Aerosol retrievals in partially clouded scenes

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Why partially clouded scenes?

Most current aerosol retrieval algorithms are developed for retrievals above homogeneous cloud fields or clear sky scenes.

The latter requires a priori cloud screening;

- filter too strict and lose data, especially
  - near-cloud scenes (increased AOT)
- filter too loose and end up with a 'contaminated' data-set
  - erratic retrievals (overestimated AOT for example)

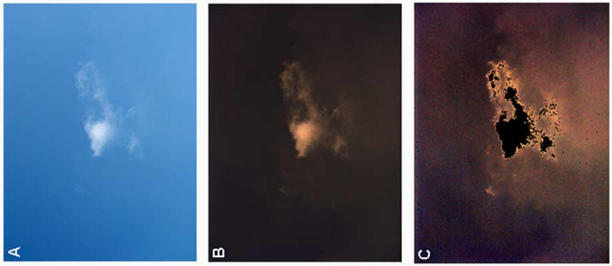

Illustration of the 'twilight' zone [Koren et. al., 2007, GRL].

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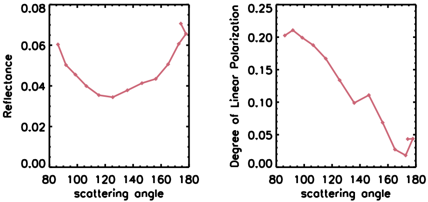


Goal & outline

Goal

- Further develop the aerosol retrieval algorithm (intended for clear sky scenes) to account for partial cloud cover, so it can retrieve aerosol properties in cloud contaminated scenes.

Today

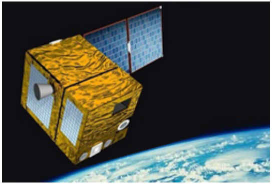
- Intermediate step: Retrievals on partially clouded scenes (with original algorithm) to asses the sensitivity to and the effect of cloud contamination.

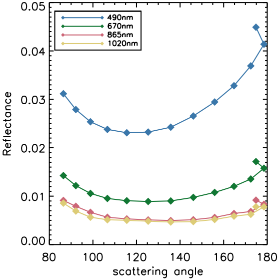
Method

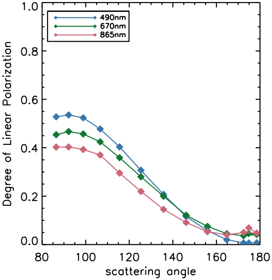
measurement

Multi-angle observations of intensity and polarization.

POLDER-3 (POLarization and Directionality of Earth's Reflectances) on board PARASOL (Polarization and Anisotropy of Reflectances for Atmospheric Science coupled with Observations from Lidar).







Intensity in 9 bands
Polarization in 3 bands
16 viewing angles

Algorithm currently uses 490, 670 & 865 nm (I, Q & U) and I at 1020 nm

Method

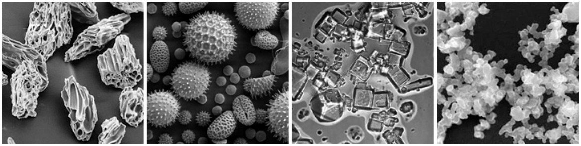
aerosol & ocean parameters

Fine & Coarse Aerosol mode;

variable	explanation
R_{eff}	Effective radius
V_{eff}	Effective variance
M_r	Reflection index (real)
M_i	Reflection index (im.)
N_c	Column density
S	frac. spher. particles (coarse mode only)

Ocean parameters;

variable	explanation
V_x	wind speed in x
V_y	wind speed in y
$Foam_{frac}$	foam fraction
$Foam_{alb}$	foam albedo
Chl_a	Chlorophyll-*a*



Micrographs, courtesy USGS, UMBC (Chere Petty), and Arizona State University (Peter Buseck).

