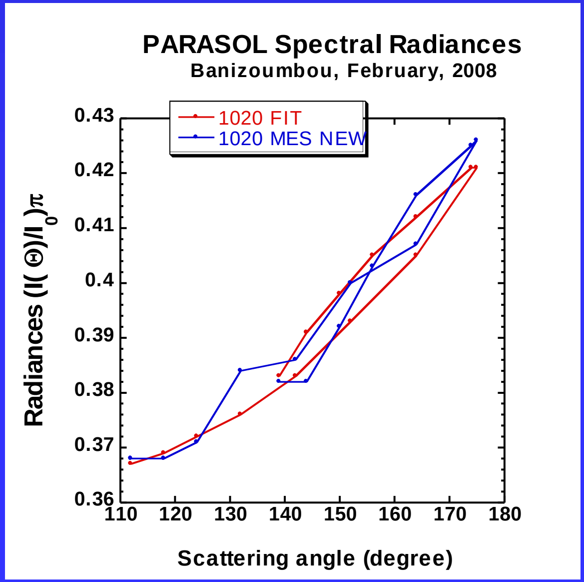




Fit of new radiances

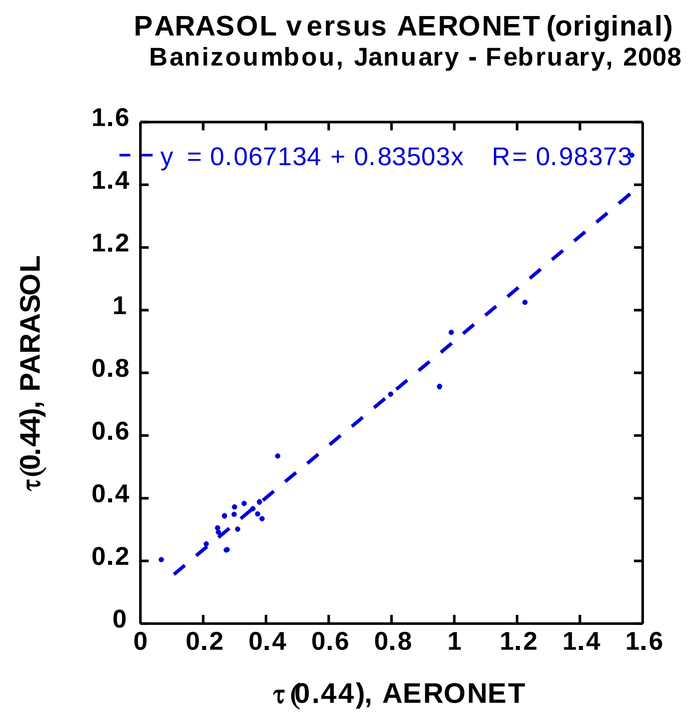




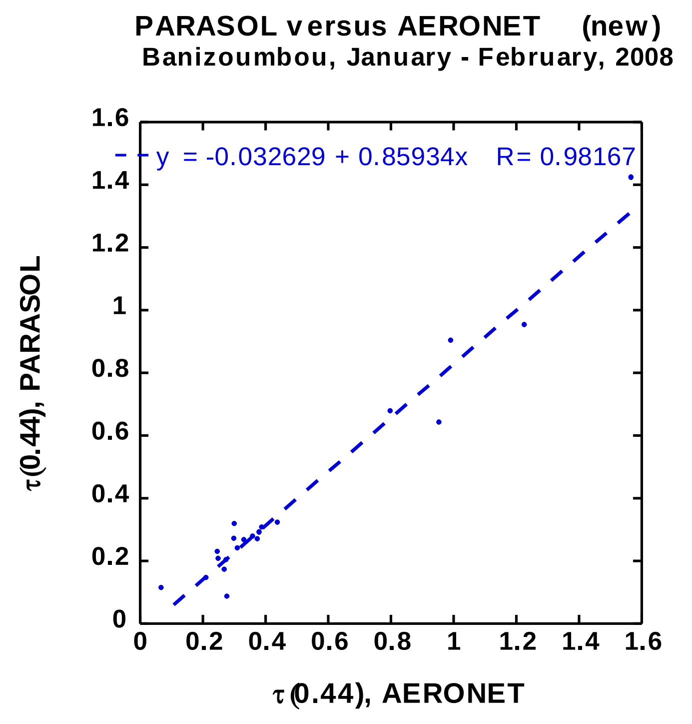


Changes in retrieved AOD (440) - DUST

Banizoumbou
(original)

