SEOM’s Sentinel-3/OLCI project CAWA: advanced GRASP aerosol retrieval

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MERIS:
- radiances at seven wavelengths: (413, 443, 490, 510, 560, 665, and 870 nm);
- single view

AEROSOL:
- size distribution (5 or more bins);
- spectral index of refraction (7 \( \lambda \));
- sphericity;

SRFACE:
- BRDF
  (3 spectrally dependent parameters);

\[ 41 = (5 \text{ (SD)} + 14 \text{ (ref. ind.)} + 1 \text{ (nonsp.)} + 21 \text{ (BRDF)} ) \]
GRASP specifics:

Inversion scheme:

- search in continues space of solution for many parameters (aerosol + surface);
- optimization as Multi-term LSM;
- adapted for synergy of observations: multi-pixel retrieval;
- single fitting procedure;
- no solution modifications (no averaging, etc.);
- all parameters (43) are retrieved simultaneously at original resolution of (~6 km);
- no location specific assumptions (except land/water/snow);
- all a priori constraints general for all pixels (~6 km);
- single initial guess.

\[
2\Psi(x) = \sum_{i=1}^{N} \left[ \Delta y_i^T W_{r,i}^{-1} \Delta y_i + \gamma_s x_i^T \Omega_{s,i} x_i + \gamma_a (x_i - x_i^*)^T W_{a,i}^{-1} (x_i - x_i^*) \right] + x^T \Omega_{\text{inter-pixel}} x
\]
The concept of multi-pixel retrieval

X

\[ (t_1; x; y) \]

\[ (t_2; x; y) \]

\[ (t_3; x; y) \]

Time-Variability Constraints

X-Variability Constraints

Y-Variability Constraints

multi-days observations
Multi-term LSM Multi-Pixel Solution:

\[
\begin{bmatrix}
  a_1 \\
  a_2 \\
  a_3
\end{bmatrix} = \left[
\begin{array}{ccc}
  F_1^T W_1^{-1} F_1 & 0 & 0 \\
  0 & F_2^T W_2^{-1} F_2 & 0 \\
  0 & 0 & F_3^T W_3^{-1} F_3
\end{array}
\right]
\begin{bmatrix}
  \gamma_1 \Omega_1 & 0 & 0 \\
  0 & \gamma_2 \Omega_2 & 0 \\
  0 & 0 & \gamma_3 \Omega_3
\end{bmatrix} + \gamma_x \Omega_x + \gamma_y \Omega_y + \gamma_t \Omega_t
\]

\[
= S_x^T S_x; \quad y = S_y^T S_y; \quad t = S_t^T S_t;
\]

43 parameters
The concept MERIS/GRASP retrieval works good with synthetic measurements.
GRASP/MERIS: AOD(560 nm), January – March 2008

GRASP is somewhat slow compared to conventional retrievals, but easily mitigated using advanced IT technology such as GPGPU.

First results: Aerosol, 35 km resolution

No assumptions !!!

meris, AOT_560 -- Global, composite

ESA CAWA project
GRASP/MERIS: AOD(560 nm), January - March 2008

Retrieves both: surface (over land) and detailed aerosol properties

No assumptions !!!

**First results:** *Surface reflectance, 35 km resolution*
MERIS Surface Reflectance over Africa and Mediterranean Region in 2008
Animation of SALB retrieval from PARASOL over Africa and Mediterranean Region in 2008

Monthly averages

**MODIS**  
**(AQUA + TERRA)**

**MERIS**

![Map showing SALB retrieval](image_url)
Animation of AOT retrieval from PARASOL over Africa and Mediterranean Region in 2008

Monthly averages

**MERIS**

**PARASOL**
Surface Albedo (670 nm) – Africa, October 2008
Surface Reflectance (660 nm) – Bodélé Depression
30/03/2008

MERIS vs. Terra
Terra vs. Aqua
Aqua vs. PARASOL
MERIS vs. PARASOL
Surface Reflectance (660 nm) – Mediterranean
25/08/2008

MERIS vs. Terra

Terra vs. Aqua

Aqua vs. PARASOL

MERIS vs. PARASOL
Ross-Li (Ross, (1981); Li, X., Strahler (1992)):

\[
BRDF_{Ross\, Li} = a_{iso}(\cdot) \times (1 + a_{vol} f_{vol} + a_{geom} f_{geom})
\]
Surface Parameters – Bodélé Depression 30/03/2008

Lambertian Component

Volumetric Component

Geometric Component

MODIS - MERIS

MODIS - PARASOL
Animation of AOT retrieval from PARASOL over Africa and Mediterranean Region in 2008

Monthly averages

MERIS

PARASOL

Processed at 10 km

Processed at 6 km
Animation of AOT retrieval from PARASOL over Africa and Mediterranean Region in 2008

