Aerosols in cloudy scenes: properties and impacts

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AeroCom

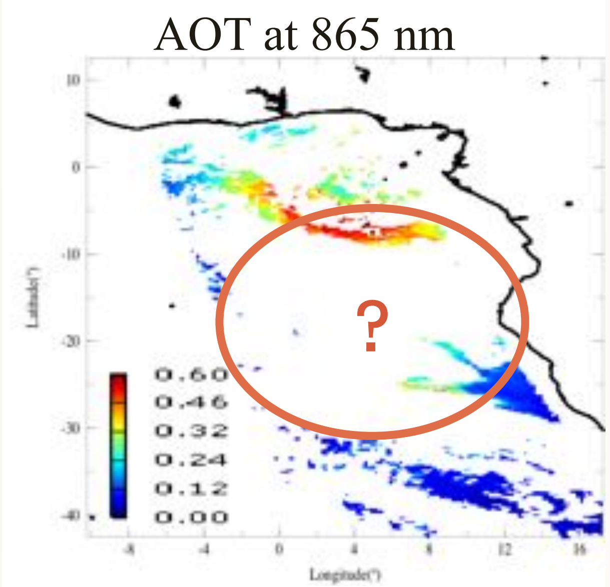
Why study aerosols above clouds ?

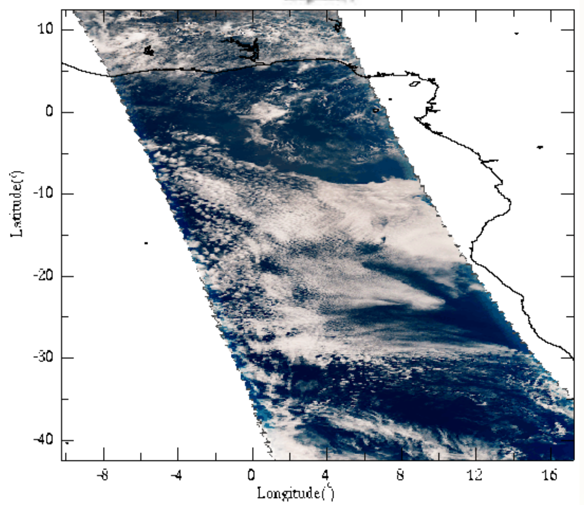
Current operational aerosol retrievals from passive observations are restricted to cloud free scenes

- ➢ **Reduce our ability to monitor aerosol properties and their effects at global scale**

Absorbing aerosols over clouds :

- ➢ **may cause a large positive radiative forcing that is relatively unexplored** (regional studies, e.g. : De Graaf et al., 2012)
- ➢ may affect the accuracy of the retrieval of cloud properties (Haywood et al., 1993)
- ➢ might affect the convection of the cloud below

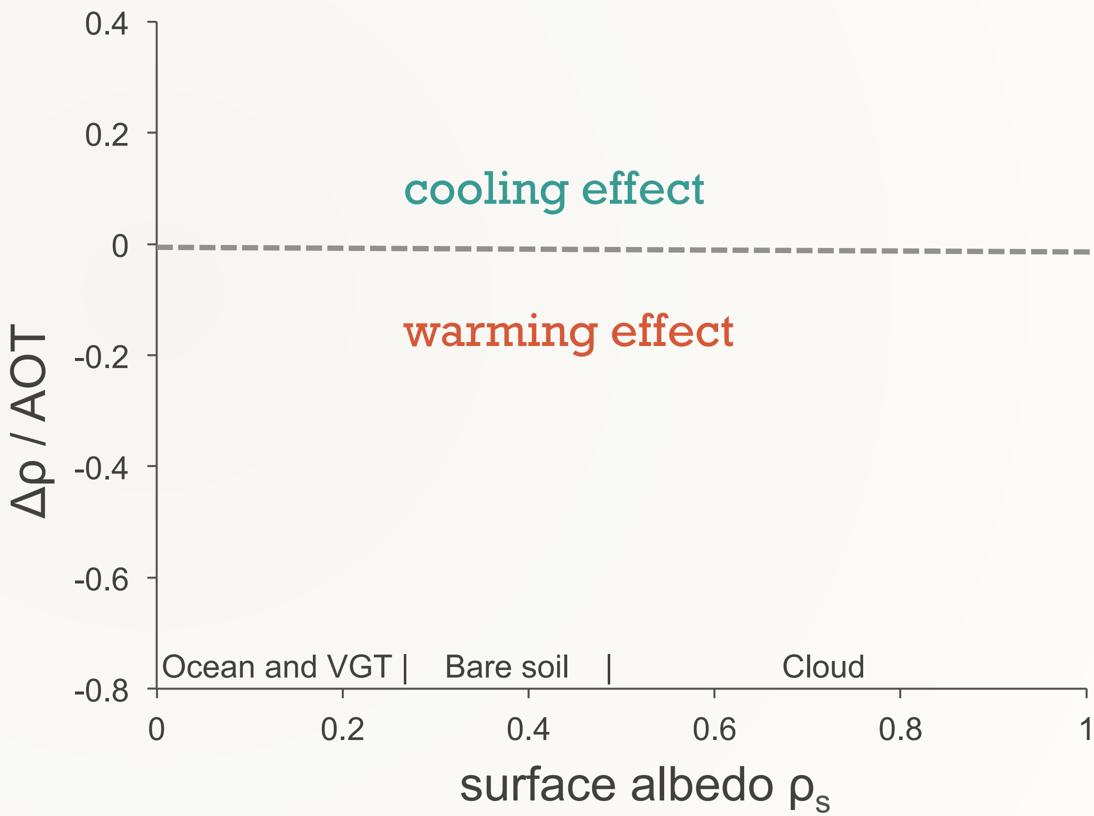




Why study aerosols above clouds ?
direct aerosol effect on climate

Perturbation of the albedo of a scene ($\Delta\rho$) by a thin aerosol layer vs. the surface albedo
(per unit of AOT)

