Enhancement and restrictions of aerosol/surface properties retrieval over land: experience based on new POLDER retrieval algorithm GRASP

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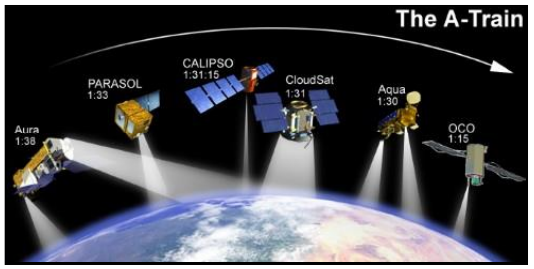
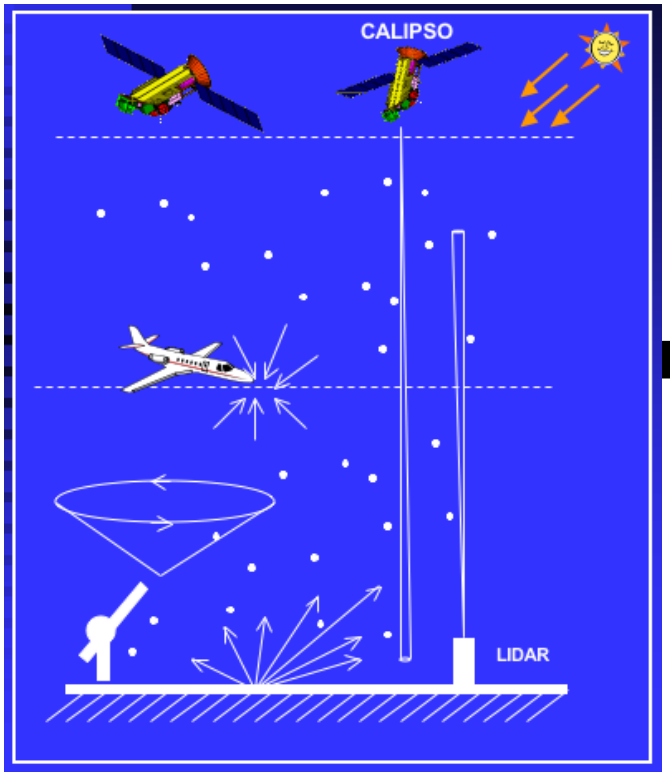
GRASP: algorithm for of multi-instrument remote sensing:



Co-incident:



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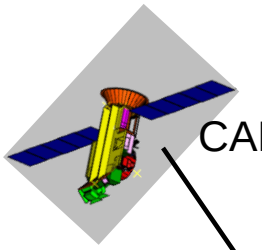
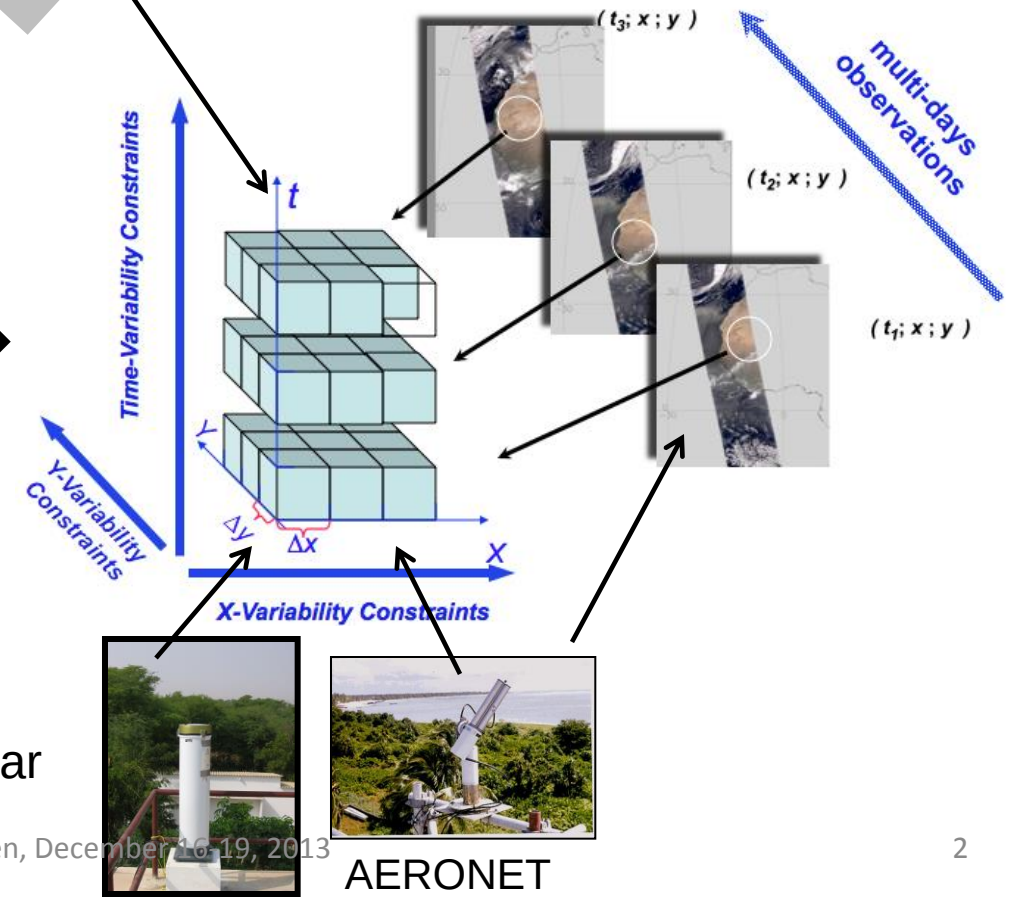


CALIPSO



lidar

AERONET

New POLDER/PARASOL algorithm (GRASP)
(Dubovik et al, AMT, 2011)

- The new algorithm uses complete set of PARASOL angular measurements in all spectral bands including both radiance and linear polarization measurements.

- Continuous space of aerosol and surface properties is used.

- The algorithm is based on statistically optimized fitting.

The core of the new PARASOL algorithm is based on the same concept as AERONET aerosol retrieval (***O. Dubovik and M. King, 2000; O. Dubovik, 2004; O. Dubovik et al, 2006***).

The concept of the algorithm

Two scenarios of retrieval (***Dubovik et al., AMT, 2011***):

- Conventional: **single-pixel retrieval** (each single pixel is inverted independently)

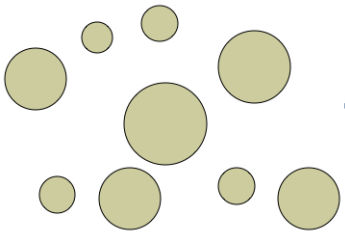
- New concept: **multiple-pixel retrieval** (group of pixels are inverted simultaneously)

GRASP aerosol model: the most comprehensive existent aerosol model

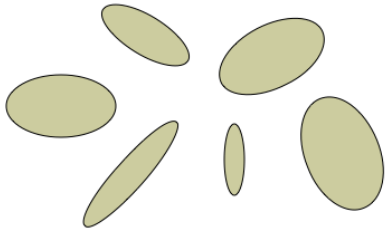
Aerosol model is the same as in AERONET retrieval (***Mixing of particle shapes (Dubovik et al., 2006)***)

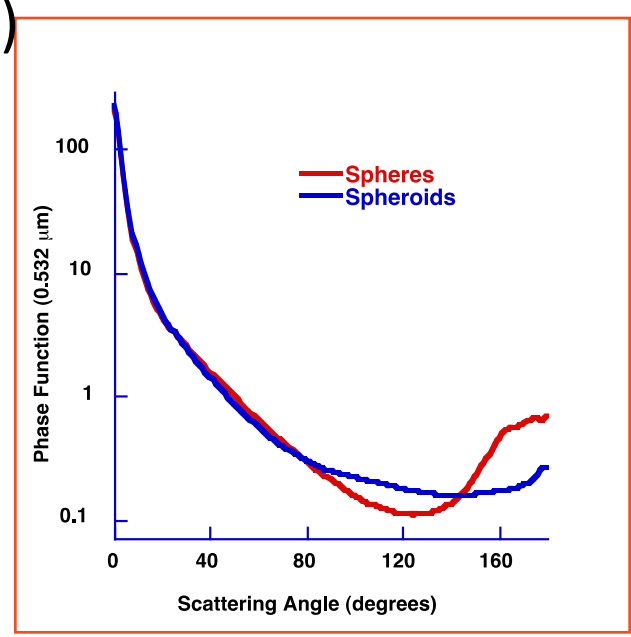
retrieved

C



+ (1-C)





$$0.012 \pounds x \pounds 625$$

$$1.3 \pounds n \pounds 1.7$$

$$1\times10^{-10} \pounds k \pounds 0.5$$

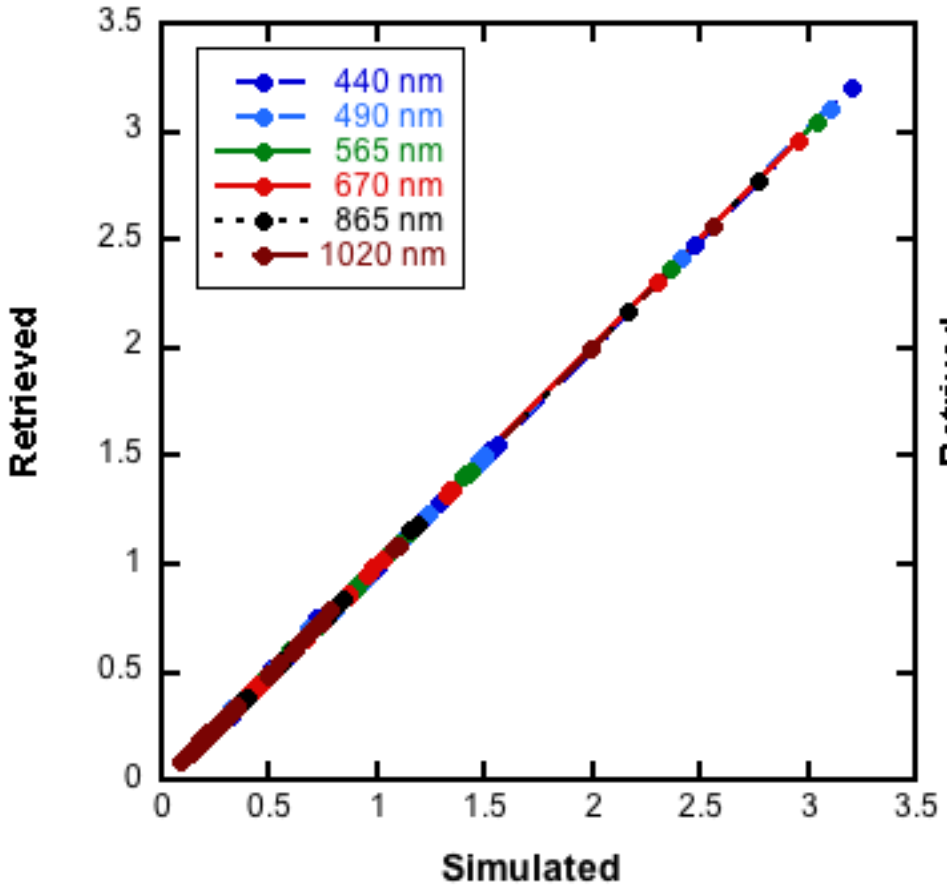
Surface reflection model

- ***Semi-empirical*** models for **surface total reflectance** description:
  - RPV model (***Rahman et al., (1993)***)
  - Ross-Li (***Ross, (1981); Li, X., Strahler (1992)***)
  - Ross-Roujean model (***Roujean et al., (1992)***)
- ***Semi-empirical*** models for **surface polarized reflectance** description:
  - Nadal-Breon model (***Nadal and Bréon, (1999)***)
  - Maignan model (***Maignan et al., (2009)***)
  - Fresnel facet model for Gaussian surfaces (***Litvinov et al., 2011***)
- ***Physically based*** models for **reflection matrix** for surfaces:
  - Cox-Munk model (for aerosol retrieval over ocean)
  - Physical models for land surface reflection matrix (***Litvinov et al., 2012***)

Synthetic measurements retrieval

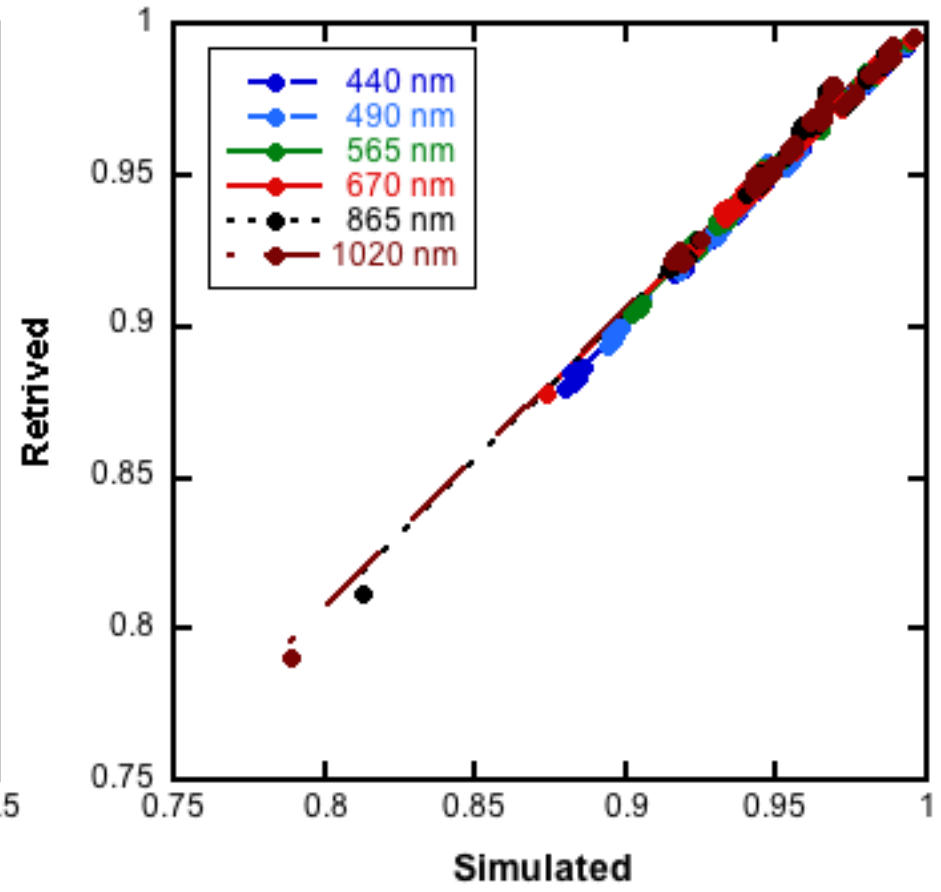
- We simulated **2 months of PARASOL measurements**
- **Aerosol and surface** properties and **aerosol concentration** were taken typical for Banizoumbou in January, February 2008.
- **The geometry** is the same as for PARASOL measurements over Banizoumbou in January, February 2008.
- **Physical models** for land surface reflection matrix (***Litvinov et al., 2012***) was used in the simulation.