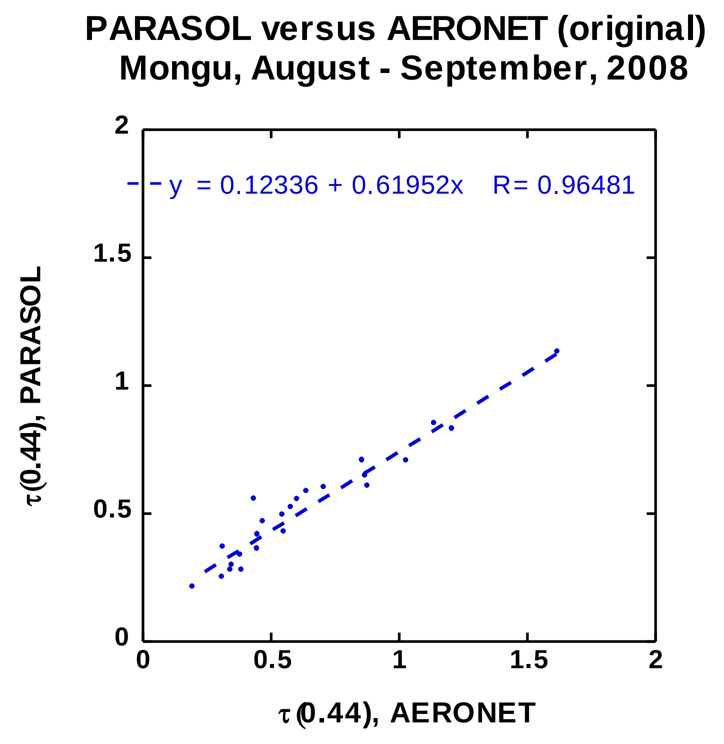


Banizoumbou
(new)



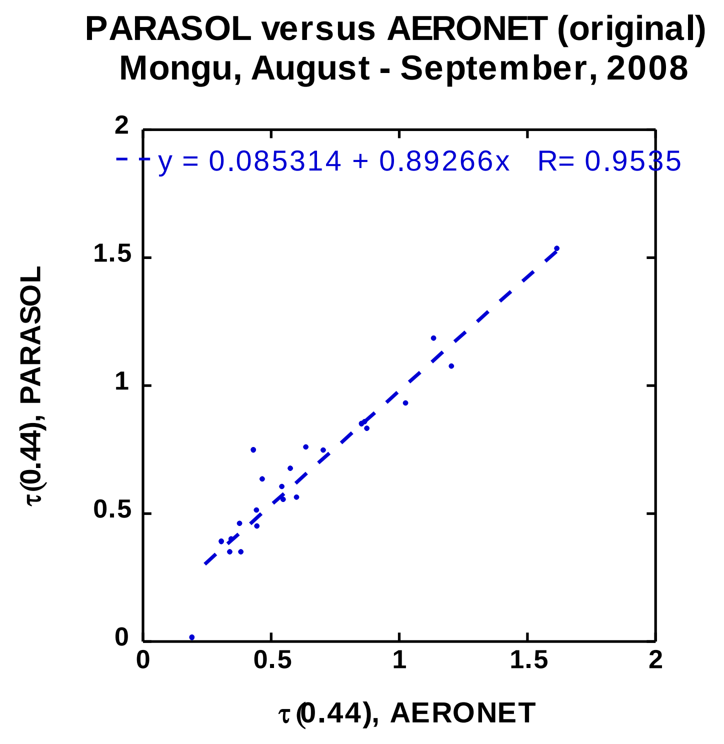
Changes in retrieved AOD (440)
(high loading)