Method

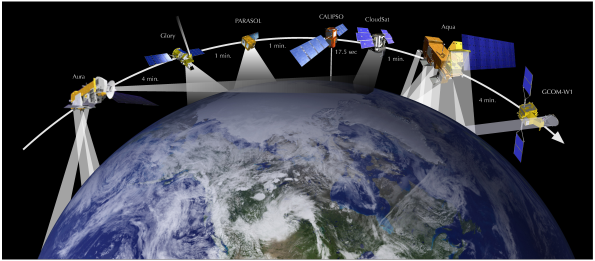
Philips-Tikhonov regularization

- Initial guess aerosol & surface/ocean parameters (LUT)
- Calculate optical properties of aerosol & surface/ocean
- Do radiative transfer calculation & obtain Jacobian
- Compare with actual measurement
- Minimize cost function

$$\hat{x} = \min_x \left(||S_y^{-\frac{1}{2}} (F(x) - y) ||^2 + \gamma ||W(x - x_\alpha)||^2 \right)$$

- Iterate these step until convergence
- filter the result based on χ^2 (i.e. goodness of fit)

Co-located MODIS & PARASOL observations



Co-locate MODIS & PARASOL data and use cloud properties from MODIS for the analysis.

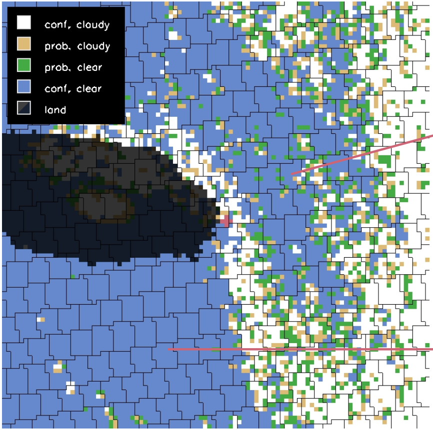
PARASOL : 6.2x6.2 km pixel (full res.) or 19x19km km pixel (medium res.)
MODIS : ∼1x1 km pixel

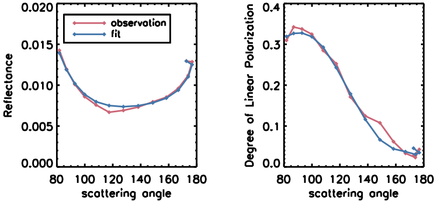
4 levels in MODIS cloud mask:
-conf. cloudy, -prob. cloudy, -prob. clear, -conf. clear

we use : f = conf. cloudy + prob. cloudy

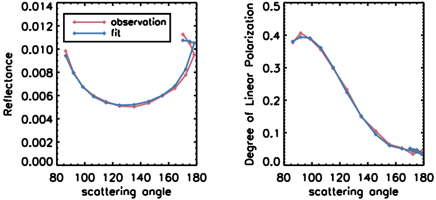
Co-located MODIS & PARASOL observations

An example





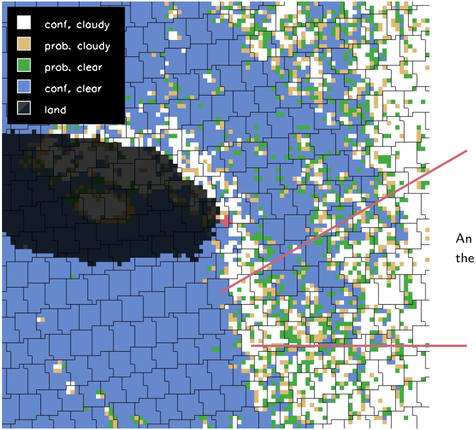
A partially clouded measurement at 865 nm (χ^2=24.4)

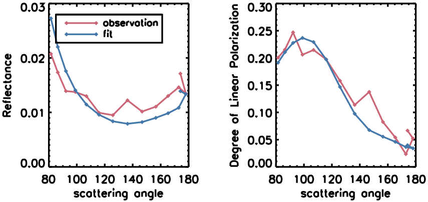


A clear sky measurement at 865 nm (χ^2 = 5.8)