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

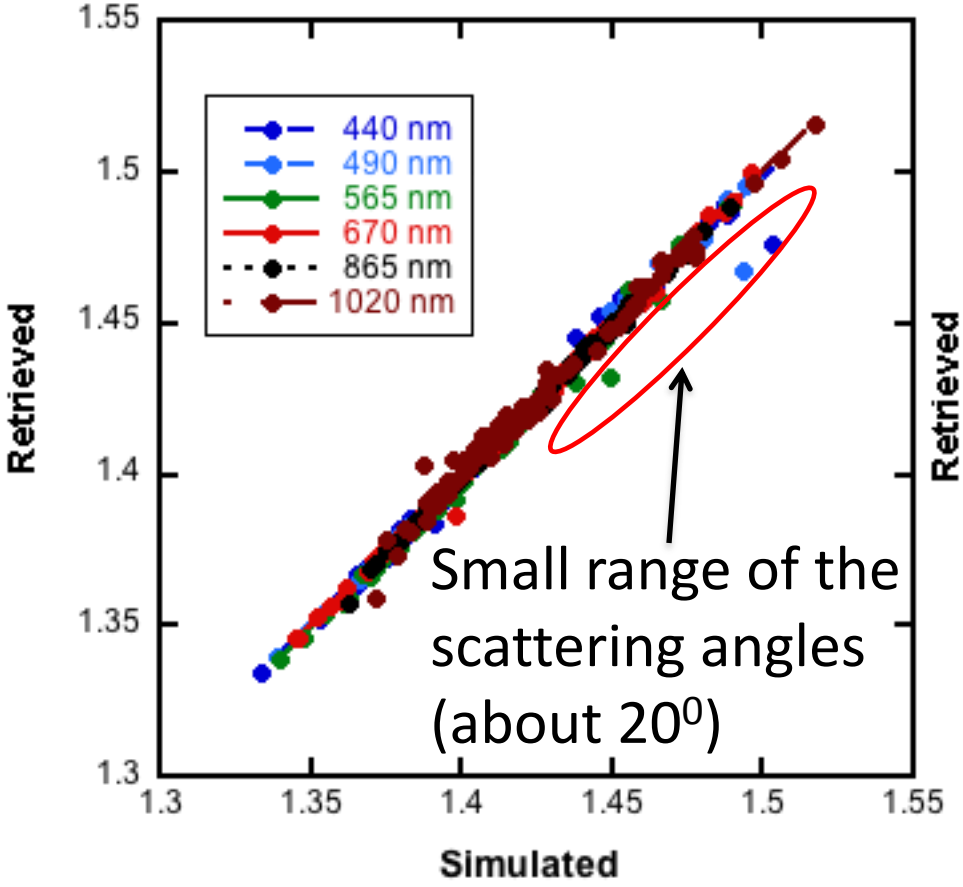


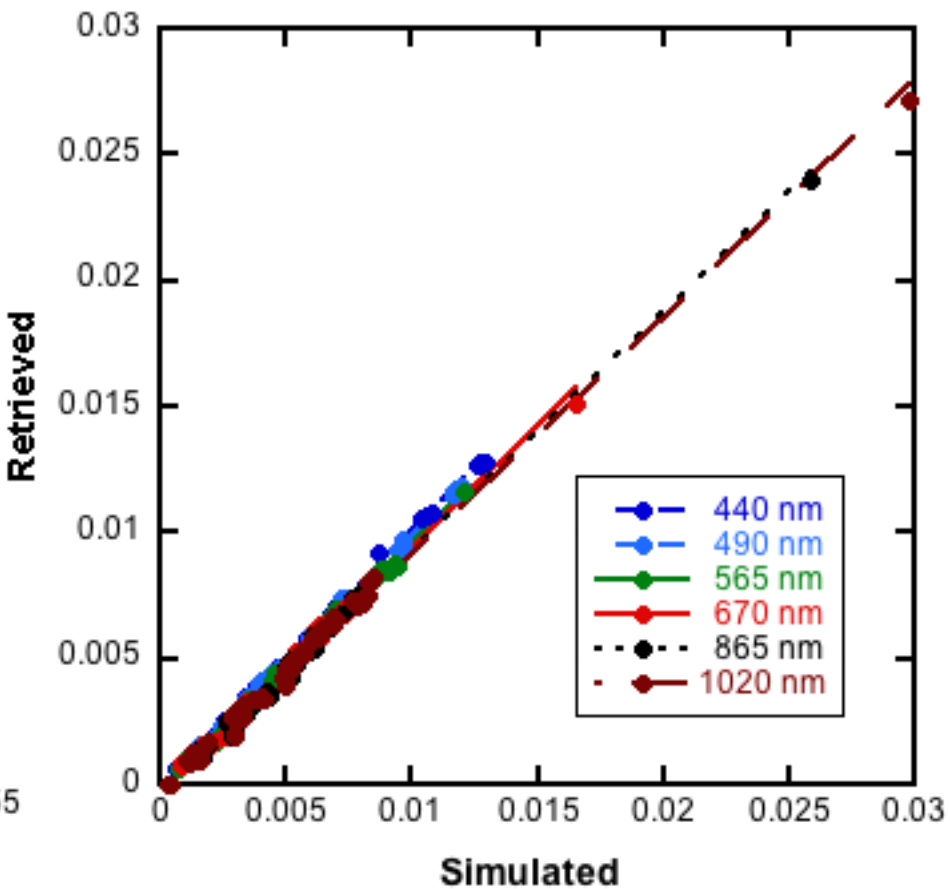
y = -0.0043839 + 1.0023x R= 0.99995
y = -0.0045597 + 1.0029x R= 0.99996
y = -0.0056832 + 1.0029x R= 0.99997
y = -0.0052555 + 1.0031x R= 0.99998
y = -0.0057708 + 1.0041x R= 0.99998
y = -0.0053979 + 1.0049x R= 0.99996

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



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





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

y = -0.00011281 + 1.0118x R= 0.99928

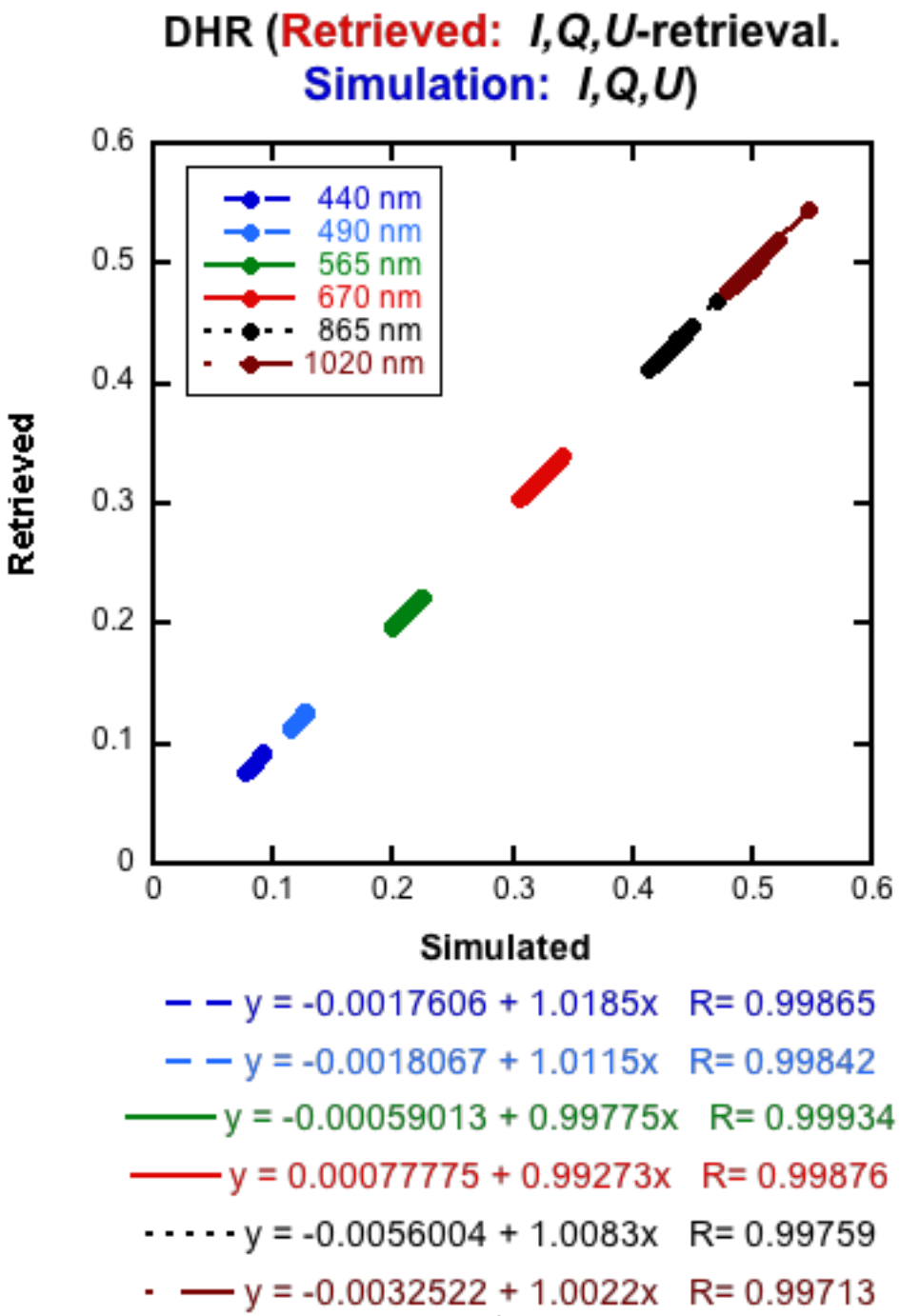
y = -0.00010855 + 1.0028x R= 0.99909

y = -0.00017203 + 0.97747x R= 0.99852

y = -0.00013111 + 0.96086x R= 0.99782

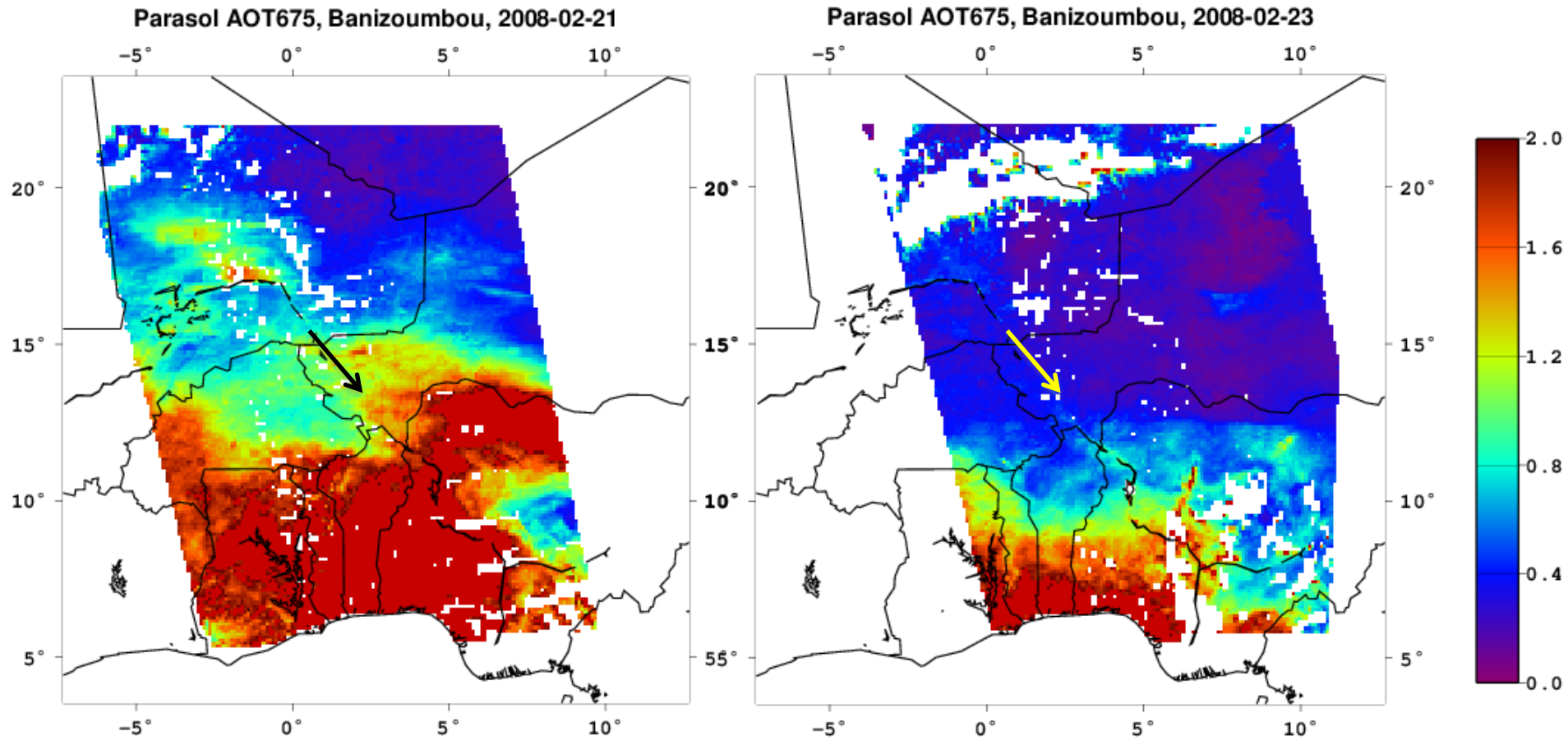
y = -0.00021565 + 0.95096x R= 0.99732

y = -0.0001892 + 0.93962x R= 0.99711


DHR (Retrieved: I,Q,U-retrieval.
Simulation: I,Q,U)
440 nm
490 nm
565 nm
670 nm
865 nm
1020 nm
Retrieved
Simulated
0
0.1
0.2
0.3
0.4
0.5
0.6
y = -0.0017606 + 1.0185x R= 0.99865
y = -0.0018067 + 1.0115x R= 0.99842
y = -0.00059013 + 0.99775x R= 0.99934
y = 0.00077775 + 0.99273x R= 0.99876
y = -0.0056004 + 1.0083x R= 0.99759
y = -0.0032522 + 1.0022x R= 0.99713

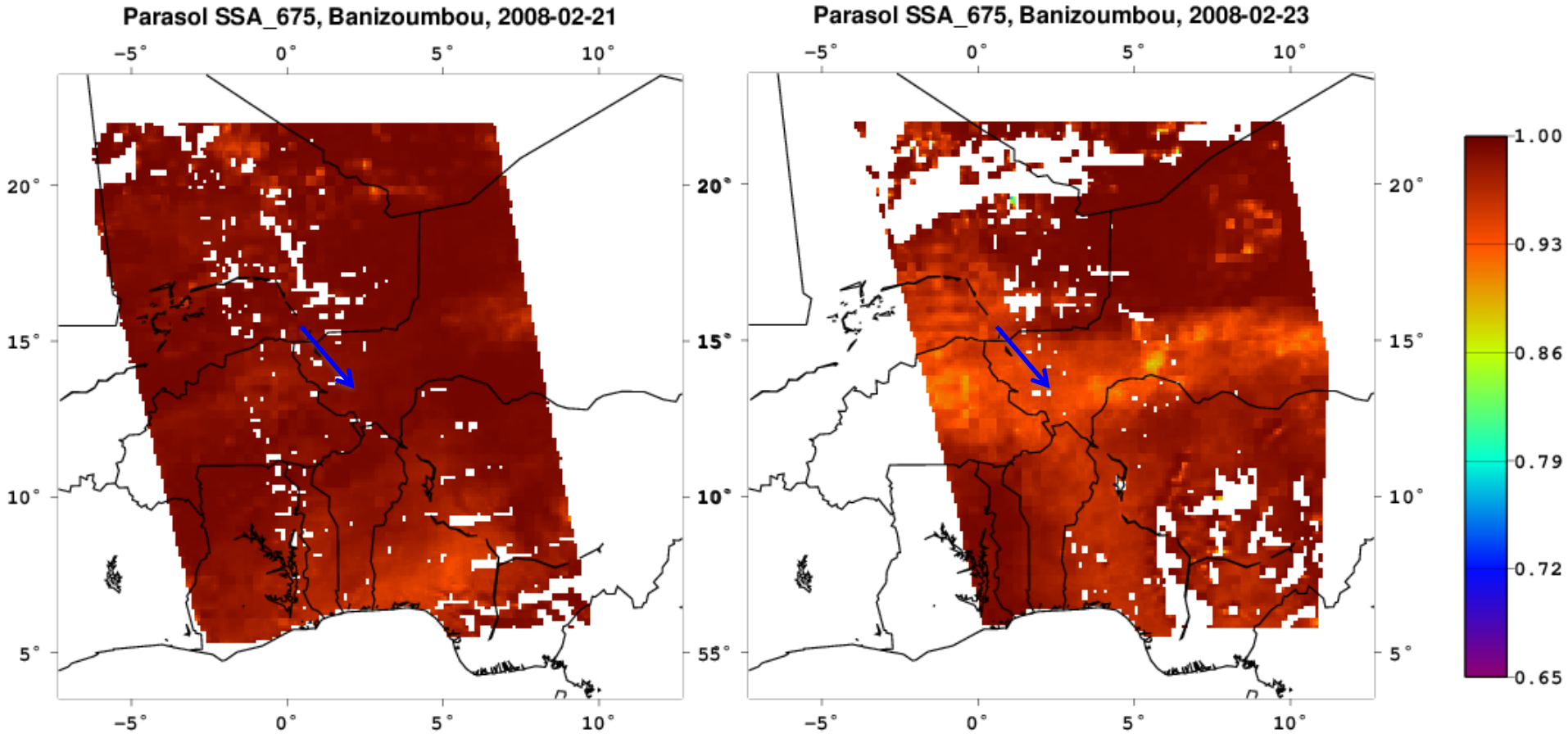
When aerosol and surface models are accurate enough, GRASP algorithm provides highly accurate retrieval of extended aerosol and surfaces properties!!!