Mongu
(original)



PARASOL versus AERONET (original)
Mongu, August - September, 2008

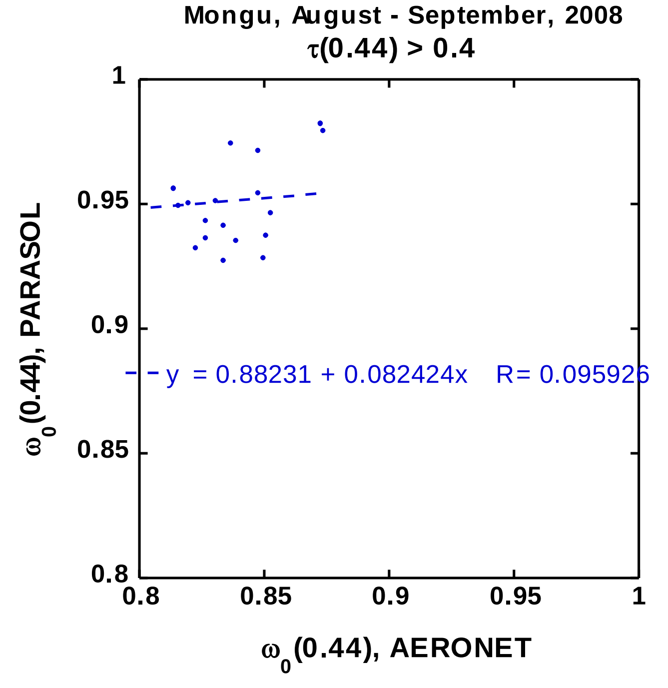
Mongu
(new)



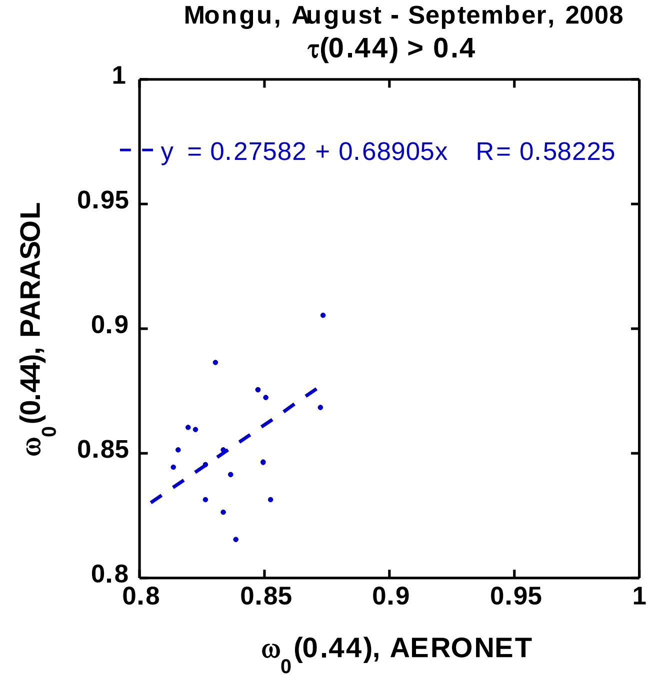
PARASOL versus AERONET (original)
Mongu, August - September, 2008

Changes in retrieved SSA (440) – BIOMAS BURNING (high loading)

Mongu
(original)