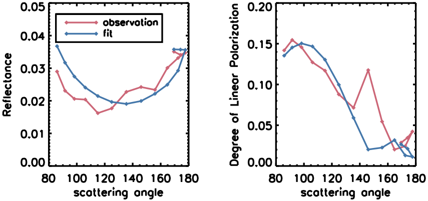
Co-located MODIS & PARASOL observations

Inhomogeneities at different scattering angles





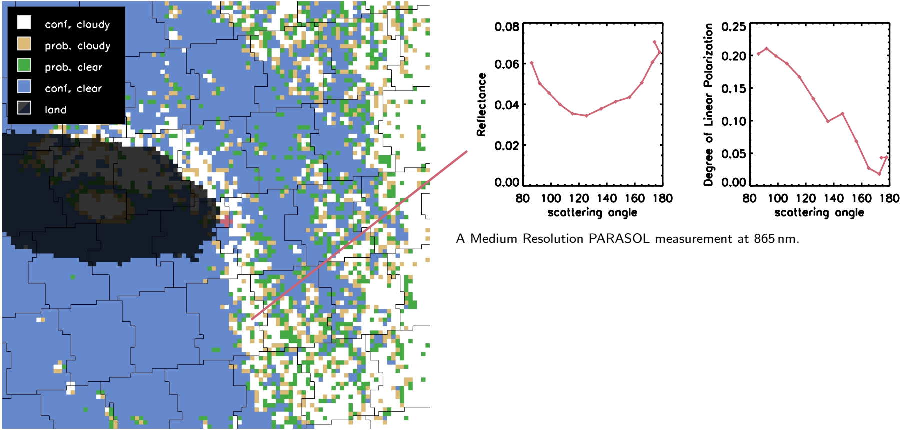
An measurement at 865 nm of a scene that was inhomogeneous at the different scattering angles (χ^2=196.7).



An measurement at 865 nm of a scene that was inhomogeneous at the different scattering angles (χ^2=351.7).

Co-located MODIS & PARASOL observations

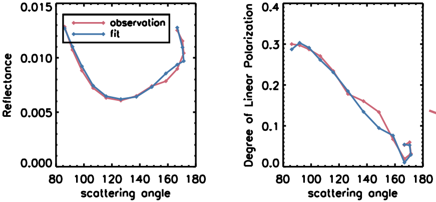
Inhomogeneities at different scattering angles



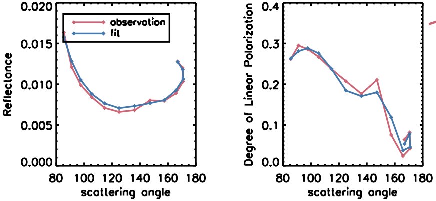
A Medium Resolution PARASOL measurement at 865 nm.

Co-located MODIS & PARASOL observations

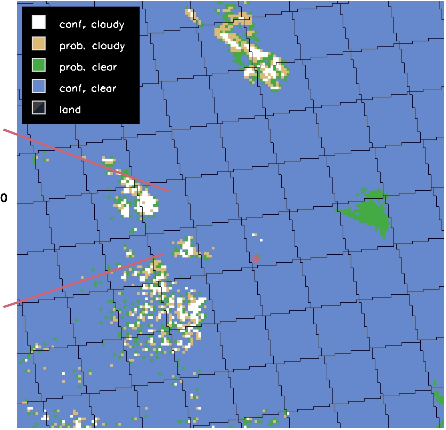
An example



A Med. Res. PARASOL observation & fit at 865 nm (χ^2=9.0).

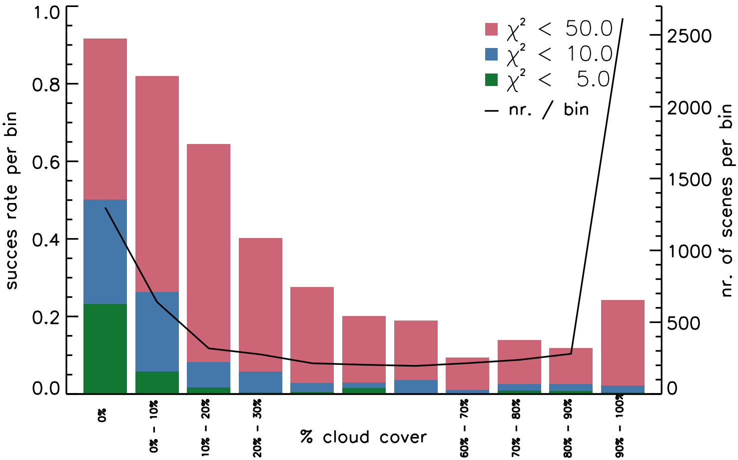


A Med. Res. PARASOL observation & fit at 865 nm (χ^2=10.6).



Results

Succes rates



Validation

Validation against 10 AERONET stations overlooking the ocean;

Anmyon, Forth Crete, Gosan SNU, Guam, Midway Island, Muscat, Shirahama, Trelew, Trinidad Head & Sevastopol.

Max distance	40 km
Max time diff.	1 hr

Figure: An AERONET sun-photometer overlooking the ocean.