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



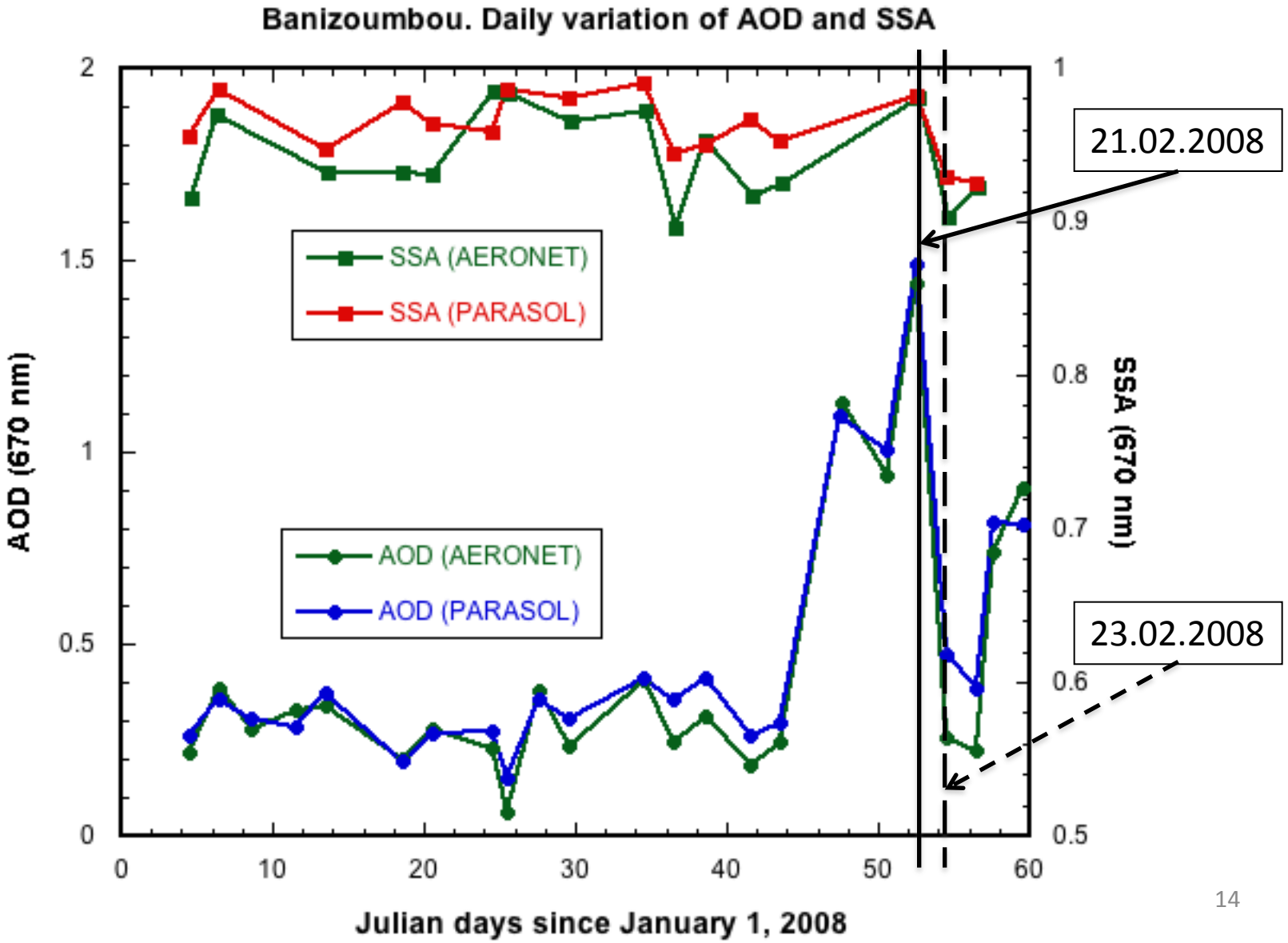
Strong spatial and temporal variation of AOD

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

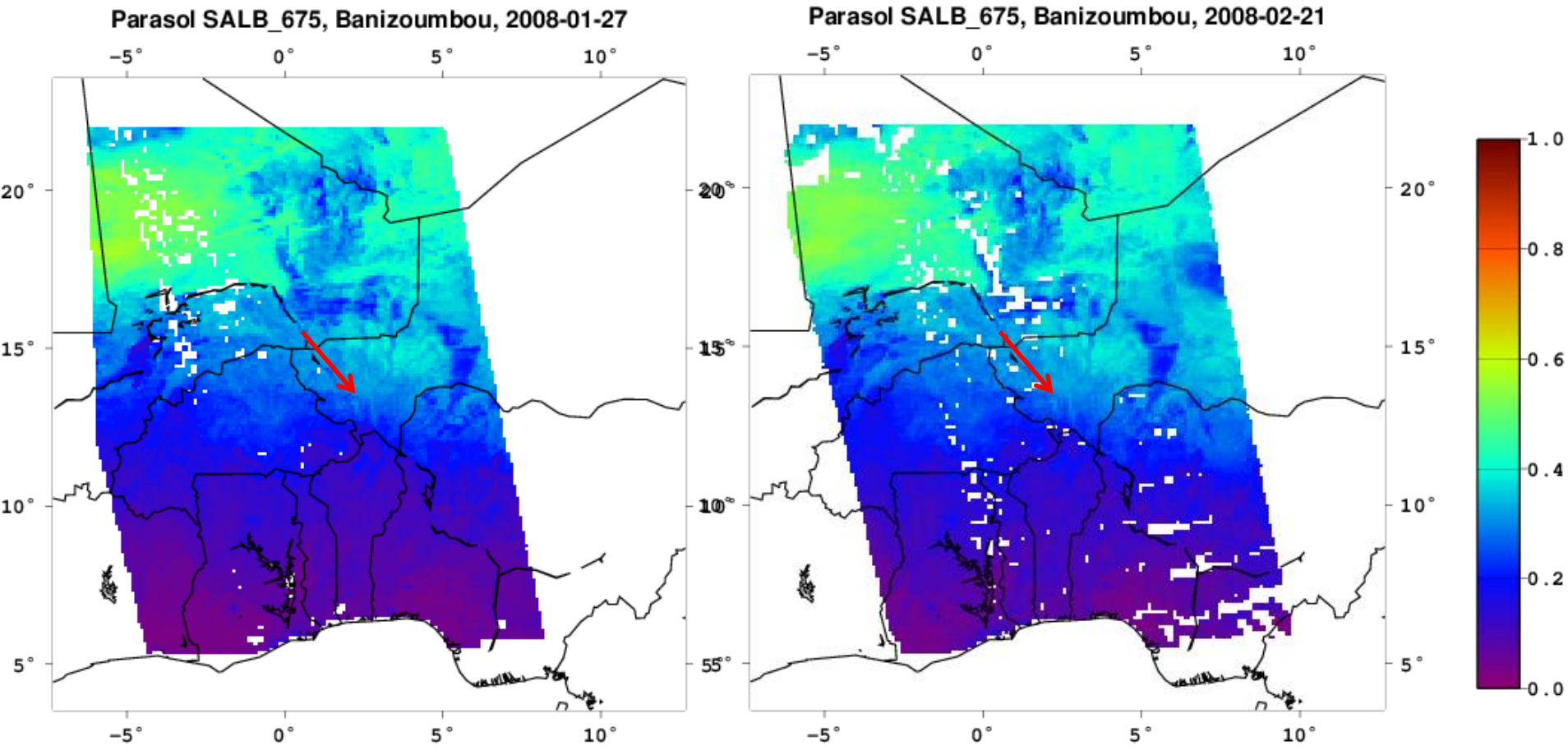


Essential temporal variation of SSA

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

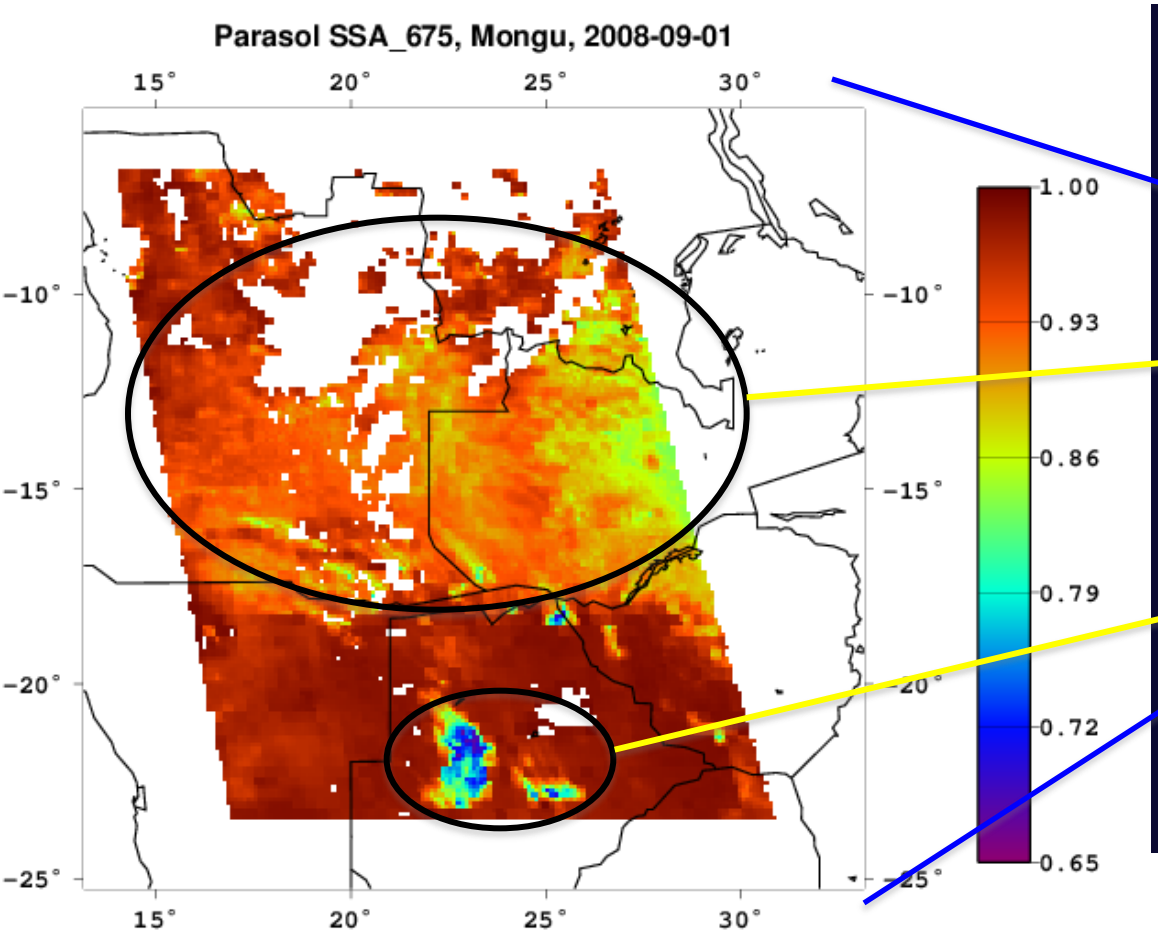


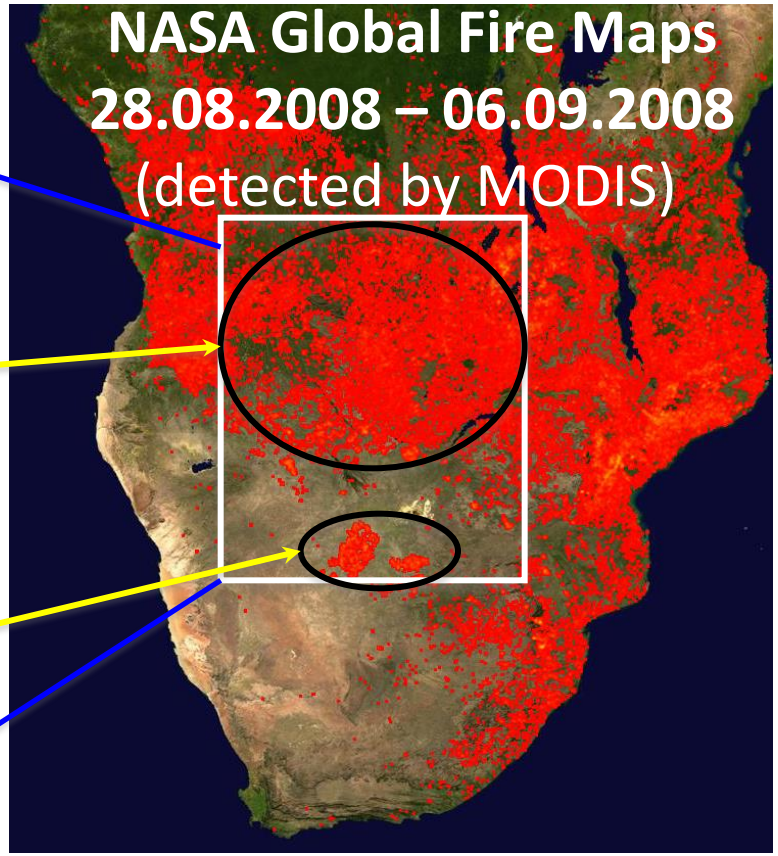
Regional maps (1800 x 1800 km). Banizoumbou, SALB 670 nm



Surface is very stable for Jan. and Febr.!

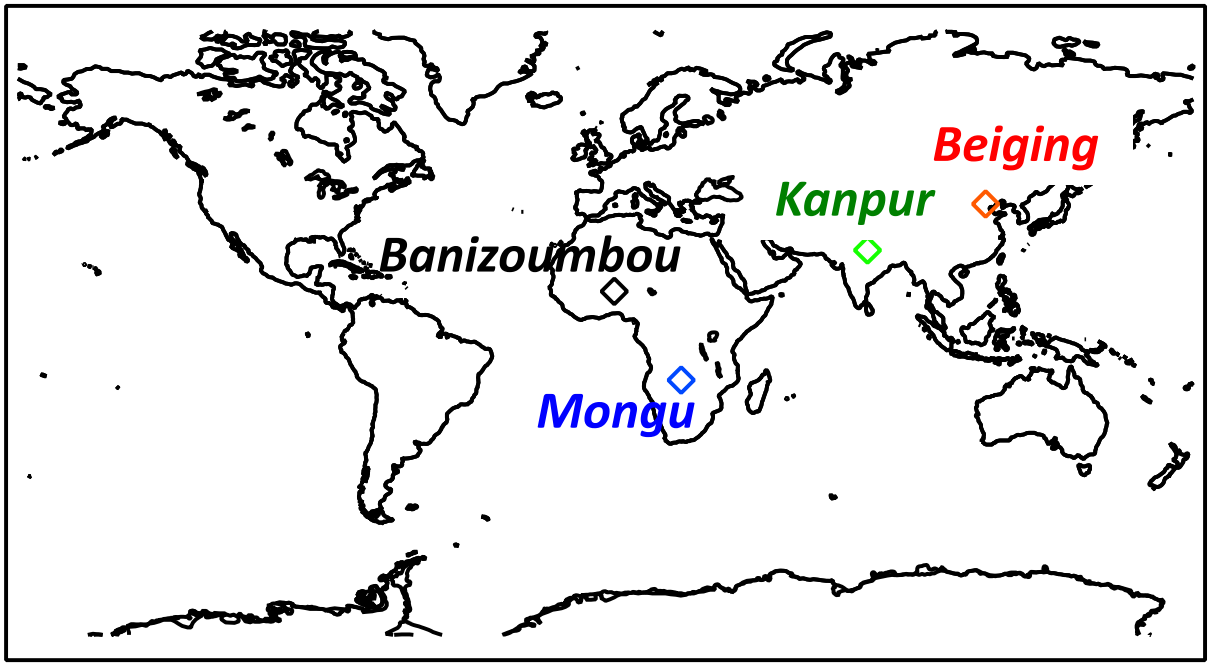
GRASP retrieval. Regional maps (1800 x 1800 km). *Mongu, SSA 670 nm*





Small SSA correspond to biomass burning!

Comparison with AERONET



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*

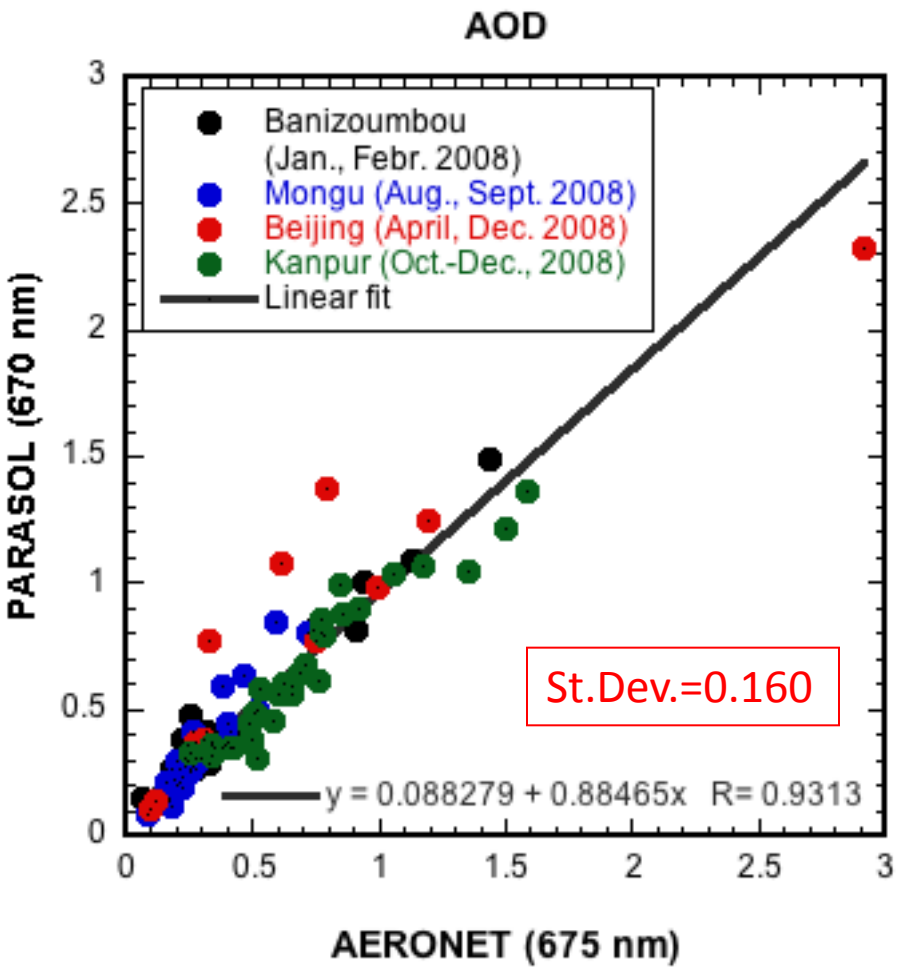
Surface: Urban. **Aerosol:** Fine and Coarse modes.