ϖ_0 : aerosol single scattering albedo
g : asymmetry parameter



$$\Delta\rho = \rho - \rho_s = aot.\left(\varpi_0.(1-g).(1-\rho_s)^2 - 4.(1-\varpi_0).\rho_s\right)$$ (Lenoble et al., 1982)

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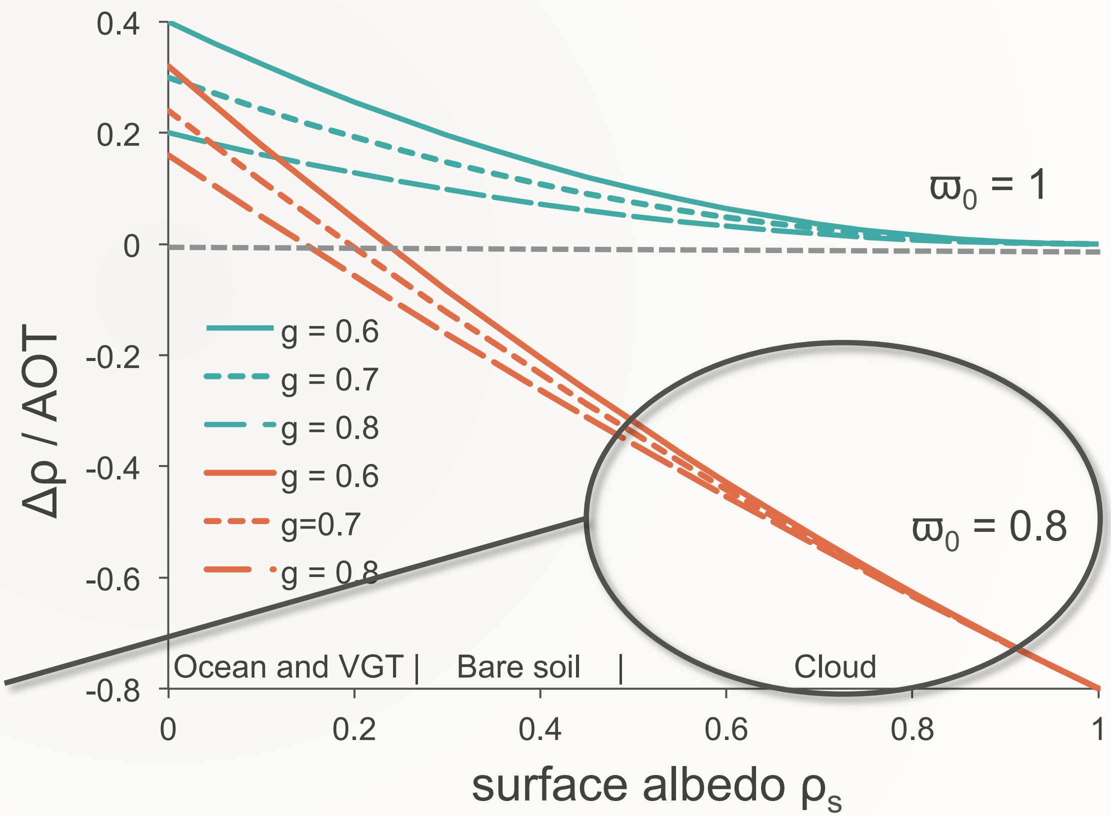

Absorbing aerosols above clouds can cause a reduction of the local planetary albedo = warming effect