Validate the;

- AOT
- SSA
- Ångström exponent
- Real refractive Index.

Validation

AOT comparison

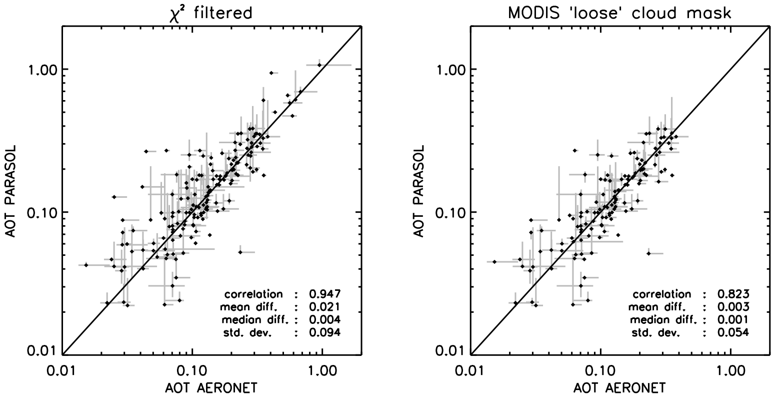


Figure: The median of the coincidently retrieved AOT at 670 nm, with the range in gray. Extra filter; meas. with $AOT_{670} > 5.0$ discarded.

Validation

Ångström exponent comparison

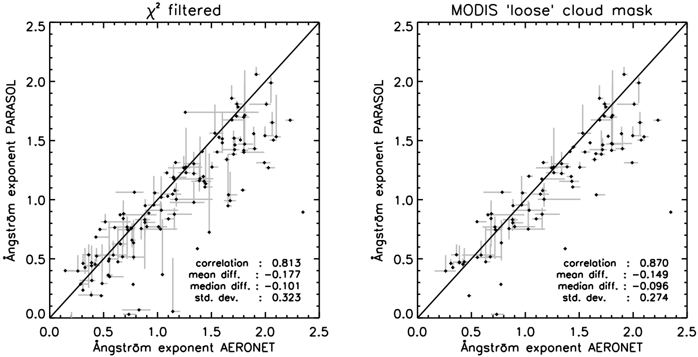


Figure: The median of the coincidently retrieved Ångström exponents at 490 nm / 670 nm, with the range in gray. Extra filter to discards measurements with $AOT_{670} < 0.1$.

Validation

SSA comparison

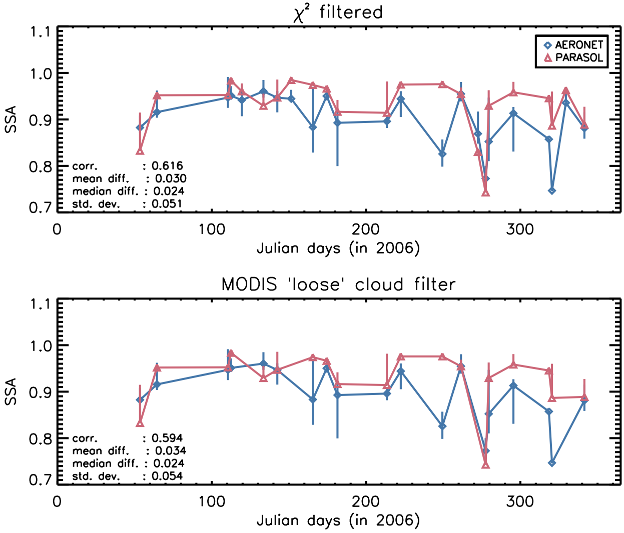


Figure: The retrieved single scattering albedo at 670 nm near Forth Crete, with the range in gray. Extra filter to discards measurements where the Avg. Ker. of $m_{i,f} < 0.1$.

Conclusion

- The original algorithm is sensitive to clouds.

  room to fit water clouds

- Clouds can be effectively screened out on basis of a goodness of fit criterion.

  the rainbow feature plays a role here

- Less near-cloud scenes and scenes with a high aerosol load are discarded.

- Retrieved AOT, SSA, Ångström exponent & Refractive indices compare well to AERONET observations.

Outlook

- Improve 3-mode retrieval (fitting COT)
- Check validity of cloud in model (neglected 3D effects, etc)

extra slides

Validation

Comparison of the real refractive index

By AERONET a real refractive index is retrieved for 1 mode.