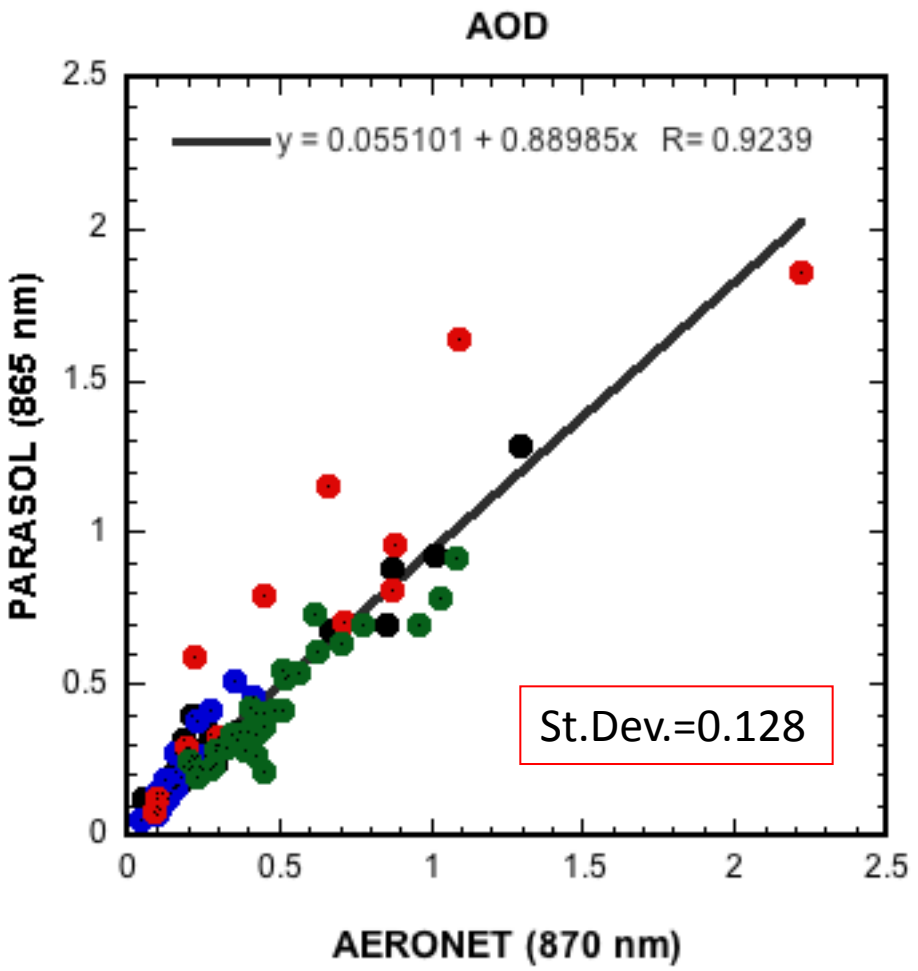
Kanpur: *October-December, 2008*

Surface: Urban. **Aerosol:** Fine and Coarse modes.

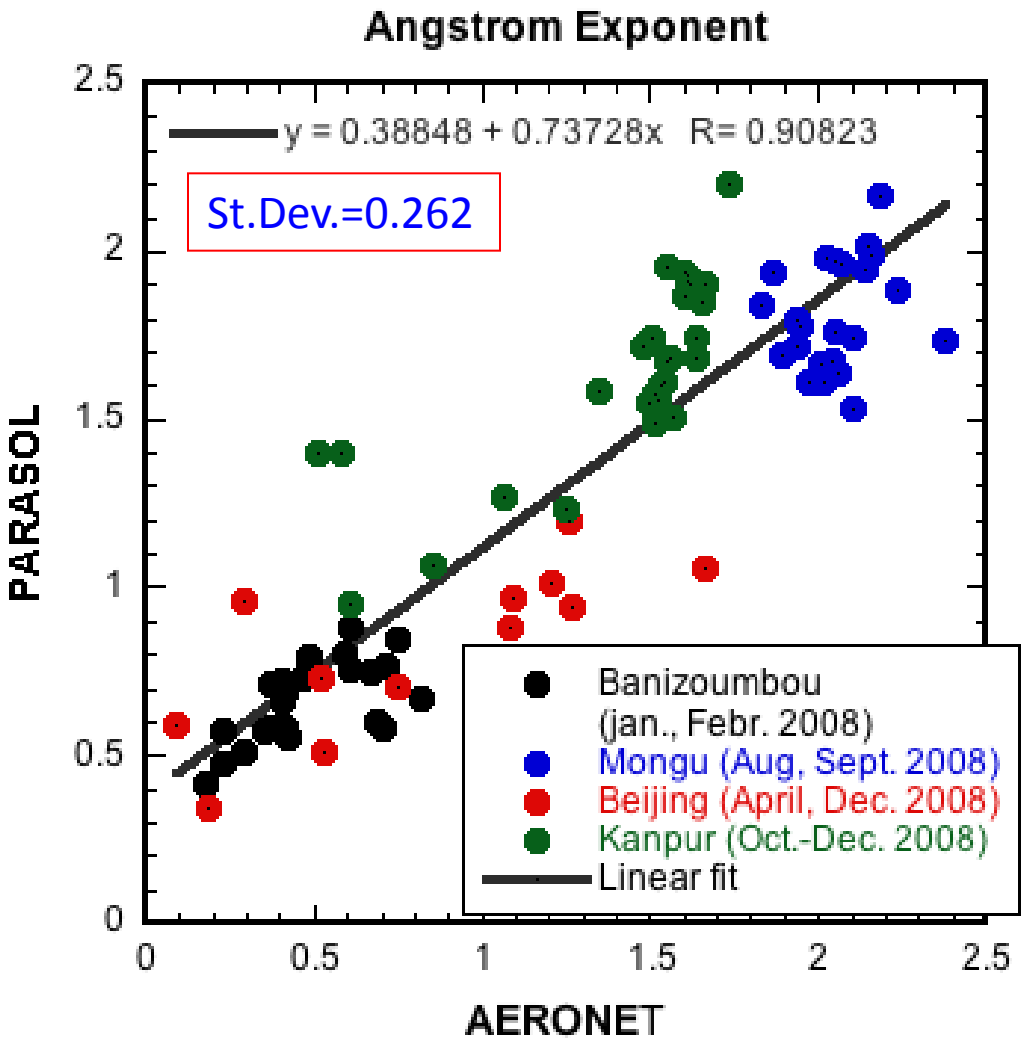
The IGBP (International Geosphere Biosphere Programme) land type specification was used