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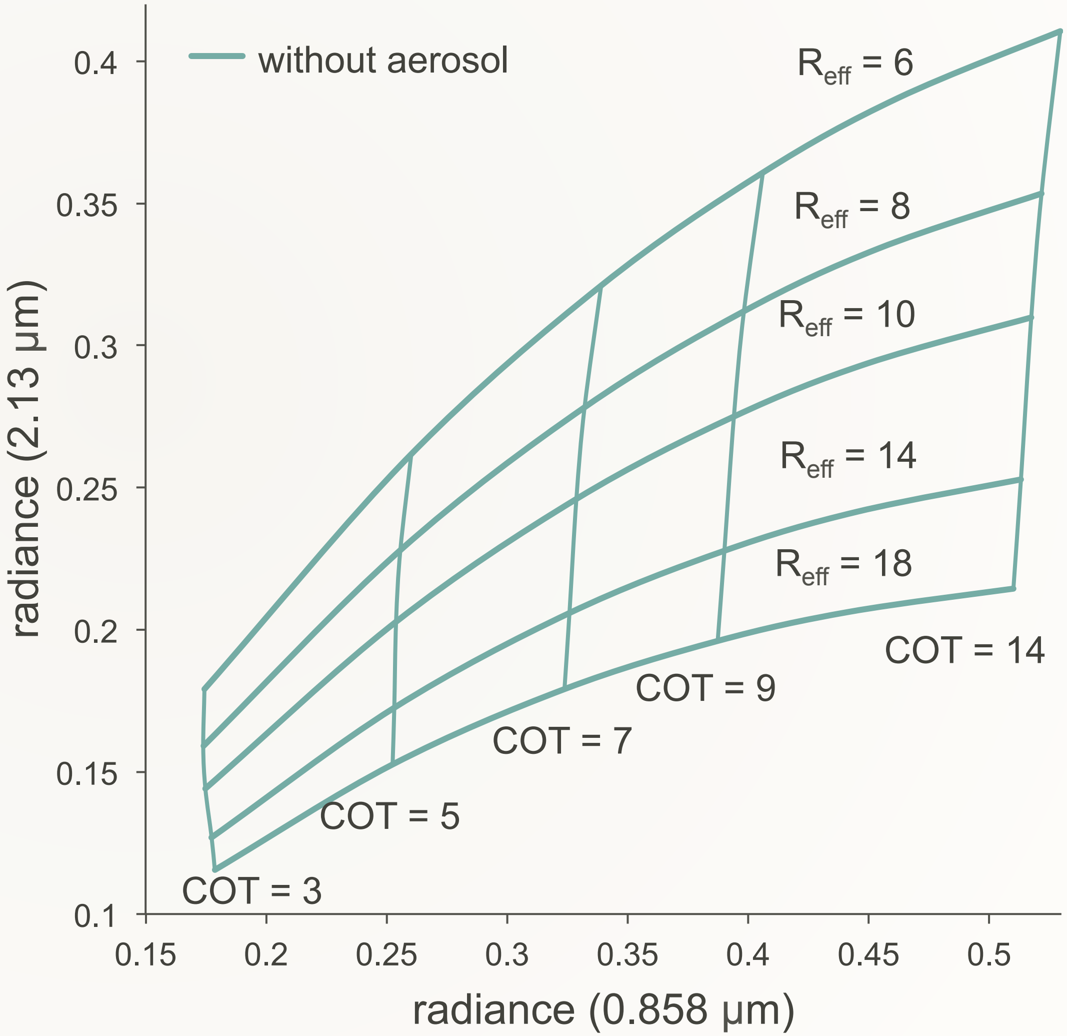
Why study aerosols above clouds ?
cloud retrieved properties biases

Simulated radiances for a couple of wavelength used by MODIS to retrieve the Cloud Optical Thickness (COT) and the droplet effective radius (r_{eff})

Nakajima and King (JAS, 1990)



Why study aerosols above clouds ?
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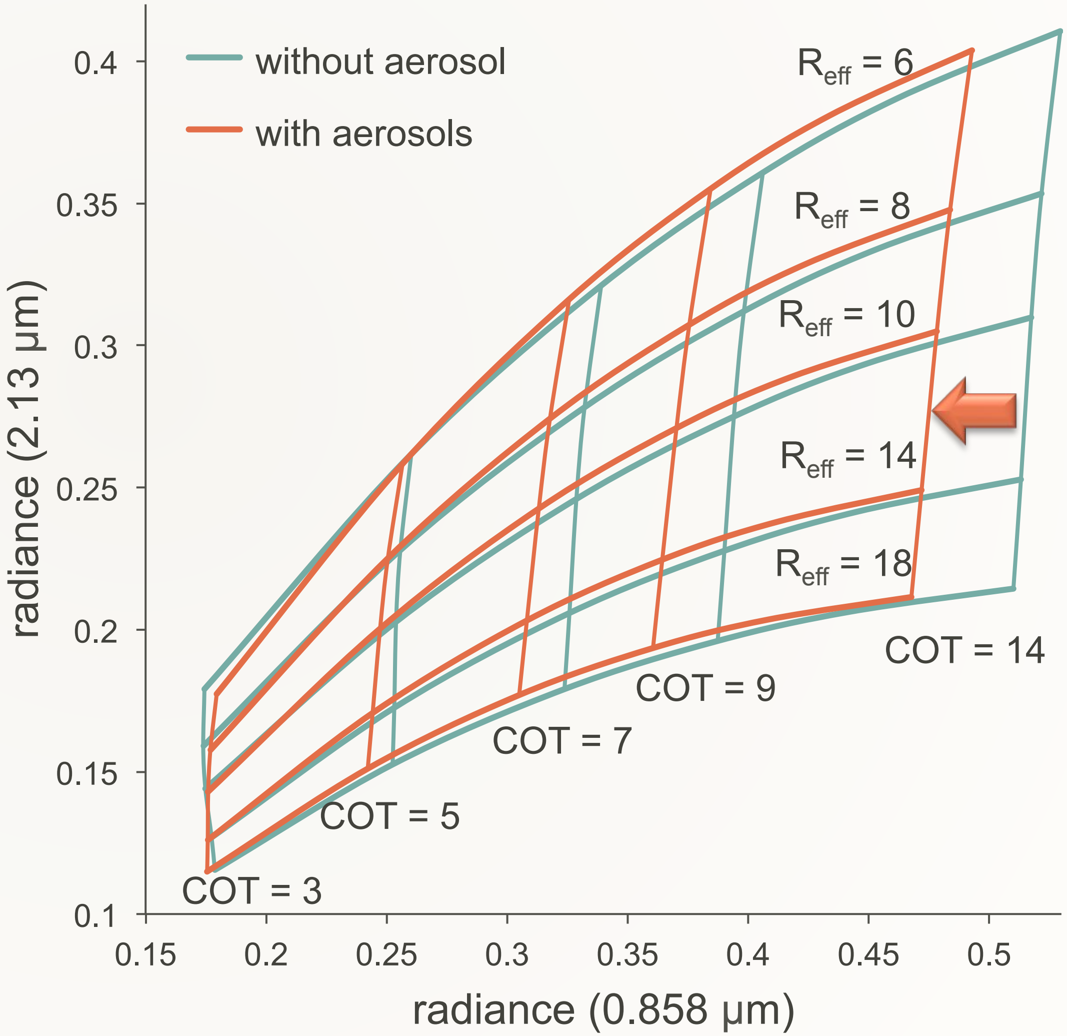
Simulated radiances for a couple of wavelength used by MODIS to retrieve the Cloud Optical Thickness (COT) and the droplet effective radius (r_{eff})