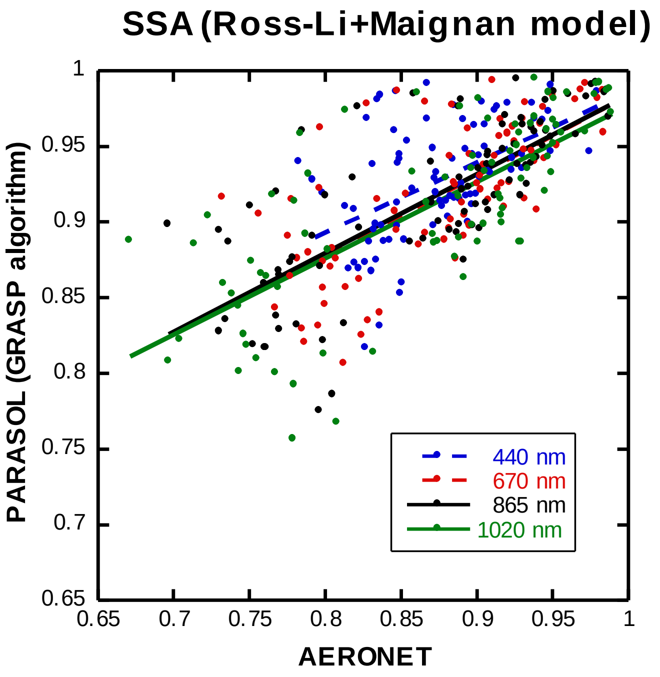
Mongu
(new)



Changes in retrieved SSA (4wl)
(high loading)

4 sites
(original)

Mongu + Banizoumbou
(new)