Monthly averages

**MODIS**

**MERIS**

Processed at 10 km
AOT (550 nm) – Africa, October 2008

Processed at 10 km
MERIS

Processed at 6 km
PARASOL
MODIS-TERRA
AOT (550 nm) – Africa, November 2008

Processed at 10 km
MERIS

Processed at 6 km
PARASOL

MODIS-TERRA
AOT (550 nm) – Mediterranean 30/03/2008

MERIS vs. Terra

Terra vs. Aqua

Aqua vs. PARASOL

MERIS vs. PARASOL
MERIS validation in ESA aerosol CCI project

MERIS ESA standard aerosol product over land (with CCI aerosol model). 2002 – 2012
GRASP/ MERIS
(January - March 2008, 10 km resolution)

No assumptions !!!

AOT(440)

Crete AERONET validation

meris, AOT_443 -- 37.06 N, 15.23 E, composite

Cairo
Mongu 06/2008 – 08/2008 (1)

Angstrom (670/870)

MERIS: \( Y = 0.950X + 1.919 \)
\( R^2 = 0.966 \) RMSE: 0.564

PARASOL: \( Y = -0.028X + 2.158 \)
\( R^2 = 0.032 \) RMSE: 0.352

Angstrom (440/870)

MERIS: \( Y = 0.367X + 0.984 \)
\( R^2 = 0.490 \) RMSE: 0.286

PARASOL: \( Y = 0.687X + 0.643 \)
\( R^2 = 0.489 \) RMSE: 0.167

AOD (440)

MERIS: \( Y = 0.809X + 0.037 \)
\( R^2 = 0.956 \) RMSE: 0.080

PARASOL: \( Y = 1.071X - 0.041 \)
\( R^2 = 0.987 \) RMSE: 0.048

AOD (670)

MERIS: \( Y = 0.866X + 0.021 \)
\( R^2 = 0.940 \) RMSE: 0.036

PARASOL: \( Y = 1.075X - 0.024 \)
\( R^2 = 0.984 \) RMSE: 0.025

AOD (870)

MERIS: \( Y = 0.872X + 0.019 \)
\( R^2 = 0.929 \) RMSE: 0.024

PARASOL: \( Y = 1.051X - 0.010 \)
\( R^2 = 0.980 \) RMSE: 0.015
MERIS PARASOL

Mongu 06/2008 – 08/2008 (3)

Graphs showing time series data for AOT440, AOT675, and AOT870 from Julian Day 160 to 240.
GRASP/ MERIS – land/water

(January - March 2008, 10 km resolution)

AOT(670 nm)

Dakar AERONET validation

ESA CAWA project
Dakar 03/2008 – 05/2008

**MERIS**

**PARASOL**

**SSA (440)**

Meris: $Y = 0.253X + 0.698$

$R^2 = 0.184$  RMSE = 0.064

Parasol: $Y = 0.222X + 0.674$

$R^2 = 0.130$  RMSE = 0.054

**SSA (670)**

Meris: $Y = 0.516X + 0.452$

$R^2 = 0.322$  RMSE = 0.044

Parasol: $Y = 0.982X + 0.033$

$R^2 = 0.496$  RMSE = 0.064

**SSA (870)**

Meris: $Y = 0.723X + 0.250$

$R^2 = 0.351$  RMSE = 0.043

Parasol: $Y = 1.493X + 0.532$

$R^2 = 0.558$  RMSE = 0.068

**RE.IMAG (440)**

Meris: $Y = 0.137X + 0.003$

$R^2 = 0.116$  RMSE = 0.005

Parasol: $Y = 0.391X + 0.004$

$R^2 = 0.225$  RMSE = 0.004

**RE.IMAG (670)**

Meris: $Y = 0.557X + 0.002$

$R^2 = 0.309$  RMSE = 0.003

Parasol: $Y = 1.016X + 0.003$

$R^2 = 0.443$  RMSE = 0.004

**RE.IMAG (870)**

Meris: $Y = 0.788X + 0.002$

$R^2 = 0.337$  RMSE = 0.004

Parasol: $Y = 1.754X + 0.002$

$R^2 = 0.513$  RMSE = 0.005
Conclusions:

**GRASP concept:**

- retrieving many characteristics simultaneously (aerosol + surface);
- statistically optimized “multi-pixel” inversion;
- etc.

*First results are promising* for MERIS:
- reliable AOD and Angstrom,
- promising for SSA *(dark surfaces, bright-???)*;
- main issue – cloud mask

- Promising alternative retrieval approach for S-3:
  - OLCI
  - OLCI + SLSTR;
  - OLCI + SLSTR + etc.