Not taking into account the presence of an aerosol layer above the cloud may lead to biases in COT and r_{eff}



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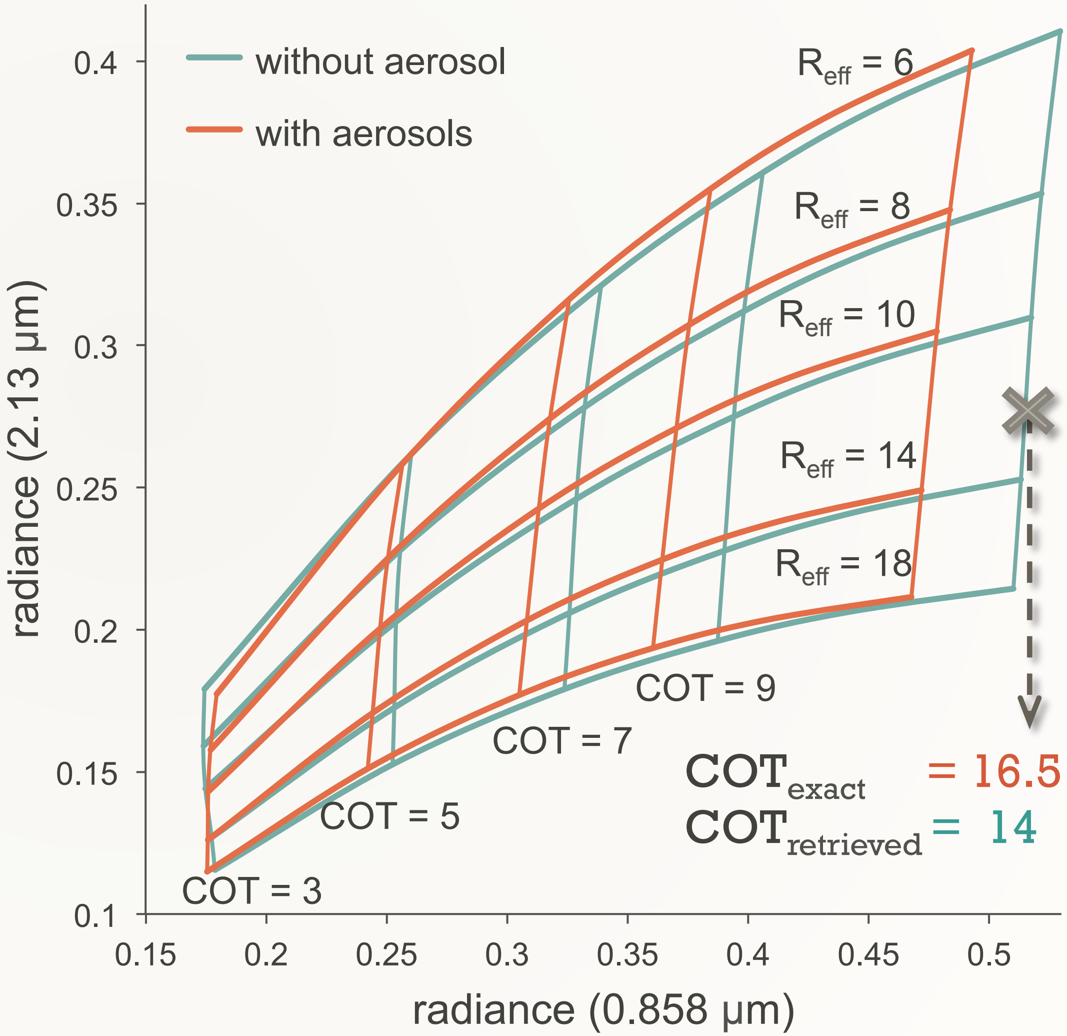
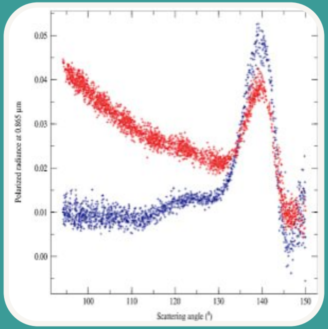
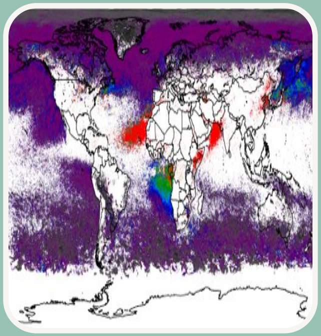