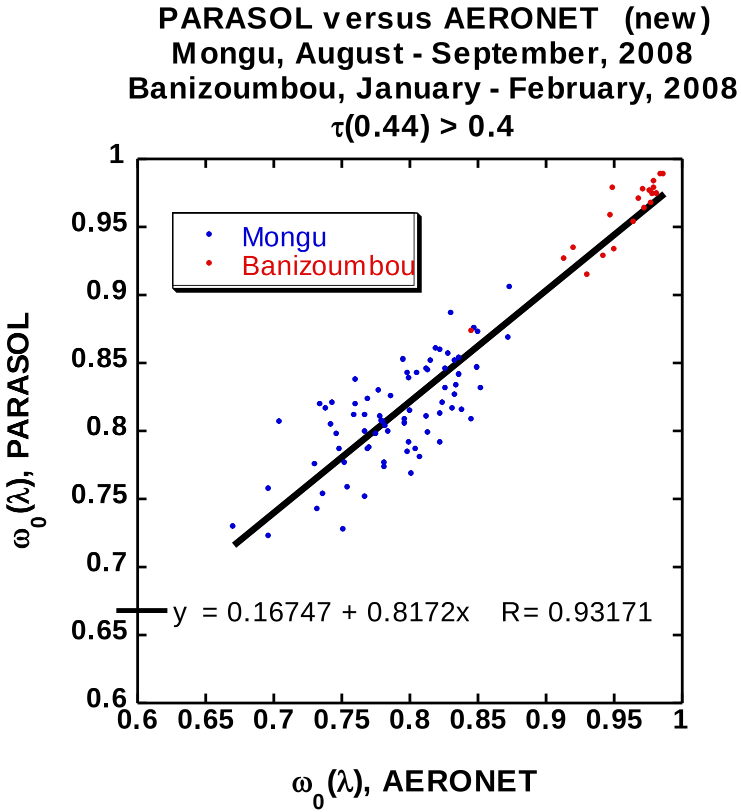


y = 0.52158 + 0.46416x R= 0.51609

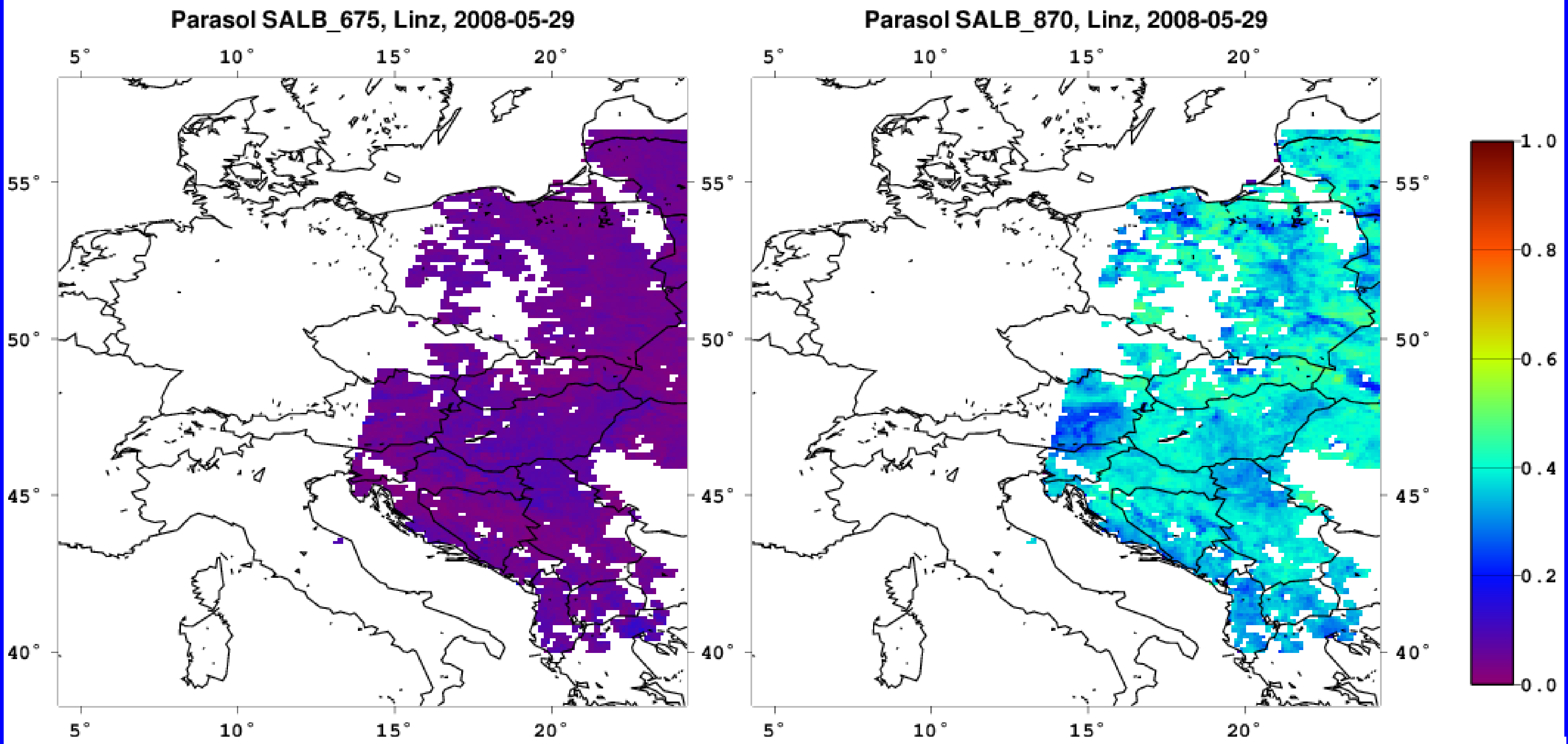
y = 0.45356 + 0.53003x R= 0.69705

y = 0.46263 + 0.52096x R= 0.752