AOD. POLDER/AERONET

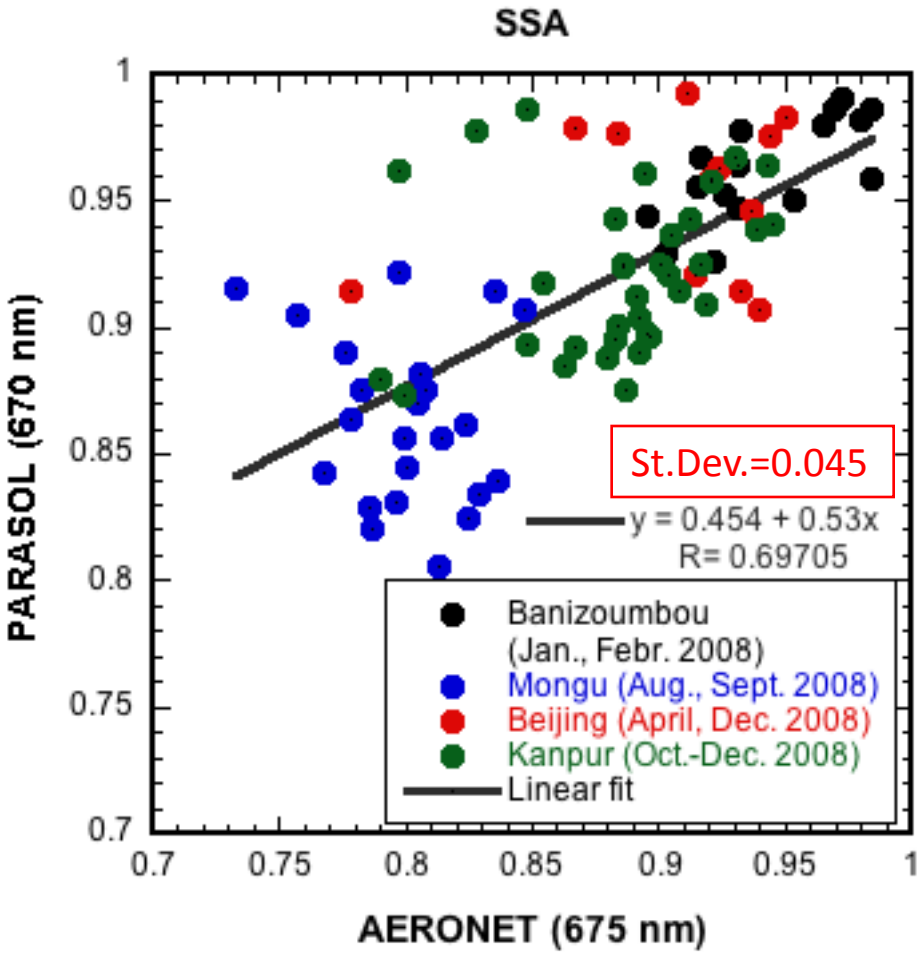


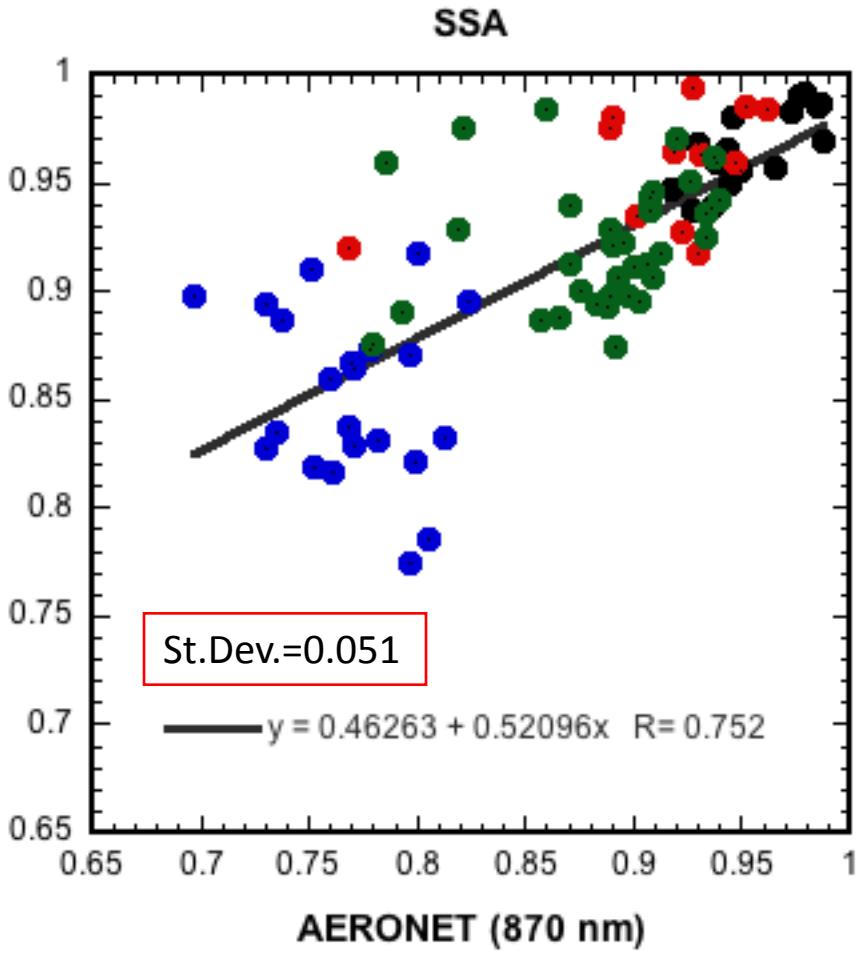


Angstrom Exponent.
POLDER/AERONET

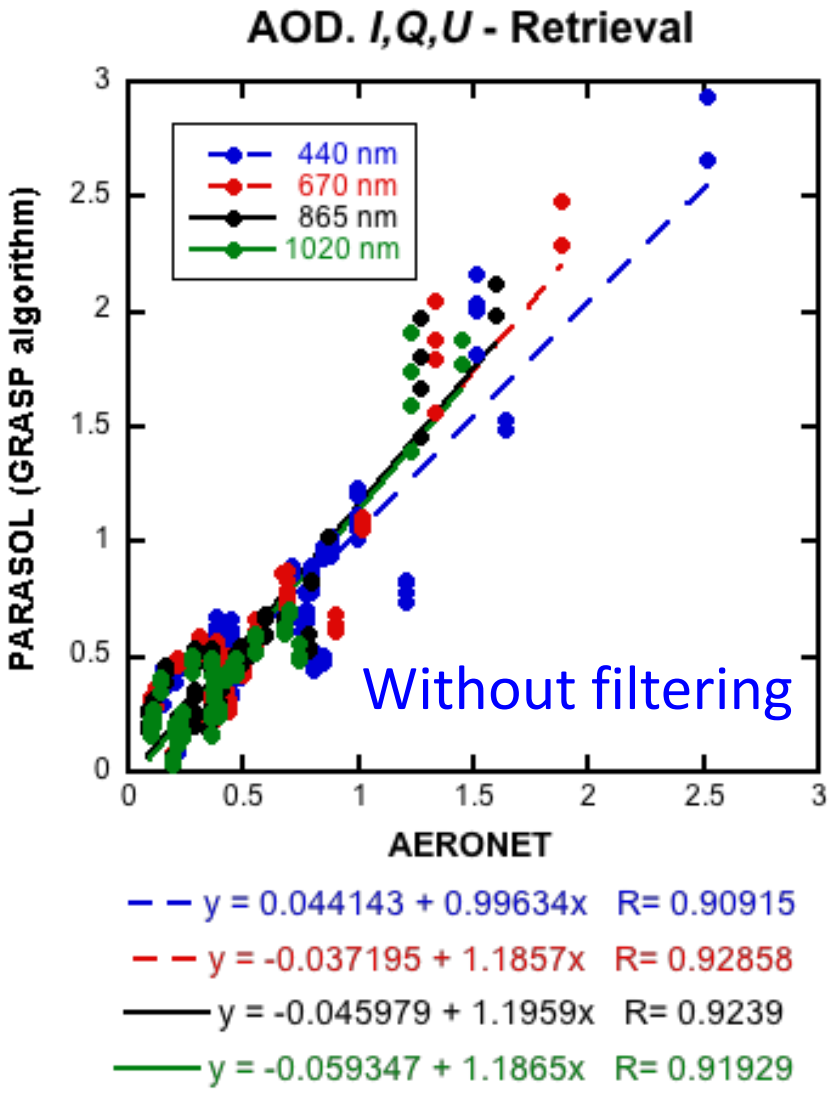


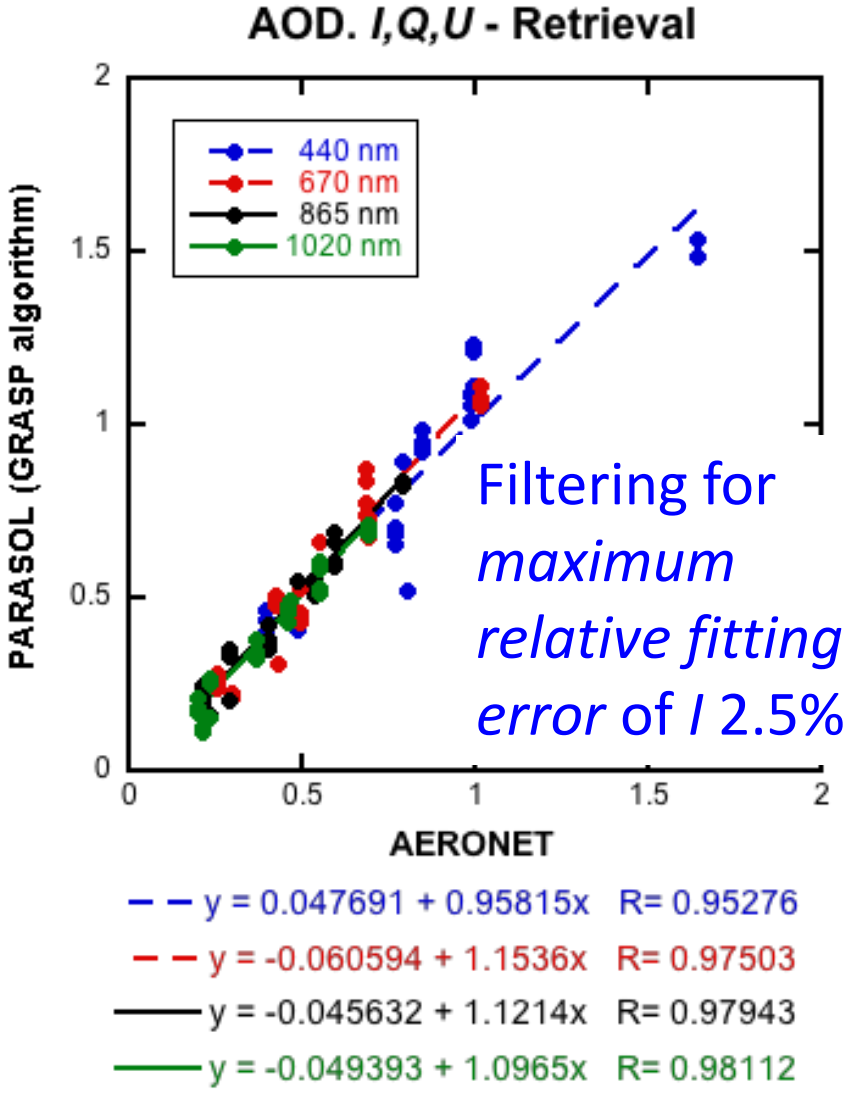
SSA. POLDER/AERONET





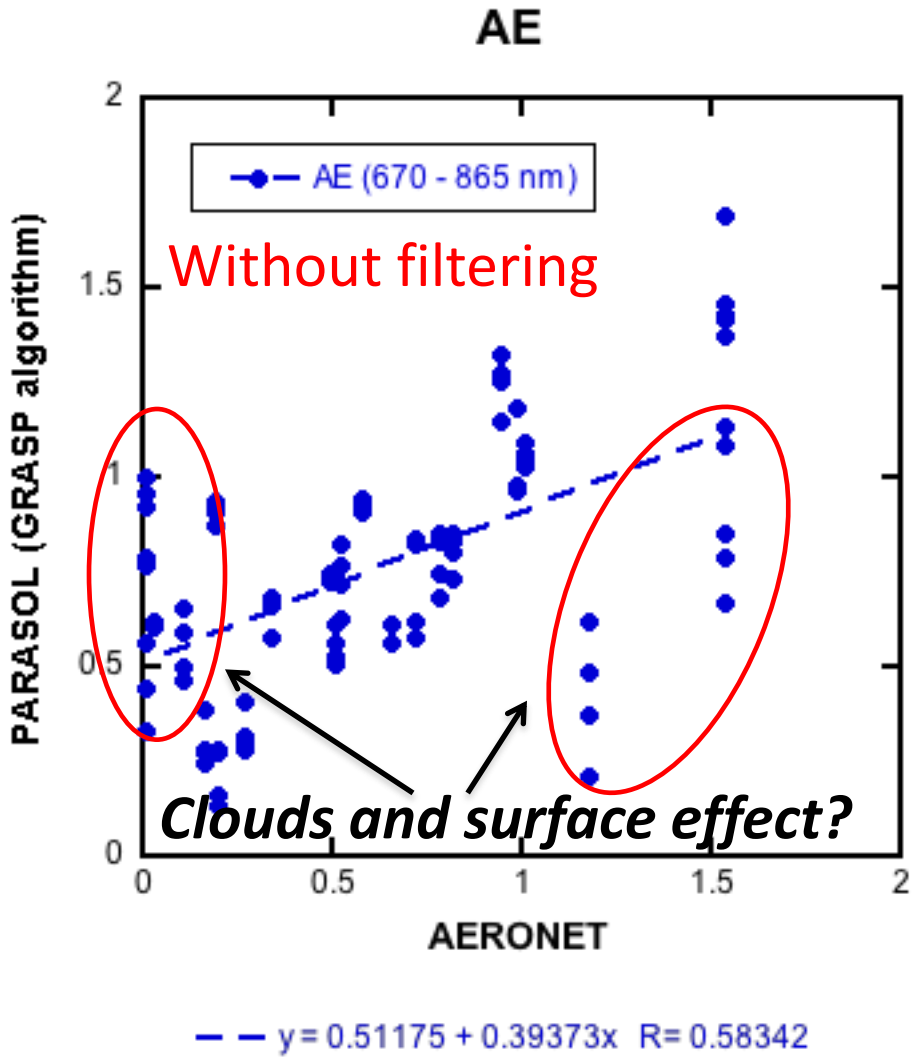
Selected AERONET station. (XiangHe, March – May. 2006).

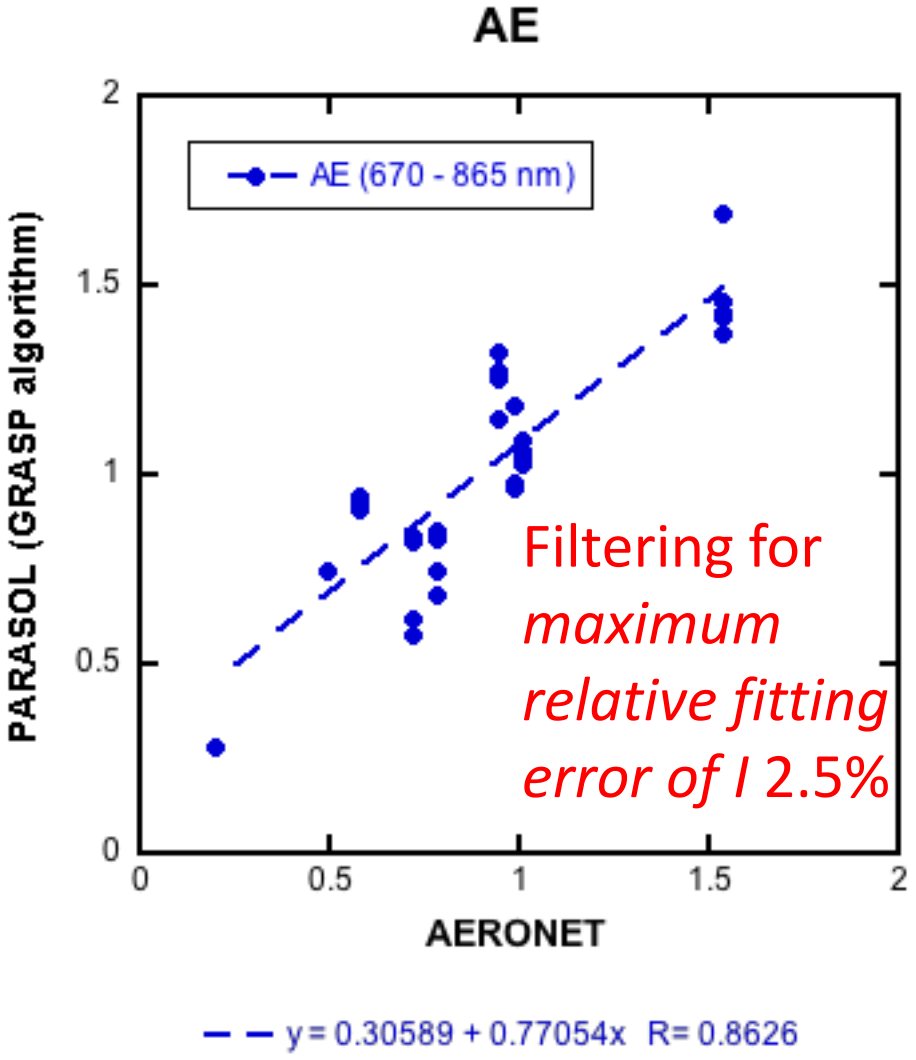




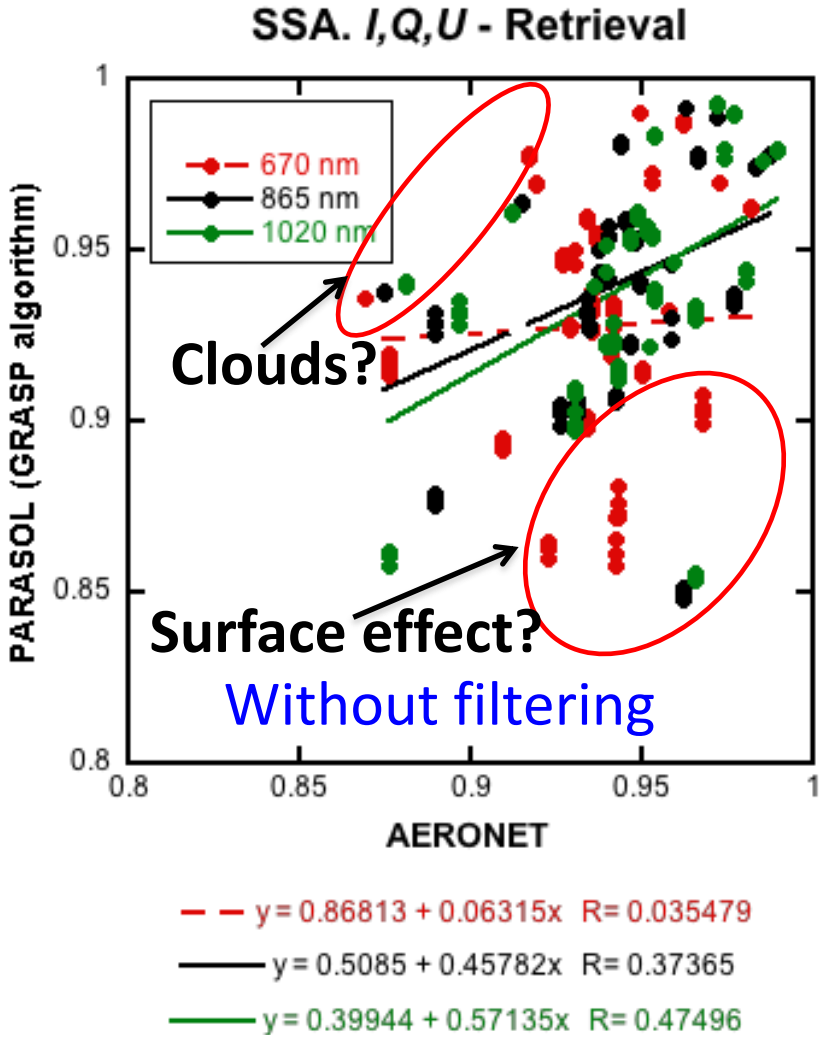
Filtering cuts both large and small AOD (*cloud contamination and surface modeling effect?*)

Selected AERONET station. (XiangHe, March – May. 2006).

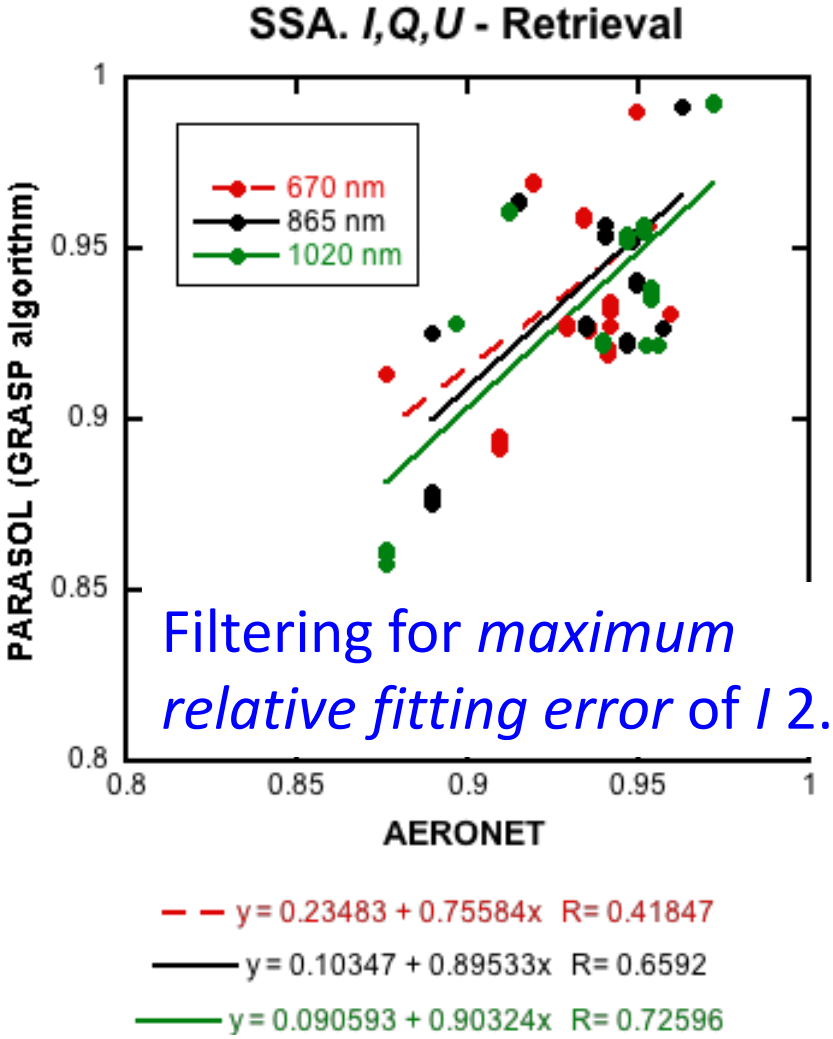




Selected AERONET station. (XiangHe, March – May. 2006).