Objectives

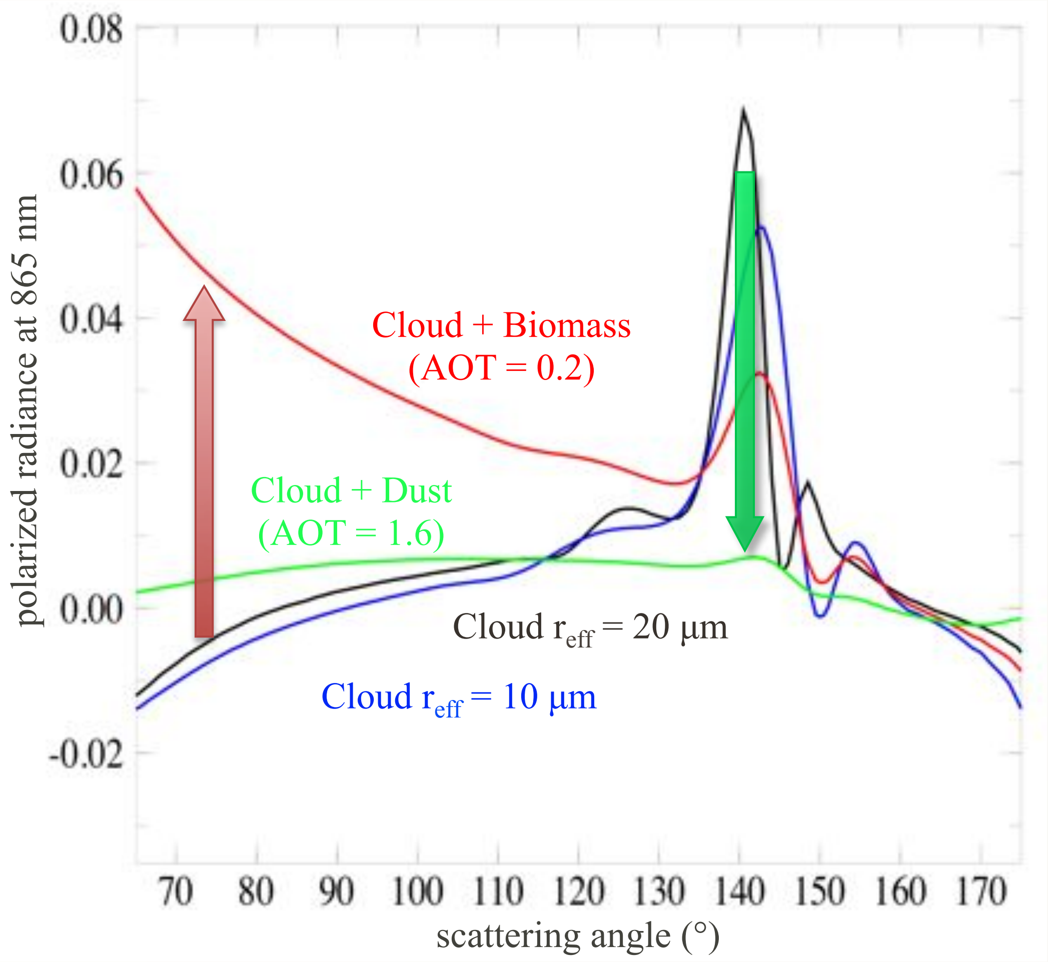


Demonstrate the ability of polarization measurements to detect aerosols above clouds



Depict the variability of the properties of aerosols above clouds at global scale

Sensitivity of polarized radiance to aerosol above clouds scenes



Polarized radiance at 865 nm :

$$L_p = \pm\sqrt{Q^2 + U^2}$$

(Q and U : Stokes parameters)
Plane-parallel transfer radiative code (1D)

Cloud:

- Presence of a cloud bow at ≈ 140°
- Range that doesn't depend on COT for COT>3

Cloud + Biomass *(small spherical particles, r_{eff} = 0.1µm)*:
Additional polarization at side scattering angle

Cloud + Dust *(coarse non-spherical particles , r_{eff} = 2.5 µm)*:
Reduction of the polarization in the cloud bow

Processing

Input data

- POLDER's polarized radiances (670 and 865 nm)
- MODIS & POLDER's cloud properties (r_{eff}, cloud top pressure, σ_{COT}, σ_{reff} …)

Simulated radiances

- Exact modeling with the Scattering Order of Scattering (SOS) code (1D)

Aerosol models

- 6 spherical fine mode aerosol models ($1.72<\alpha<2.95$)
- 1 spheroid dust model ($\alpha=0.36$)
- refractive index = 1.47 – i 0.01