y = 0.47302 + 0.50372x R= 0.72943

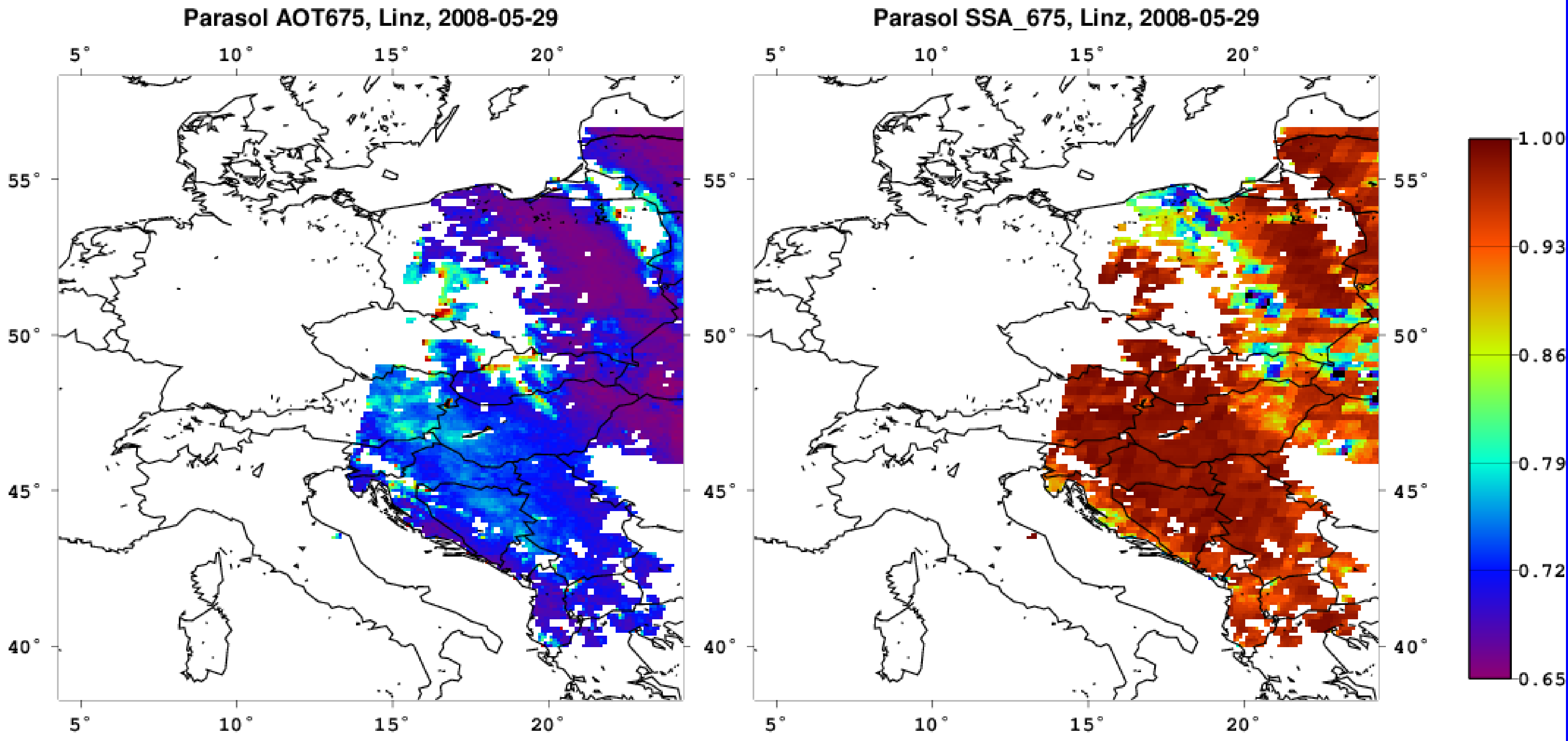


GRASP retrieval. Regional maps (1800 x 1800 km). *Europe, SALB 670 and 865 nm*



Big contrast between 670 and 865 nm because of vegetation!!!