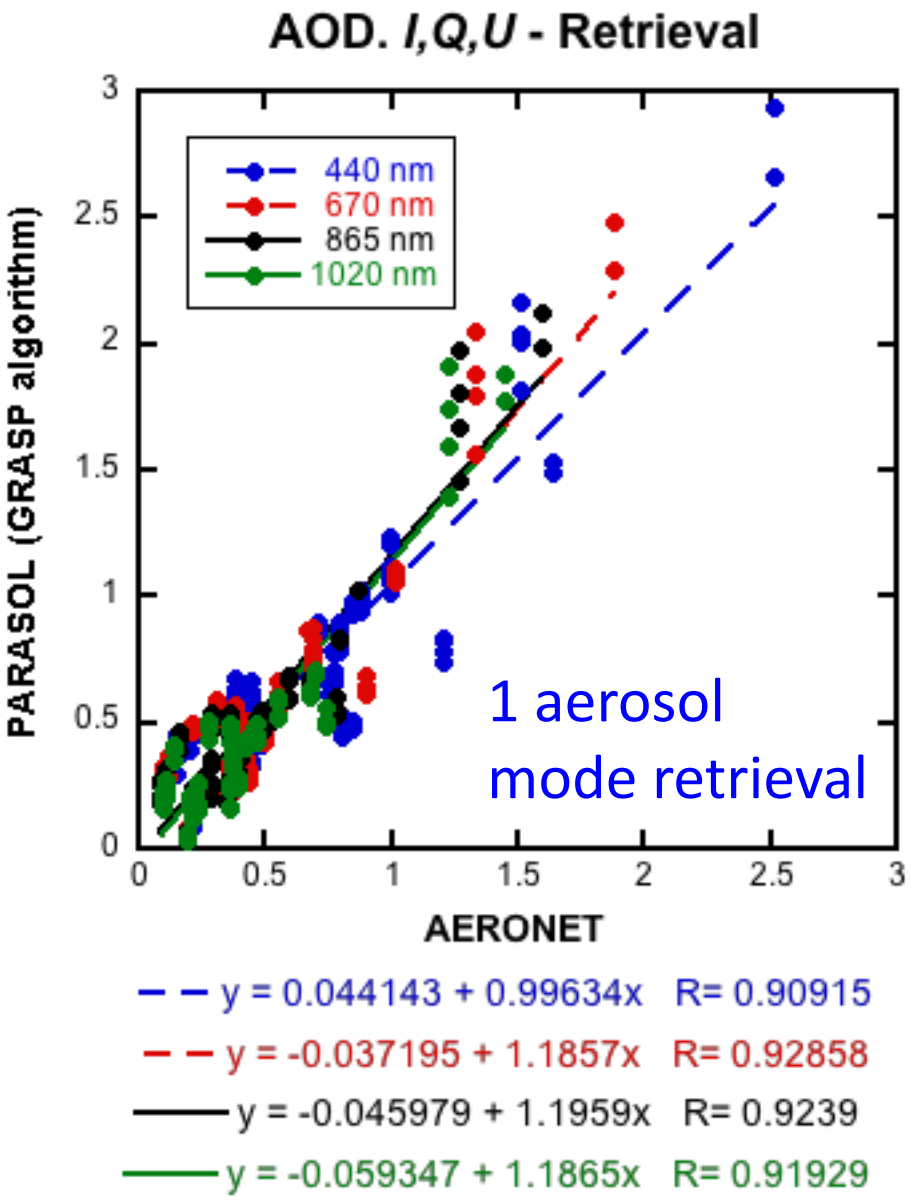
Without filtering

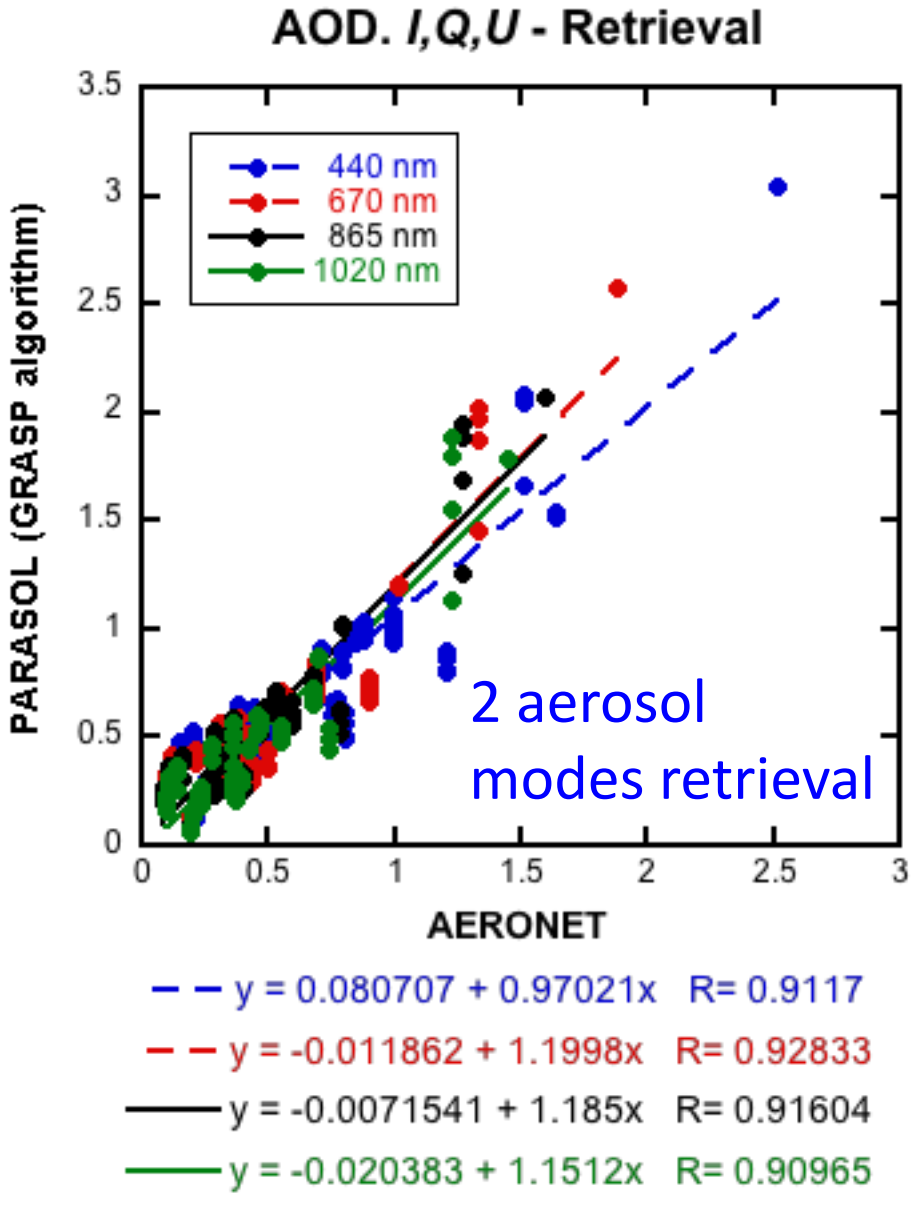


Filtering for *maximum relative fitting error* of *I* 2.5%

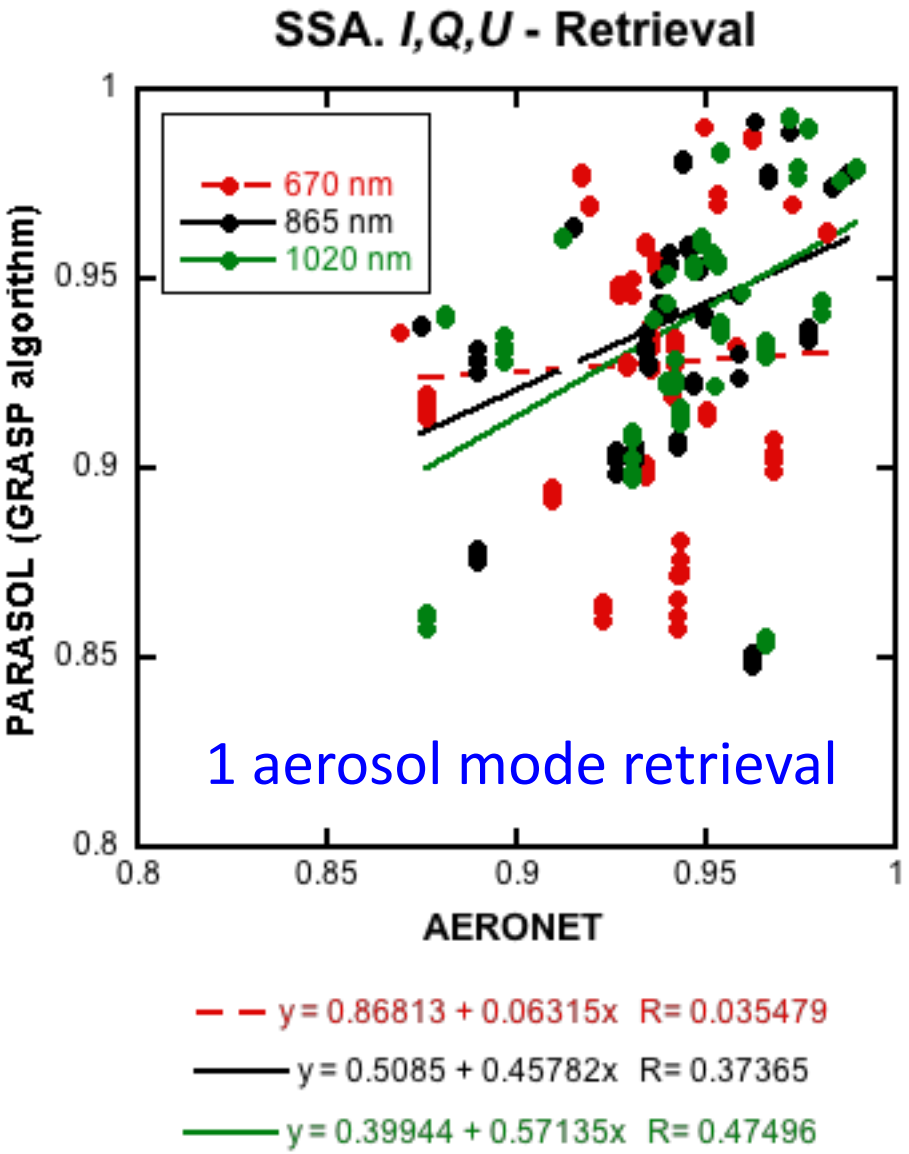
Surface reflection and aerosol/clouds interaction are the main challenges of enhanced aerosol characterization!

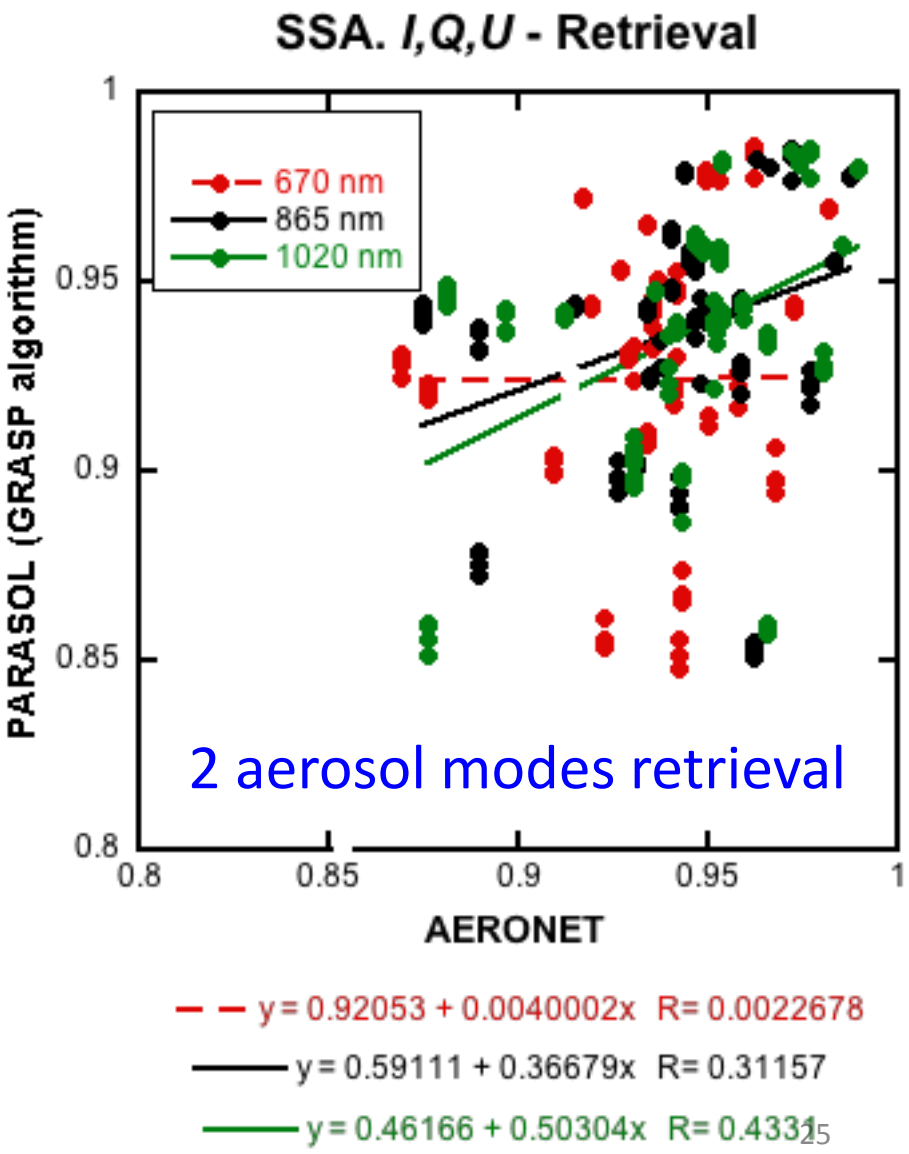
1 aerosol mode retrieval vs 2 modes (different *m, size distribution*). XiangHe, China, March-May, 2006



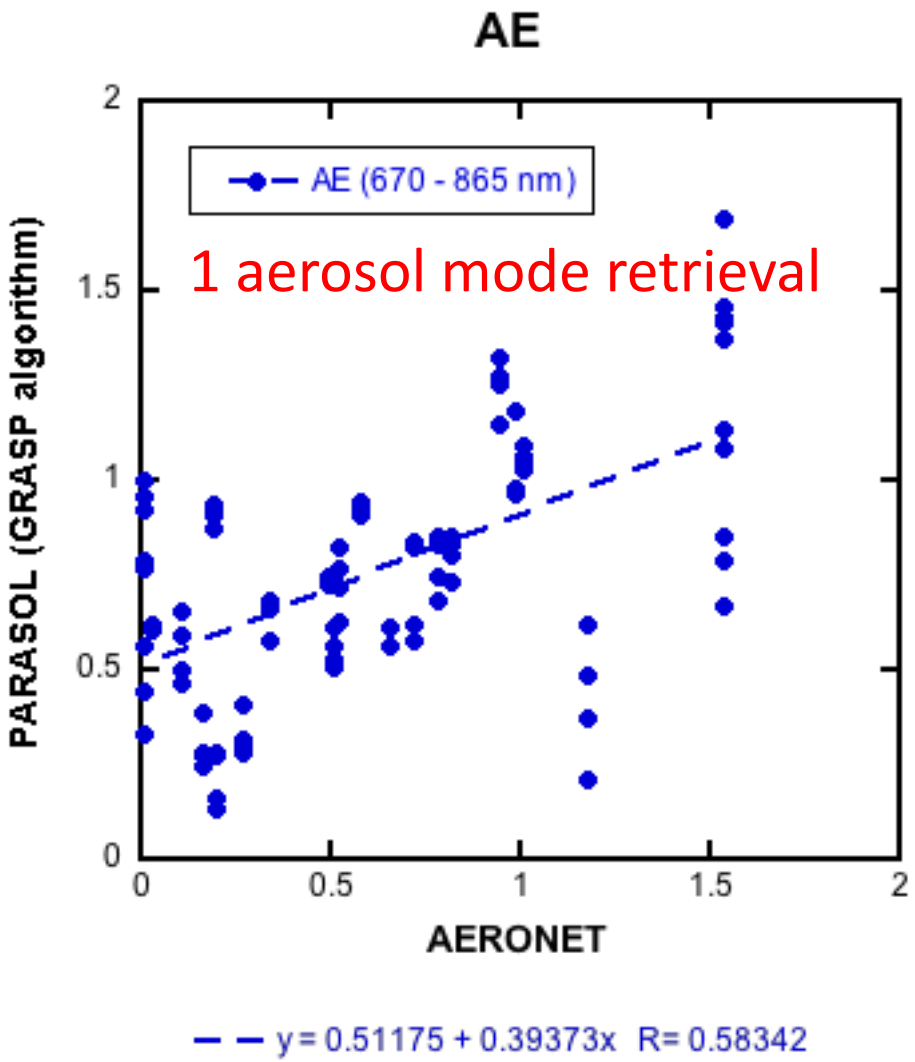


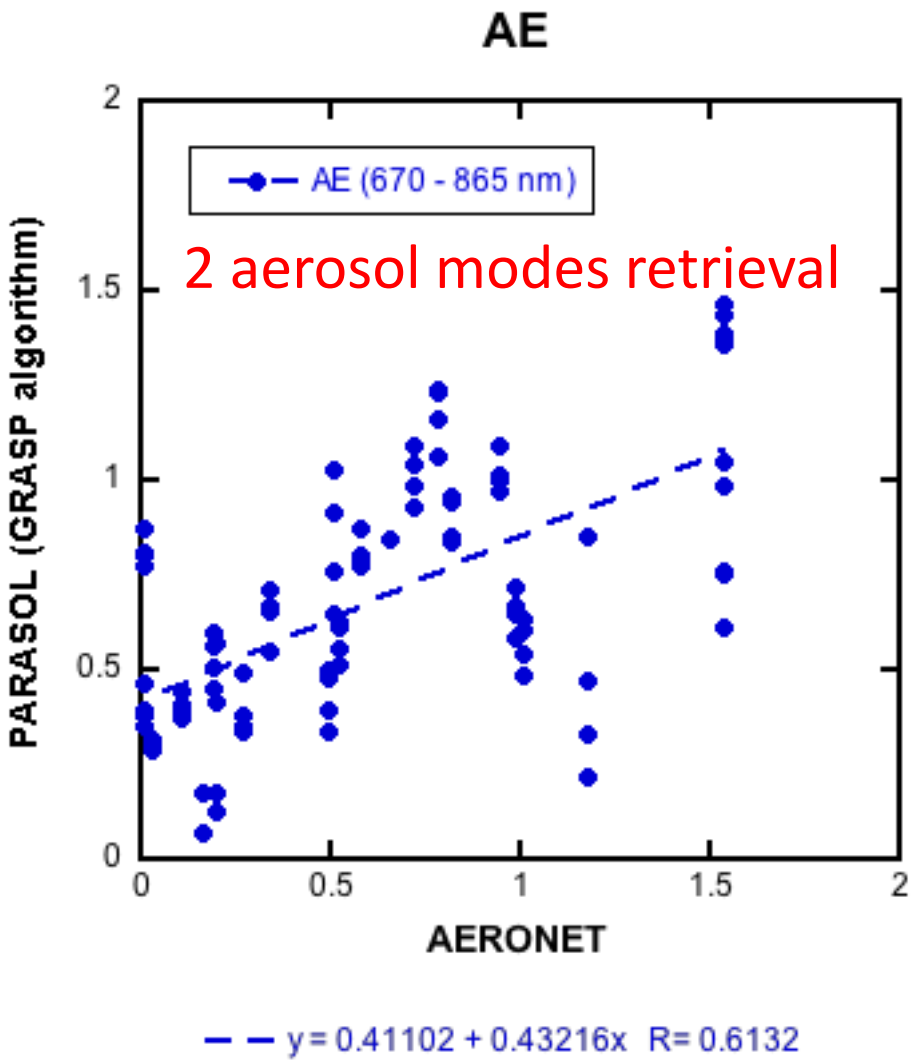
1 aerosol mode retrieval vs 2 modes (different *m, size distribution*). **XiangHe, China, March-May, 2006**





1 aerosol mode retrieval vs 2 modes (different *m, size distribution*). XiangHe, China, March-May, 2006





Sensitivity to several aerosol modes (*with different complex refractive index and size distribution*) **is small !!!**

Possible reasons of little sensitivity to different aerosol modes (complex refractive index)

1. **Limited range of scattering angles** from the space-borne instruments.
   The widest ranges for PARASOL (XiangHe, March-May, 2006):
   80^0-155^0; 70^0-140^0; 90^0-177^0.
2. **Averaged single scattering properties** in RTE:

$$< \mathbf{P} >= \frac{\sum_k < w_k > \times < \mathbf{P}_k > t_k}{< w > t_{total}}$$

3. **Multiple scattering washes out the single scattering properties.**

How can we increase sensitivity to different aerosol modes?