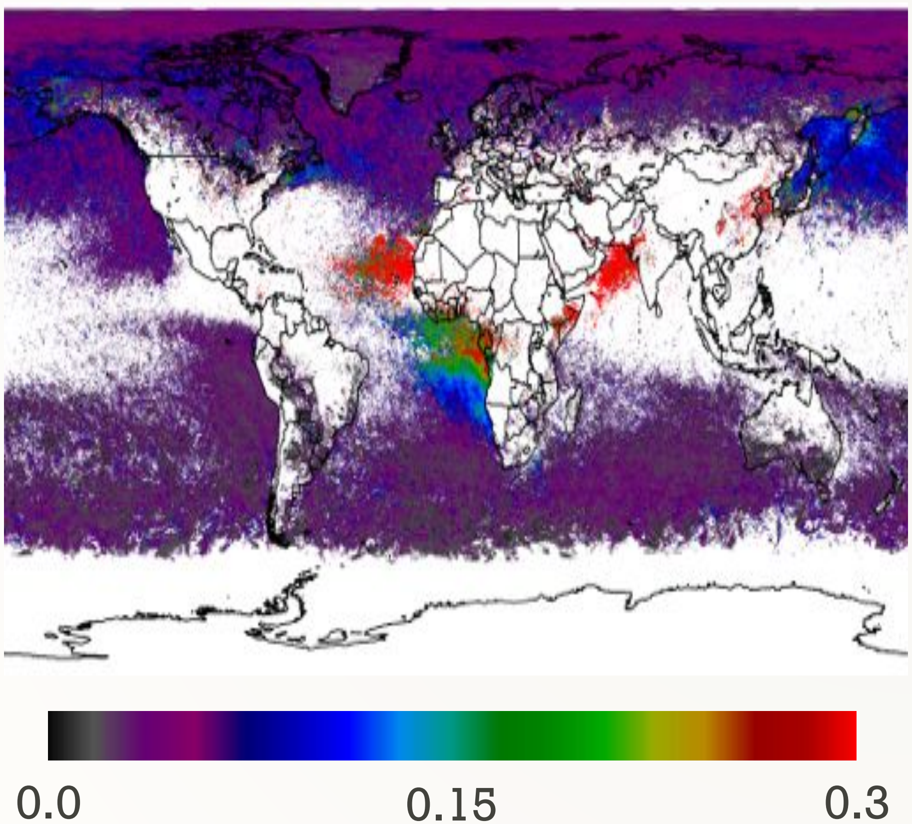
Filters

- σ_{COT}, σ_{reff}, cloud top pressure, final product quality …
- COT ≥ 3
- $BTD_{8-11} \leq -1.25$ K

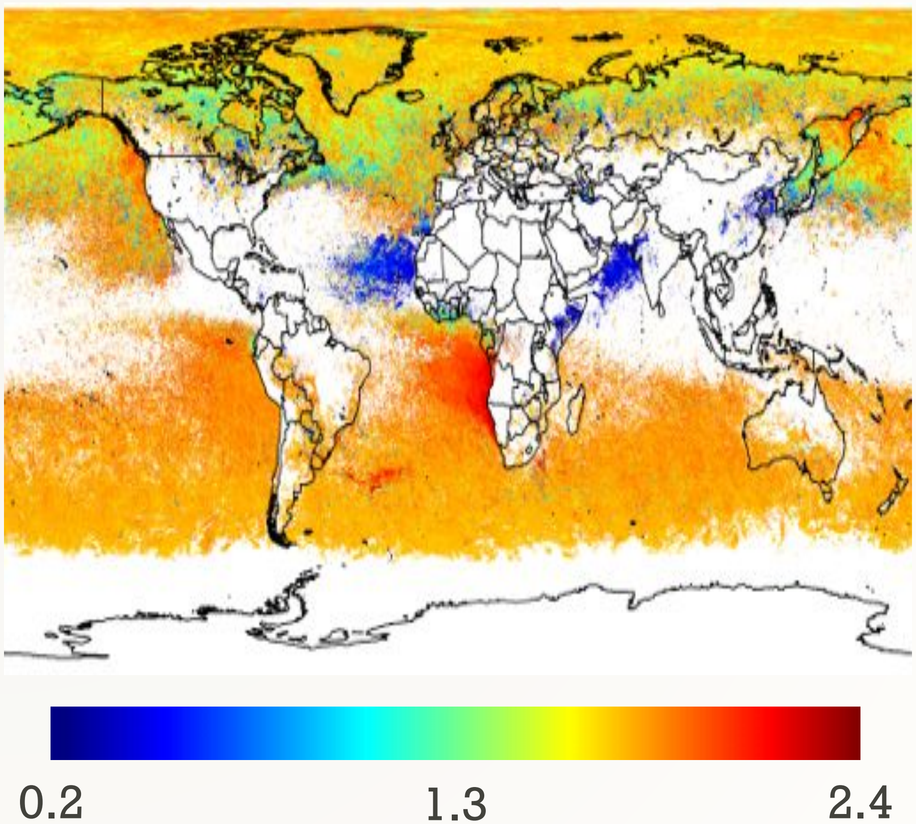
Global distribution of aerosols above clouds