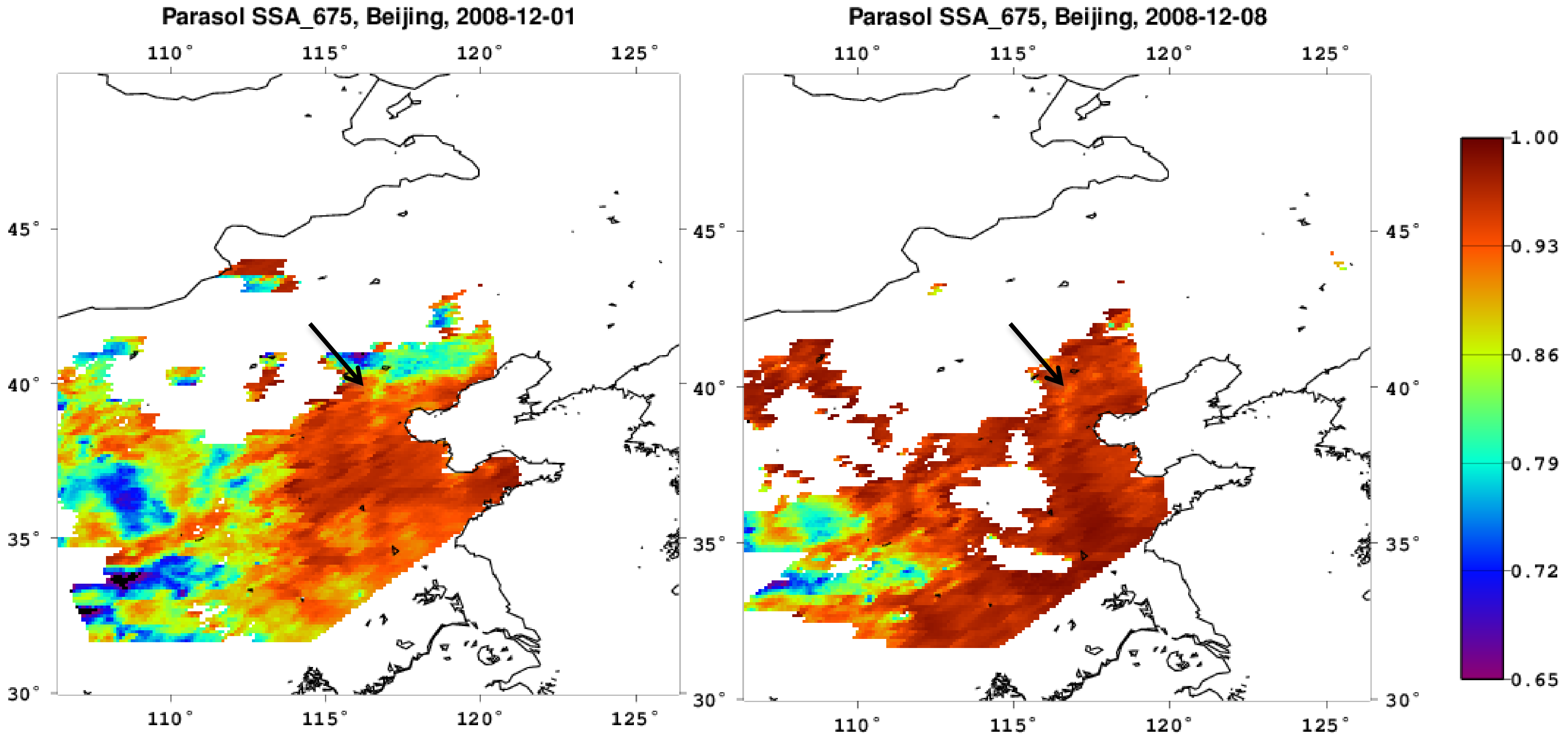
GRASP retrieval. Regional maps (1800 x 1800 km). *Europe, AOD and SSA 670 nm*