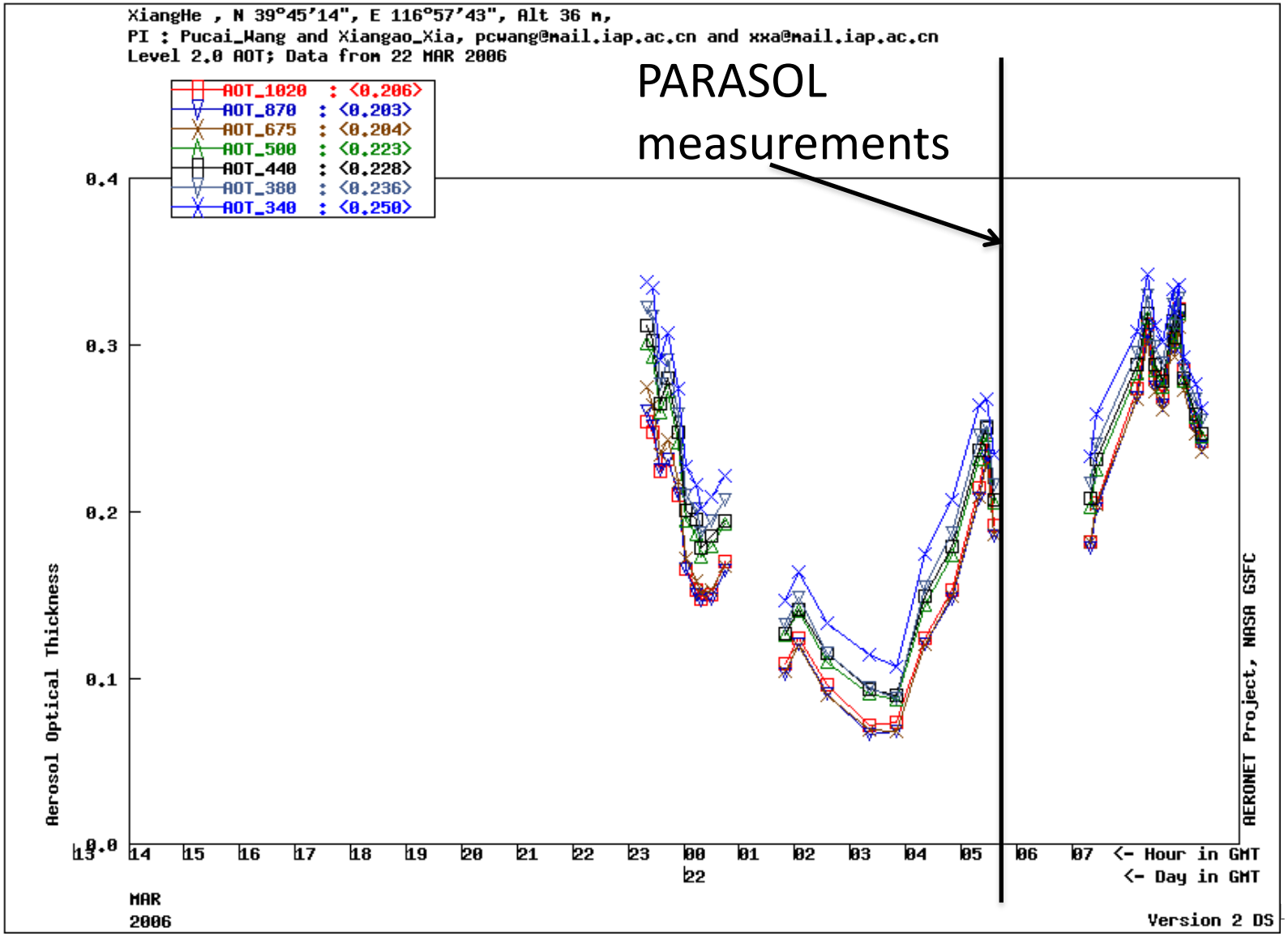
1. **Combination with LIDAR measurements** (increased sensitivity is already demonstrated for combination of ground based sun-photometer and LIDAR measurements (*A.Lopatin et al*. AMT, 2013)
2. **Multi-sensor retrieval (include additional information from different space-borne and graund-based)**.

Resume

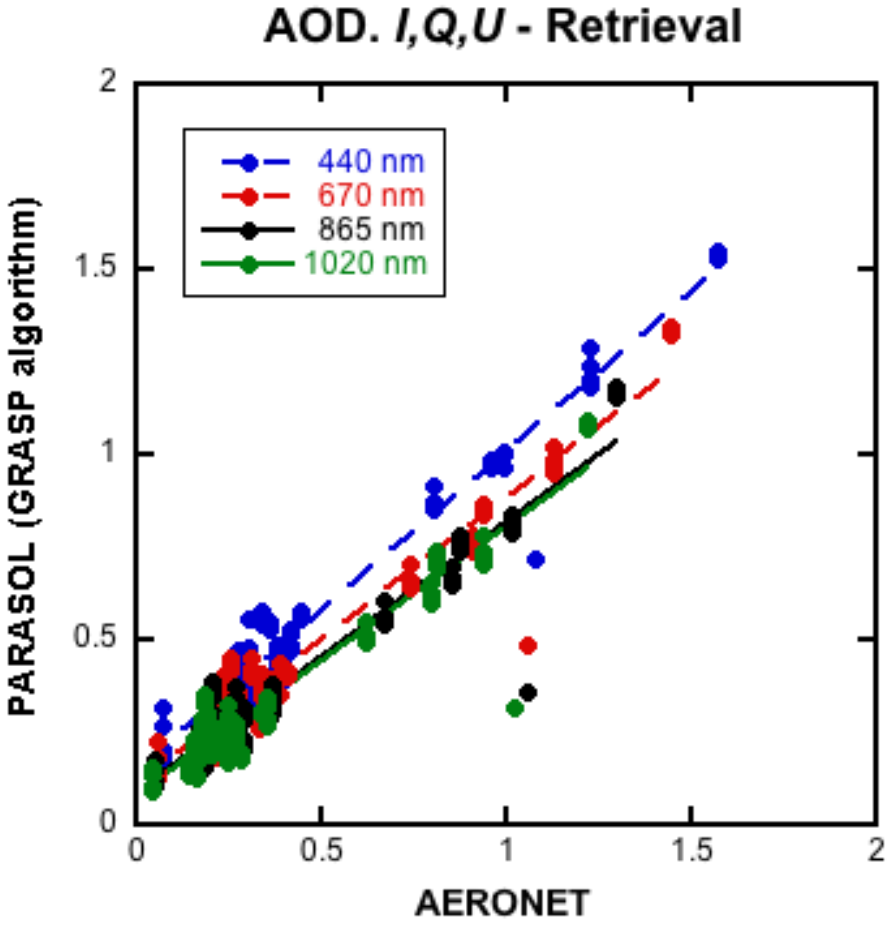
- **GRASP algorithm performs well** for different aerosol and surface types.
- **GRASP is able provide accurate retrieval of extended aerosol properties.**
- ***Cloud contamination and surface modeling*** are still the main challenges for enhanced aerosol characterization.
- **Multi-sensor retrieval is necessary to enhance retrieval of extended aerosol properties (separate different aerosol modes).**

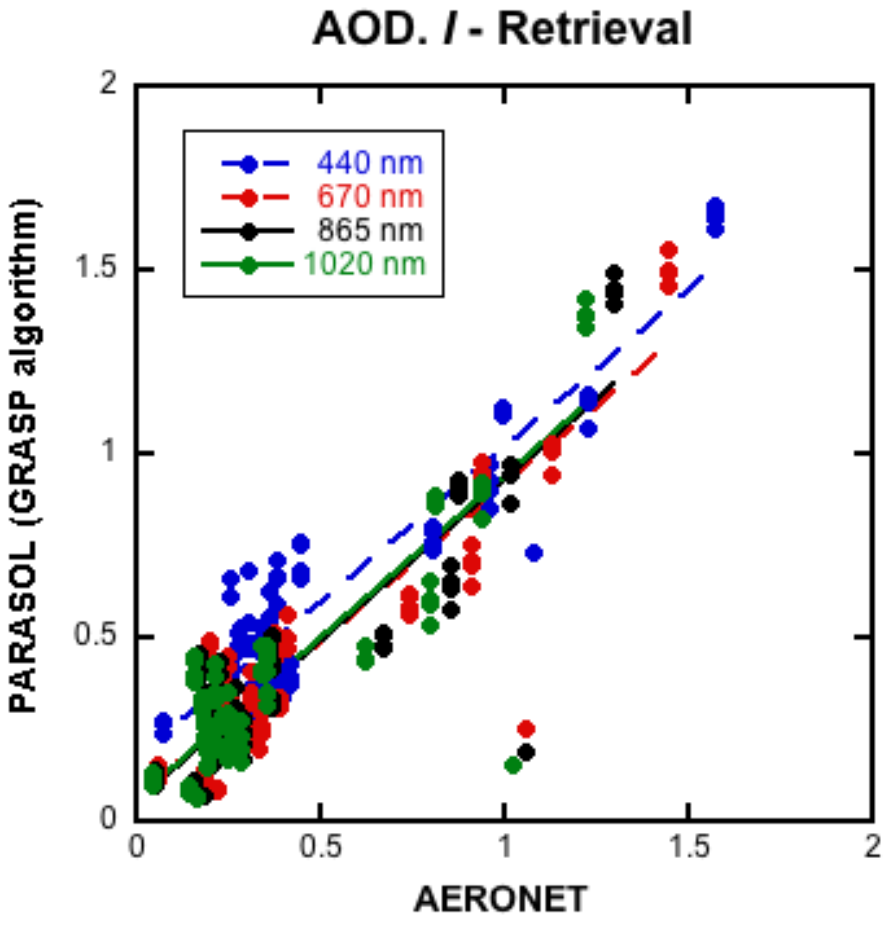
Bonus slides

AERONET and PARASOL measurements. XiangHe, 22.03.2006.

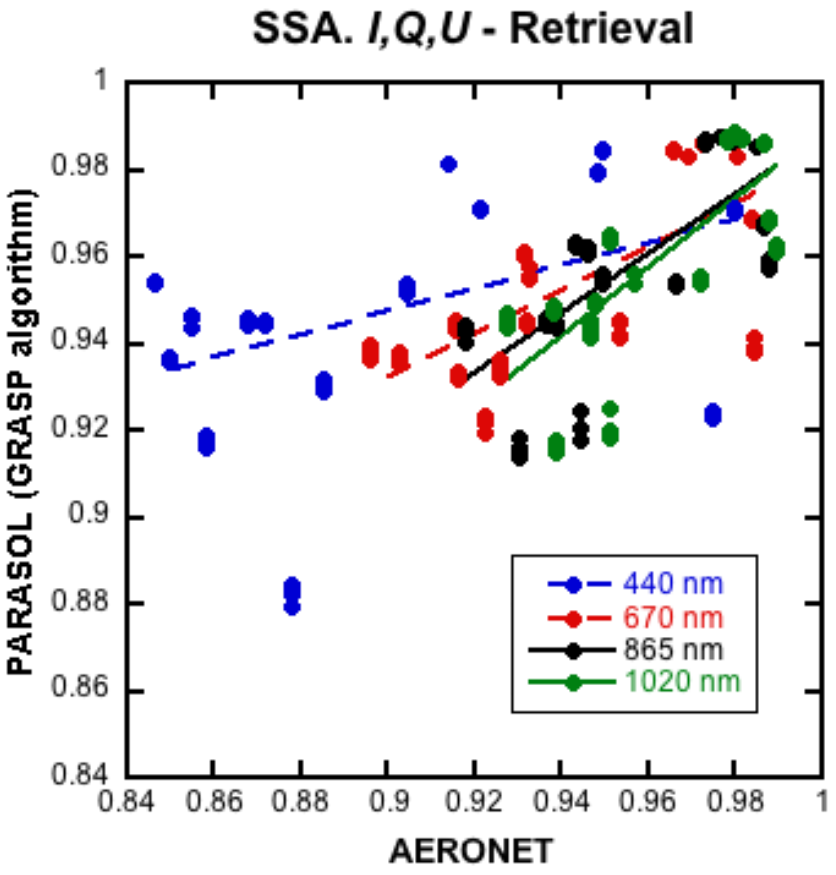


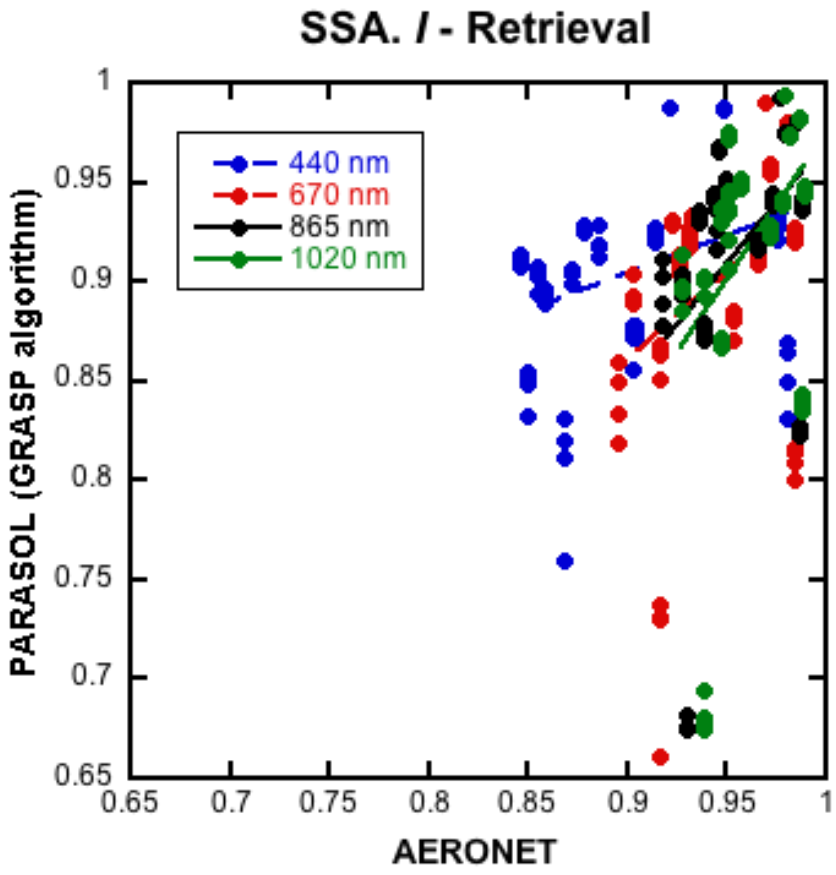
I,Q,U retrieval vs *I*-retrieval and *Q,U*-retrieval: AOD (Banizoumbou)



