GRASP unified aerosol retrieval algorithm: application to POLDER, other satellite and ground observations:

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GRASP: Generalized Retrieval of Aerosol and Surface Properties

GRASP open source

Surfaces reflectance

Columnar aerosol

Profiles of aerosol

Single scattering

Meteorological instruments

Laboratory measurements
Particle Size Distribution:
0.05 \mu m \leq R (22 bins) \leq 15 \mu m

Complex Refractive Index at
\lambda = 0.44; 0.67; 0.87; 1.02 \mu m

Similar to AERONET model:

dV/d\ln r - size distribution (~22 values);
n(\lambda) and k(\lambda) - ref. index (4 +4 values)
C_{spher} (%) - spherical fraction (1 value)
Phase matrix inversion

Example of water suspension inversion

Refractive index:
- Real part = ~ 1.34;
- Imaginary part = ~ 0.0006

More recent papers:
Gayet et al. 2012,
Espinosa et al. 2017, 2019;
Schuster et al. 2019
Ground-based applications:

AERONET – like retrievals
GRASP-AOD (Torres et al. 2017)
AERONET/Luna photometers, etc. synergies;

GRASP – AOD (Torres et al., 2017)

Moon AOD

AOD measurements during the night

GRASP-AOD retrievals

Airborne PLASMA

AOD measurements flight PLASMA

GRASP-AOD retrievals

Sky-camera applications

Román et al., 2016
Generalized Aerosol Retrieval from Radiometer and Lidar Combined data - **GARRLiC algorithm**

- Lopatin et al., 2013
- Benavent-Oltra, et al. 2017
- Román et al., 2018;
- Tsekeri et al., 2017;
- etc.
GRASP/GARRLiC: development and operations

ACTRIS-2 general scheme

Archive reprocessed and backfilled; new incoming data processed on a daily basis

A few production results

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Access upon data policy validation and authorization

http://www.icare.univ-lille1.fr/data_policy?policy=garrlic

User access request

Access web form
Data Policy validation

email

CNR-IMAA + CNRS/LOA PIs

Go-ahead

CNR-IMAA + CNRS/LOA PIs

Access granted
GRASP satellite developments

◆ GRASP satellite products:

POLDER – 1,2 (18 months), POLDER-3 (2004 – 2013)

◆ GRASP operational algorithm prototypes:

3MI, Sentinel-4, OLCI/Sentinel-3, SLSTR/SentinelS-3

◆ GRASP research developments:

HARP, HIMAWARI, SGLI, MODIS, AVHHR, S5P, etc.
2004-2013 POLDER/PARASOL:

AOD, SSA, aerosol height, sphericity, etc.

ocean and land

winter 2009
PARASOL Validation vs AERONET 2004 - 2013

SSA(670) \( R=0.55 \) Land + Ocean

SSA(870) \( R=0.6 \)
Propriétés d’aérosol à partir de 3MI

Exemple

3MI: Swath: ~ 2200 km
Global coverage: every ~ 4 km
Viewing direction: 10 – 14 (80° – 180°);
for aerosol (0.41, 0.44, 0.49, 0.56, 0.67, 0.87, 1.65, 2.13);
for gas absorption (0.763, 0.765, 910);
polarization (0.41, 0.44, 0.49, 0.56, 0.67, 0.87, 1.65, 2.13);

3MI

AOD

SSA

Angström

NRT 3MI/GRASP

Résultats des tests
GRASP/MERIS 2002-2012 product has been generated

10 km resolution

GRASP/MERIS:
year 2008 averages

AOD(560 nm)

No location specific assumptions !!!

No climatologies!

Surface Albedo (670 nm)

ESA CAWA project
September, 2008

Total extinction for aerosol optical properties for 560 nm

GRASP/Parasol

GRASP/Meris

Total extinction for aerosol optical properties for 560 nm

GRASP/Parasol

GRASP/Meris
Validation vs AERONET over land

GRASP/PARASOL

GRASP/MERIS

Workshop sur l’utilisation des produits aérosols, 26 mai 2019, Toulouse
2004-2013 POLDER/PARASOL:

AOD, SSA, aerosol height, sphericity, etc.

Important features of GRASP retrieval:

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

\[ P_{1,2,3} = P_1 P_2 P_3 \ldots \approx \exp\left(-\frac{1}{2} \sum_i \Delta f_i^T C_i^{-1} \Delta f_i\right) = \text{max} \]

\[ \frac{1}{2} \sum_i \Delta f_i^T C_i^{-1} \Delta f_i = \text{min} \]

where \( \Delta_i = f_i^* - f_i(a) \) and \( f_i^* \) - measurements or a priori data

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

- Optimum data combination
- Optimum use of a priori information
- Continuous solution space
- More “sophisticated”
- Generally more time consuming
- Rigorous error estimations
- Large number of retrieved parameters with less assumption
The concept of multi-pixel retrieval

Dubovik et al. 2011

Workshop sur l’utilisation des produits aérosols, 26 mai 2019, Toulouse
POLDER - 1, -2, - 3, 3MI developments:

Base Aerosol Products: Spectral AOD, SSA, scale height, non-sphericity fraction

Potential new aerosol products:
- Aerosol typing based on aerosol products;
- Retrieval of aerosol chemical composition (Li et al., 2019);
- Retrieval of MP 2.5;
- Aerosol typing based on aerosol products;
- Retrieval of sources by inverse modeling using (Chen et al. 2018);
- multi – instrument synergies, etc.