Parasol AOT675, Linz, 2008-05-29

Parasol SSA_675, Linz, 2008-05-29

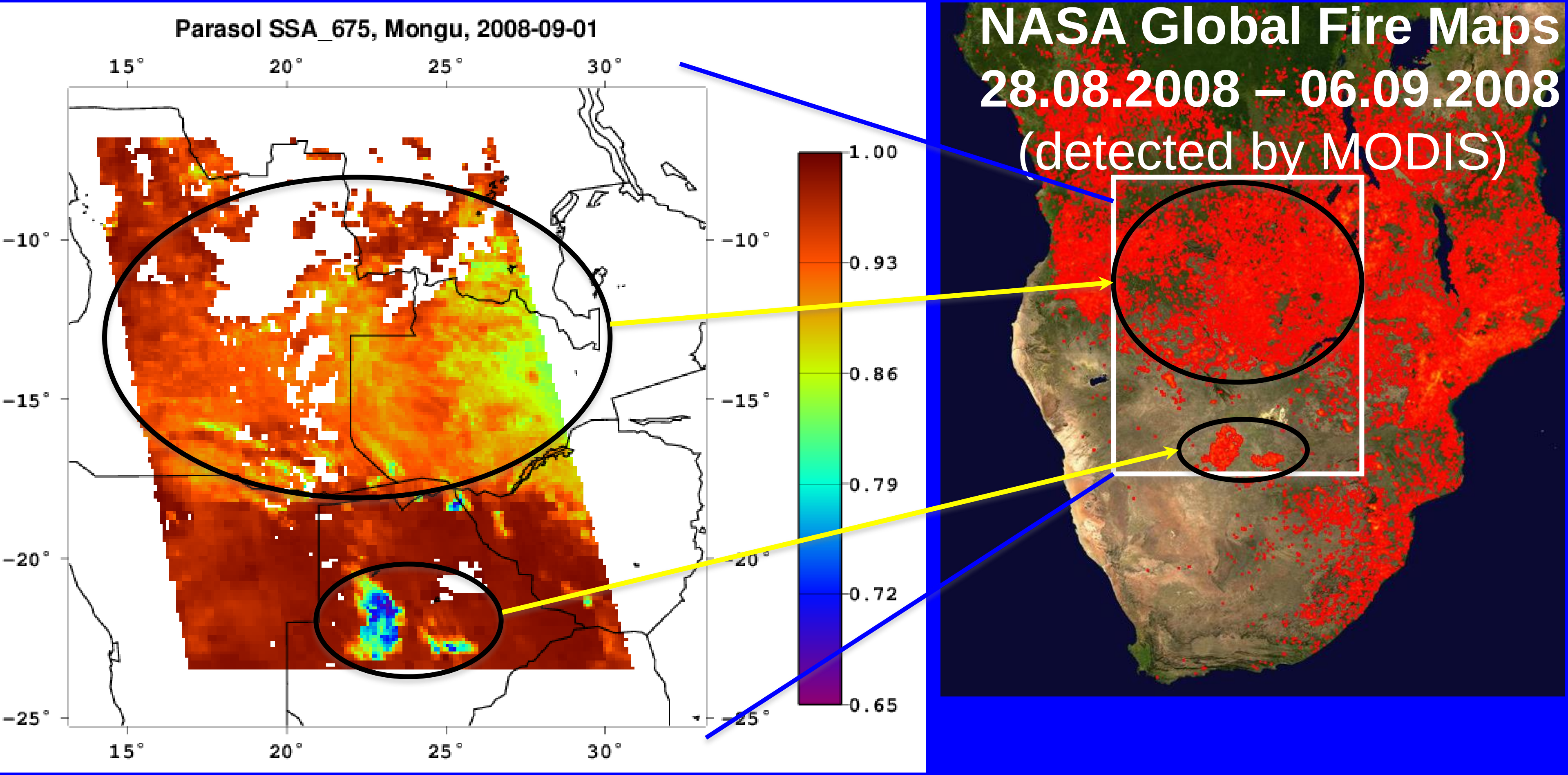
Strong spatial variation of AOD and SSA

GRASP retrieval. Regional maps (1800 x 1800 km). *Beijing, SSA 670 nm*



Strong spatial and temporal variation of SSA

GRASP retrieval. Regional maps (1800 x 1800 km). *Mongu, SSA 670 nm*



NASA Global Fire Maps
28.08.2008 – 06.09.2008
(detected by MODIS)

Small SSA correspond to biomass burning!

Dubovik et al., AMT, 2011

GRASP Status:

Core Algorithm is developed and performs well:

- uses very elaborated aerosol and RT models;
- inversion is based on rigorous statistical optimization;
- *performs well in numerical test (Dubovik et al. 2011, Kokhanovsky et al. 2010);*
- *has a lot of flexibility*
- GRASP is under acceleration on GPU;
- Cloud retrieval is to be integrated into GRASP;

Promises:

- Operational PARASOL aerosol product (SSA, etc.) in 2014;
- Open Source GRASP code is to be available to a wide community;
- Using GRASP for other sensors has some potential