By our algorithm, two real refractive indices are retrieved (1 per mode).

We can only compare our total particle volume weighted real refractive index with AERONET;

$$m_{comb} = \frac{V_{fine} m_{r,fine} + V_{coarse} m_{r,coarse}}{V_{fine} + V_{coarse}} \quad (1)$$

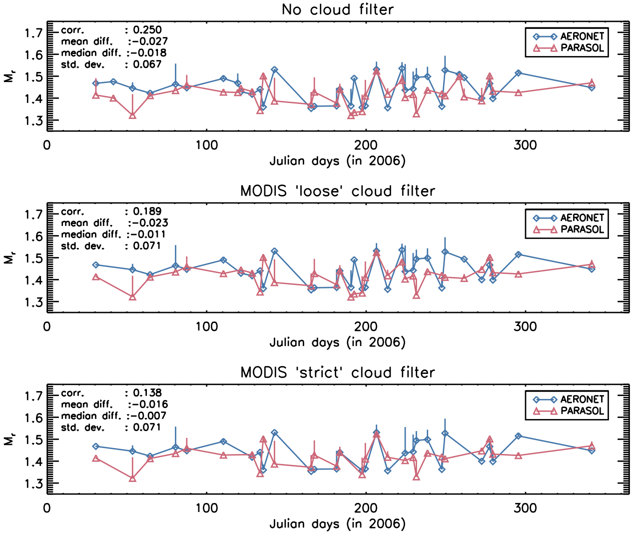


Figure: The median of the coincidently retrieved real refractive index[1] near Forth Crete

[1] See previous slide

3-mode retrievals

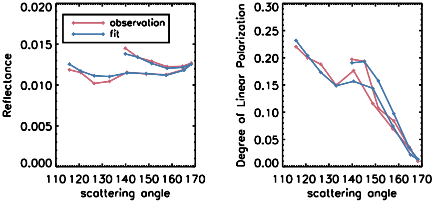
including a cloud in the algorithm

Include cloud by adding a 3rd mode, representing water droplets.
gamma-size distribution (instead of log-normal)

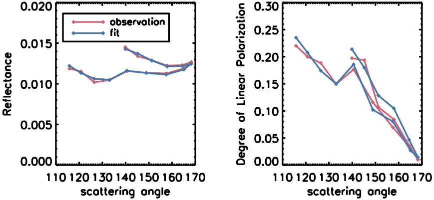
parameter	value
R_{eff}	use MODIS data or apriori
V_{eff}	fixed at 0.1 μm
M_r	fixed (wavelength dependent [Segelstein, 1981])
M_i	fixed (wavelength dependent [Segelstein, 1981])
N_c	-
S	fixed at 1.0
f	use MODIS data

3-mode retrievals

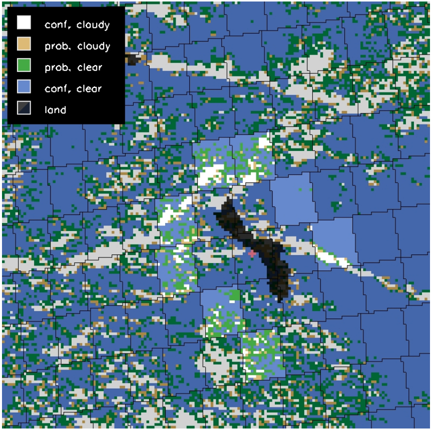
preliminary results



A Med. Res. PARASOL observation & fit (χ^2=11.7).



A Med. Res. PARASOL observation & fit at 865 nm (χ^2=6.8).



3-mode retrievals

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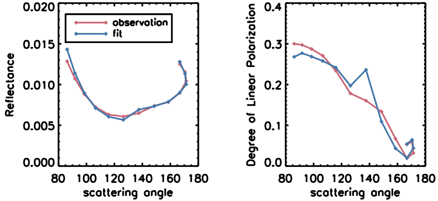
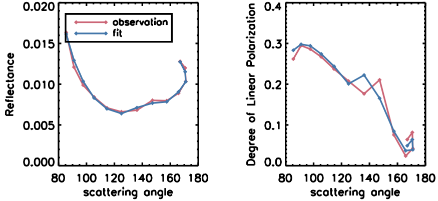


A Medium Resolution PARASOL measurement at 865 nm (χ^2=20.0).



A Medium Resolution PARASOL measurement at 865 nm (χ^2=10.7).