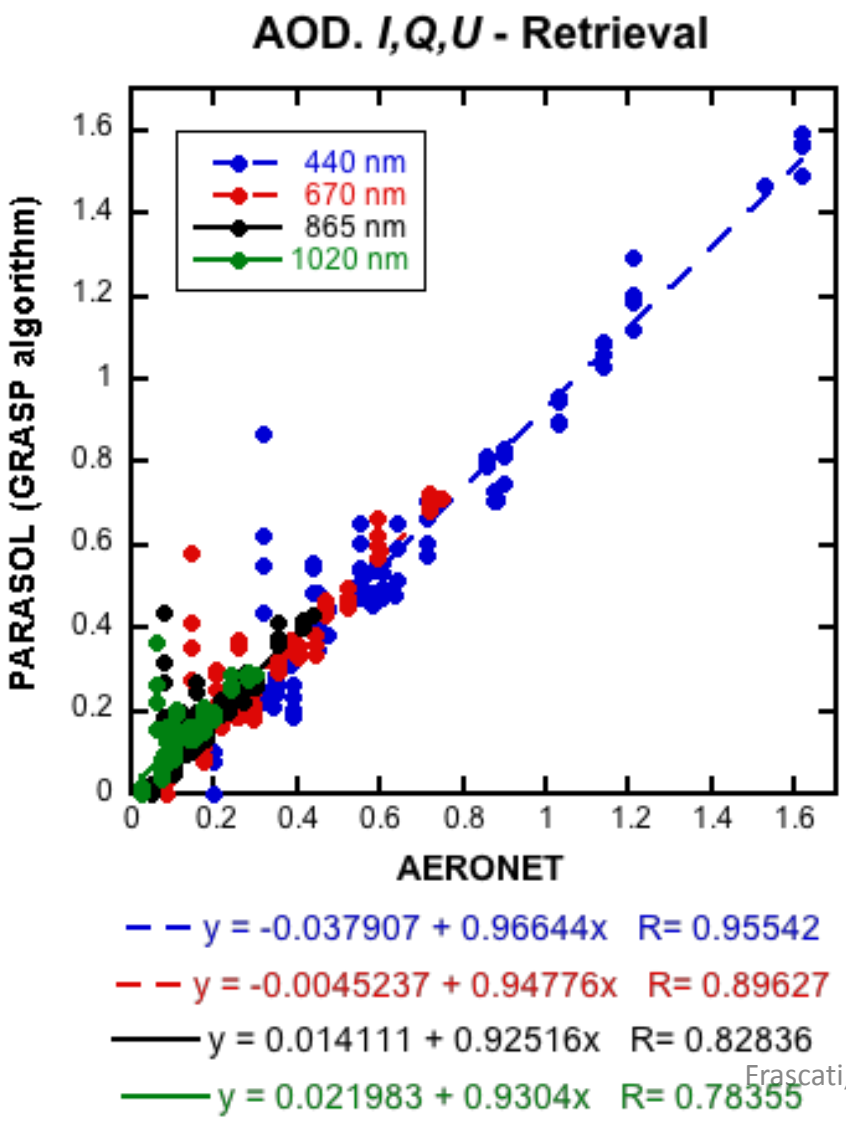


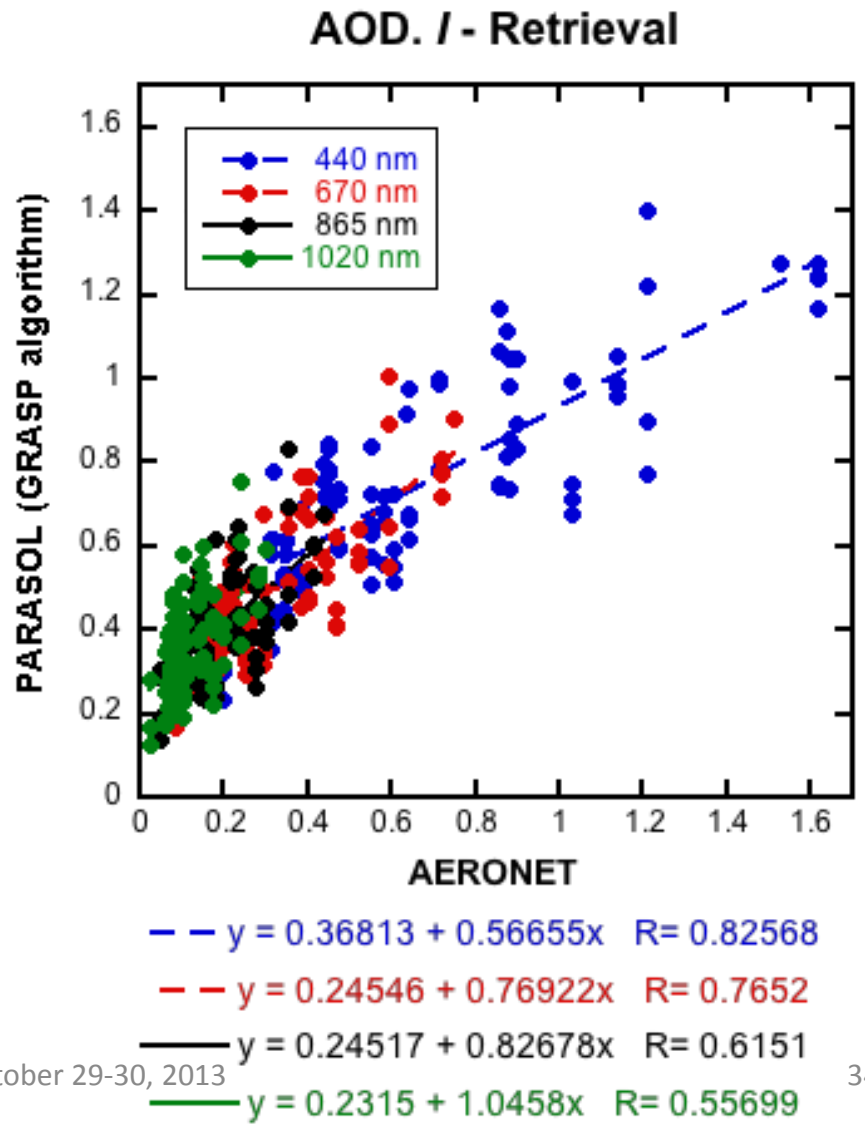
I,Q,U retrieval vs *I*-retrieval and *Q,U*-retrieval: SSA (Banizoumbou)



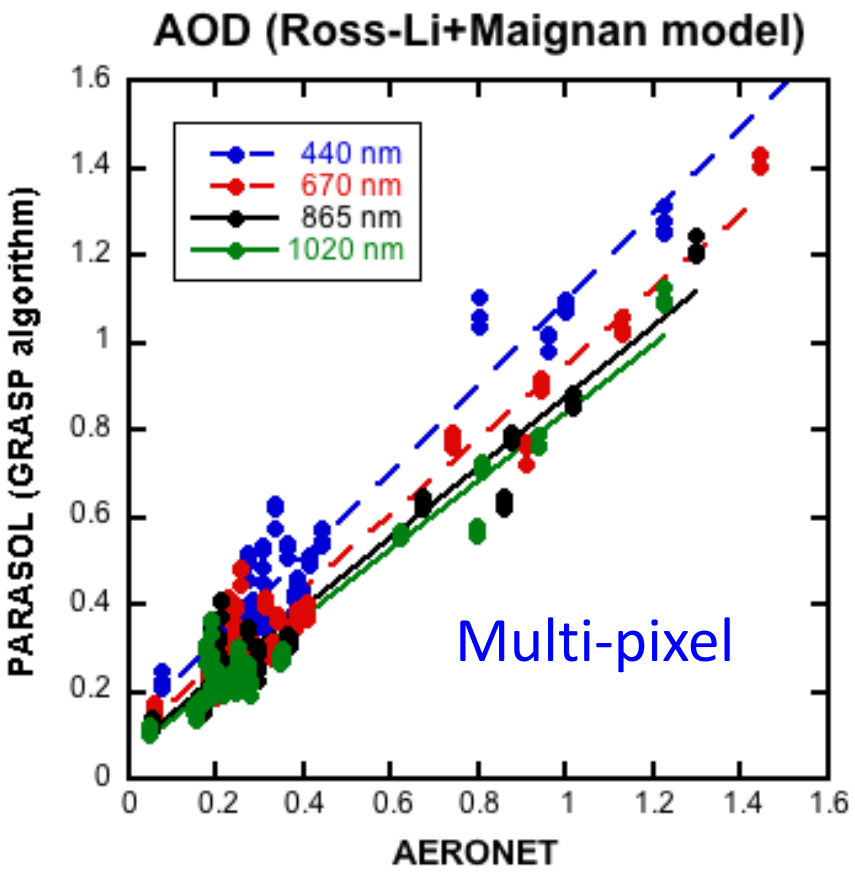


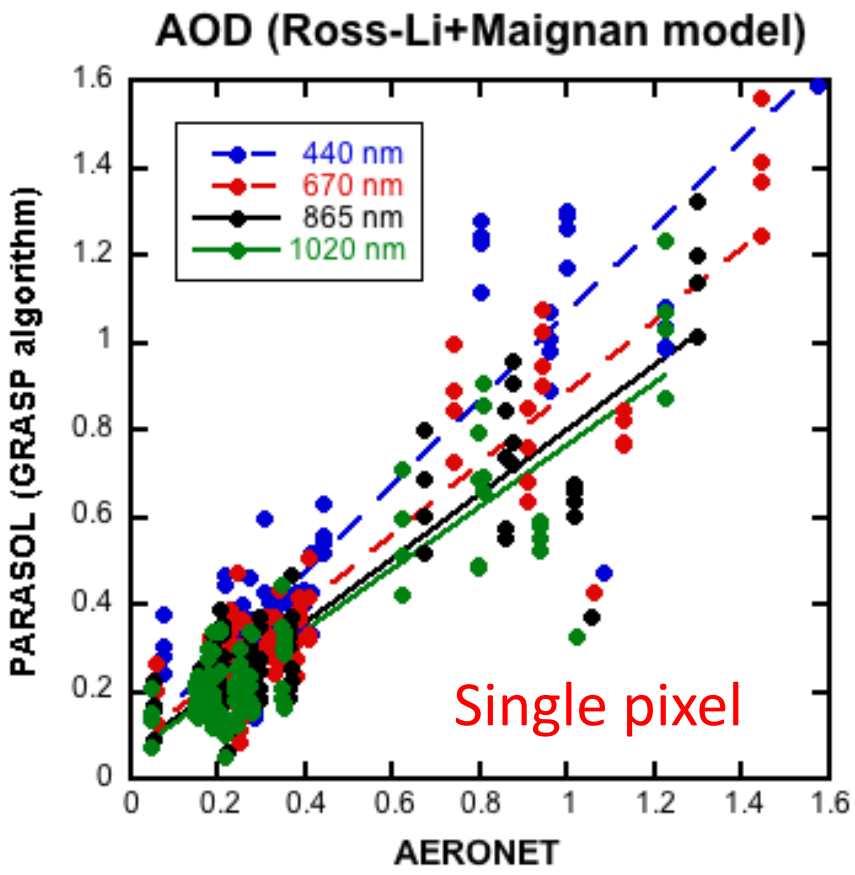
I,Q,U retrieval vs *I*-retrieval and *Q,U*-retrieval: AOD (Mongu. August, September 2008)





Multi-pixel vs Single pixel retrieval: AOD (Banizoumbou)





y = 0.12192 + 0.97819x R= 0.97994

y = 0.087867 + 0.86168x R= 0.97581

y = 0.074249 + 0.8012x R= 0.97066

y = 0.06075 + 0.78051x R= 0.96956

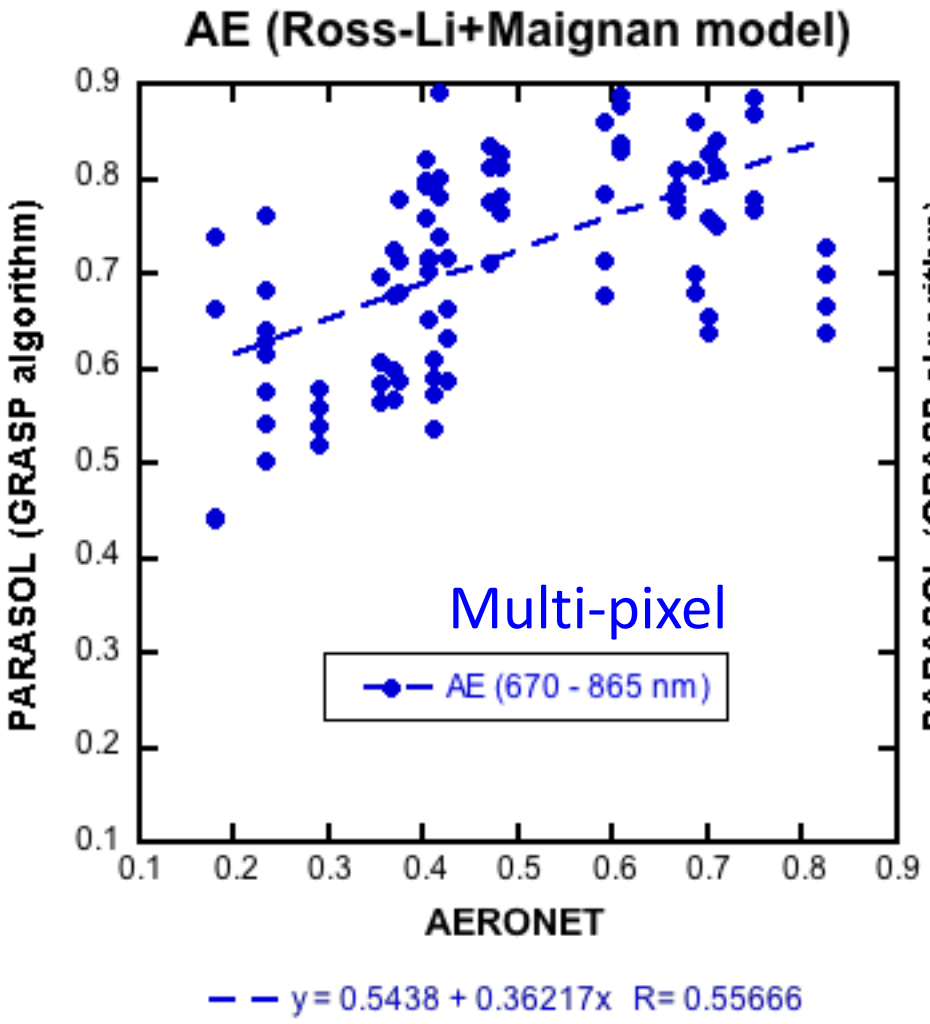
y = 0.077448 + 0.98265x R= 0.92246

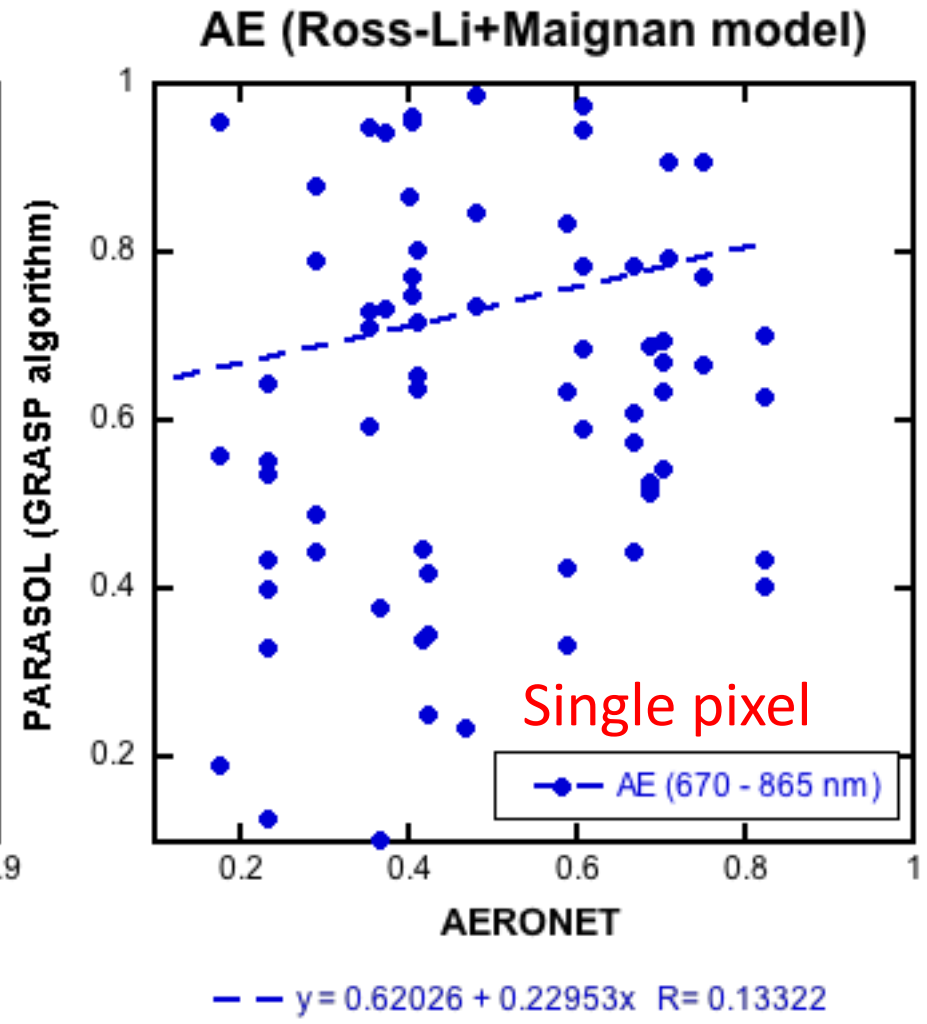
y = 0.06989 + 0.82x R= 0.92278

y = 0.068237 + 0.73534x R= 0.90682

y = 0.058765 + 0.70787x R= 0.89082

Multi-pixel vs Single pixel retrieval: AE (Banizoumbou)





Multi-pixel vs Single pixel retrieval: SSA (Banizoumbou)