Surface reflectance products:
- BRDF over land and ocean, etc.
Dust detection with GRASP

Dust events:
- High AOD
- Angstrom Exponent < 0.5
- SSA (440 - 1020) > 0.9
Aerosol type detection with GRASP

Summer 2009

Winter 2009

Autumn 2009

Smoke frequency of occurrence
Aerosol type detection with GRASP

Mineral dust frequency of occurrence

GRASP/PARASOL Summer 2009 MineralDust (type 8)

GRASP/PARASOL Autumn 2009 MineralDust (type 8)

Summer 2009

Autumn 2009
Li et al., 2019

Validation et exploitation du produit « composition des aérosols » à partir de télédétection

**GRASP/Opt. -> composition modèle de conversion**

**Appliquer au réseau AERONET (mesures au sol)**

**Dust-dominated**

- **Volume concentration (mm/m³)**
  - Banizoumbou 2008
    - BC: Avg=3.6, Std=2.2
    - BrC: Avg=22.1, Std=18.9
    - Dust: Avg=1400.7, Std=511.9
    - FeOx: Avg=12.2, Std=8.6
  - Horin 2008
    - BC: Avg=21.6, Std=5.4
    - BrC: Avg=75.7, Std=37.0
    - Dust: Avg=712.0, Std=447.5
    - Iron: Avg=6.8, Std=8.1

**Biomass burning**

**Appliquer à l'archive PARASOL (mesures satellitaire)**

- **Concentrations volumiques (mg/m²)**
- **Automne 2008**
size distribution (spectral AOD)

refractive index (~ water fraction)

scale height

PM2.5 from polarimetry?
Correlation of population density and pollution

POPULATION DENSITY MAP OF ASIA

Fine AOD 565nm 2011 Winter

Pollution

Fine AOD 565nm 2011 Summer

Fine AOD 565nm 2011 Autumn

AOD\textsubscript{fine}(565)
PM2.5 climatology

WHO Global Urban Ambient Air Pollution Database

PARASOL/GRASP 2008

PM2.5

K=0.821  a=0.65  b=26.00  RMSE=60.957
N=115  Aver.=121.513

PARASOL/GRASP PM2.5 over Beijing 2009–2012
Imagery comparisons

**PARASOL/GRASP**

Normalized Difference Vegetation Index

**NDVI**

**MERIS/GRASP**

DHR(670)

**DHR(670)**

**DHR(670)**

**MISR/GRASP**

Directional Hemispherical Reflectance at 670 nm

**DHR(670)**

**DHR(670)**

September 2008
PARASOL wind speed retrieval

Details are in presentation by Fruin et al., in press

July 2008

ECMWF

Year 2008
GRASP atmospheric correction and aerosol at high resolution
VENµS and Sentinel-2

Proposed scheme for VENµS and Sentinel-2 data processing

- optimized processing of fine spatial;
- resolution satellite observations;

Atmospheric spherical albedo from coarse resolution
Surface albedo from coarse resolution
Top of Atm. Reflectance

Atm. Refl. (black surface) from coarse resolution
Surface total reflectance for fine resolution
Surf+Atm Coupling

VENµS and Sentinel-2-optimized processing of fine spatial; resolution satellite observations;

ACIX
Atmospheric Correction Inter-comparison eXercise

Collaboration with O. Hougol

R(\vartheta_v, \vartheta_0, \Delta \varphi) = R_{atm}(\vartheta_v, \vartheta_0, \Delta \varphi) + t^\uparrow t^\downarrow (R_{surf}(\vartheta_v, \vartheta_0, \Delta \varphi) - \rho_0) + \frac{T^\uparrow(\vartheta_v)T^\downarrow(\vartheta_0)\rho_0}{1 - S_{atm}\rho_0}

GRASP atmospheric correction module
(Litvinov et al., 2018 in prep.)

GRASP atmospheric correction and aerosol at high resolution
VENµS and Sentinel-2

Atmospheric Correction Inter-comparison eXercise
Inverse modeling

Global AEROSOL properties

GRASP

PARASOL Global or observations

GEOS-CHEM

Inverse modeling algorithms

Emissions of: aerosol (desert dust)

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Emissions of desert dust and carbonaceous aerosol emissions species inverted from POLDER/PARASOL

2010

Black Carbon
Organic Carbon
Desert Dust

“Bottom-up”

“Top-down”

Difference

BC (+166.7%)
OC (+184.0%)
DD (-49.4%)

Chen et al., 2018, 2019 (in preparation)

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GRASP – ACE Summer School

in the frame of Marie Curie RISE project of Horizon 2020 program

Overbooked...

Outlook
- GRASP concept and overview
- Overview of passive and active remote sensing

Atmospheric radiation modeling
- Modelling of aerosol particles, accounting for non-sphericity and inhomogeneity
- Accounting for multiple scattering, Radiative Transfer, Surface reflectance
- Modelling gaseous absorption in atmosphere

Introduction to numerical inversion
- Principles of statistical estimation
- Utilisation of a priori constraints
- Non-linear inversion
- Error estimates

GRASP practice
- Algorithm structure and functionalities
- Radiative Transfer
- Spheroid package and aerosol scattering
- Phase function (nephelometers)

GRASP inversions
- Ground based: AOD, radiometers, lidars, radiometer+lidar
- Space and airborne: radiometers, lidars
- Multi-instrument observation
- Synergy of ground-based and satellite observations


... also tapas, wines & other cultural heritage

GRANADA
MISR/GRASP shows more high AOD compared to MISR/JPL.

MISR/GRASP and MISR/JPL are in reasonable agreement.

PARASOL/GRASP

18 February 2018

MISR/JPL

MISR/GRASP
MISR/GRASP has more points, higher correlations, smaller RMSE, but for some sites it MISR/GRASP shows bias