Summer 2009

AOT at 865 nm



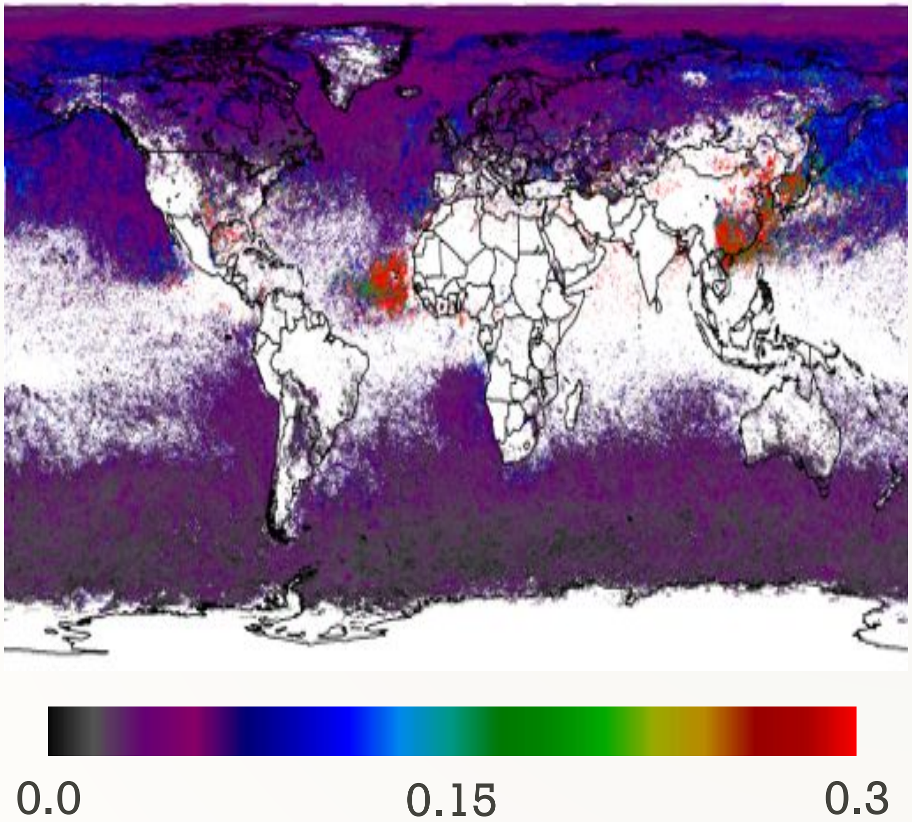
ångström



Global distribution of aerosols above clouds

Spring 2009

AOT at 865 nm



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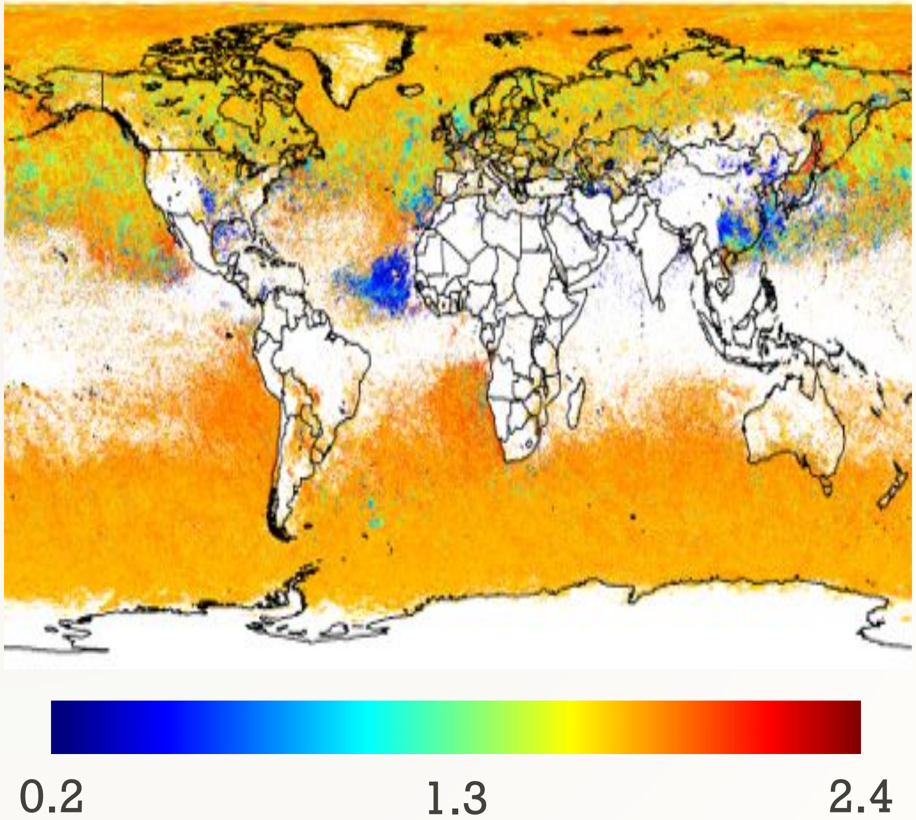
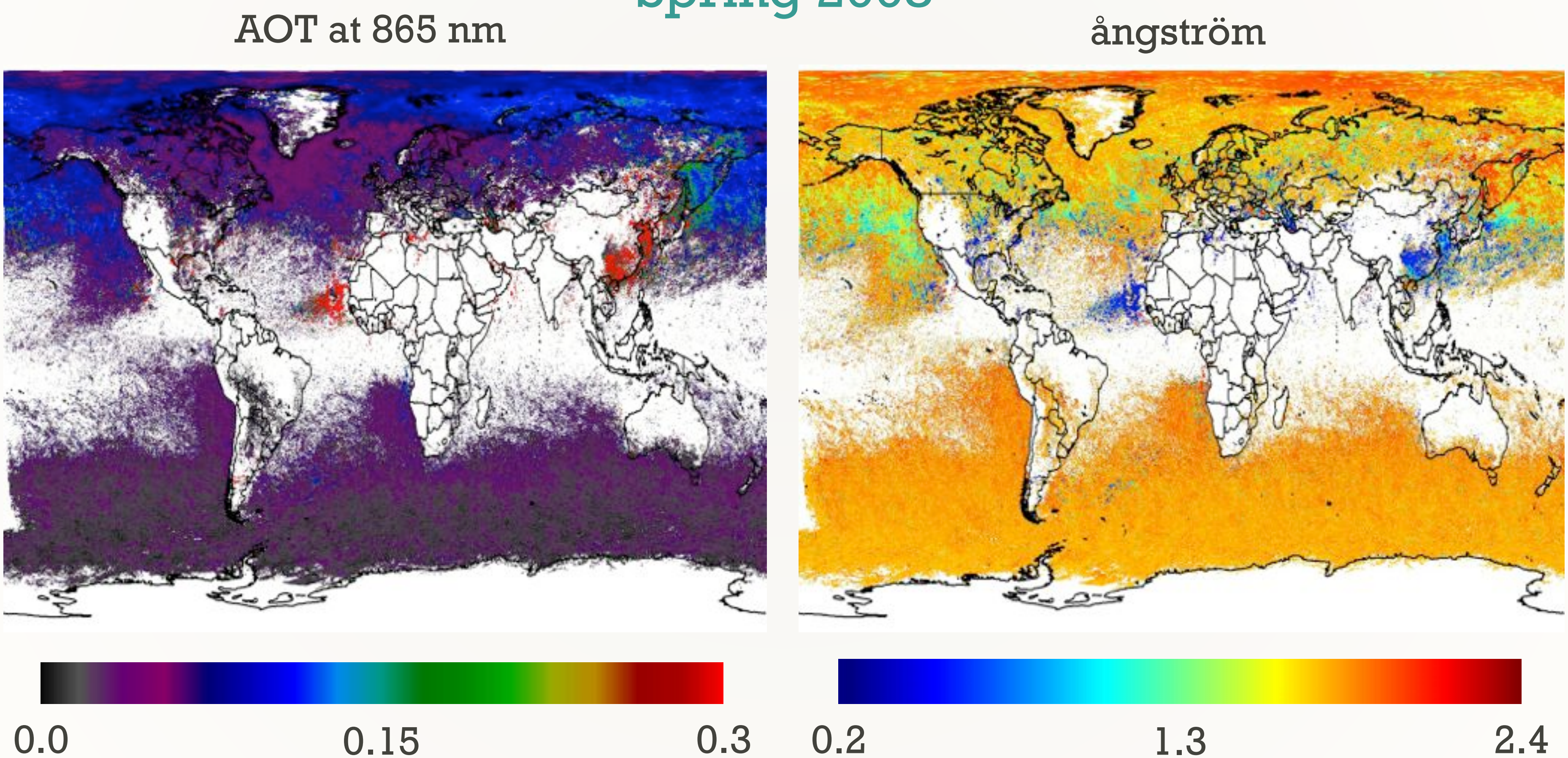


Global distribution of aerosols above clouds

Spring 2008



submitted manuscript: Waquet et al., GRL, 2013

Aerosol absorption above clouds

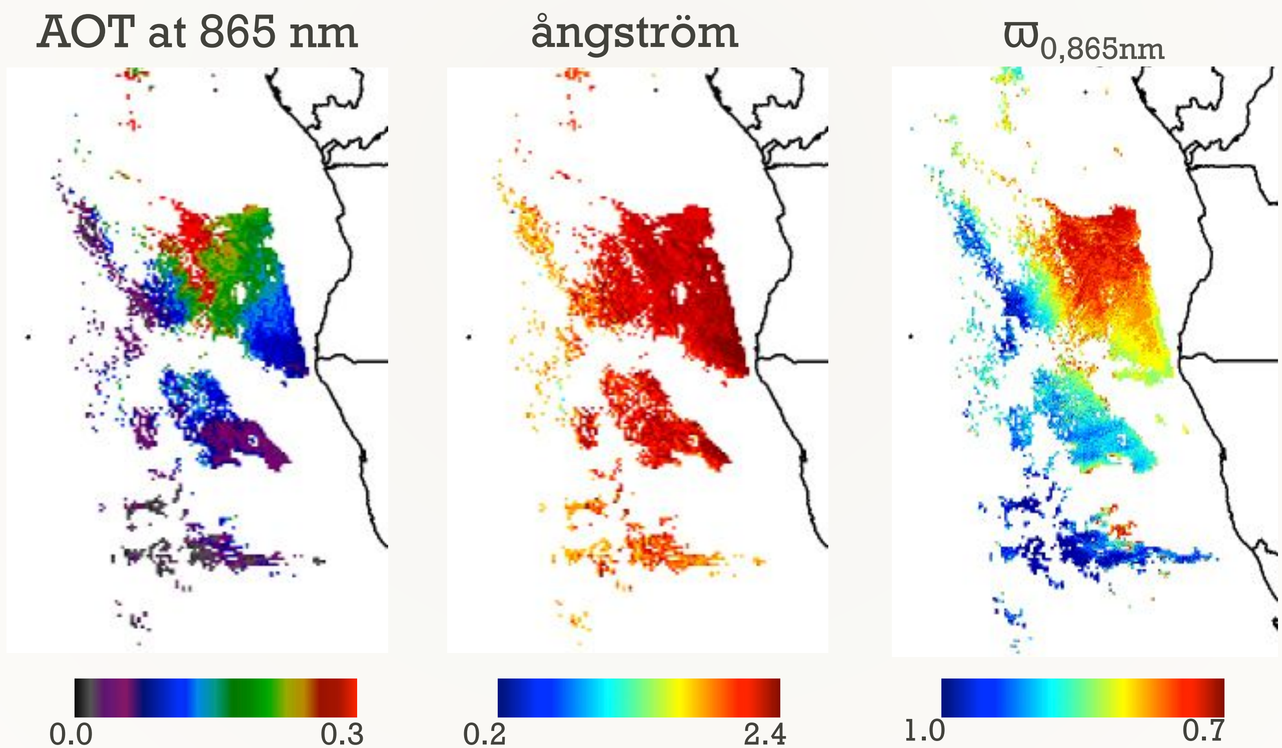
Polarization is mostly sensitive to scattering process.

The operational algorithm results are obtained under an assumption about the aerosol absorption (m = 1.47-0.01i).

- Soon, the estimation of the single scattering albedo ϖ_0 will enable to correct the retrieved AOT above clouds.

Aerosol absorption above clouds

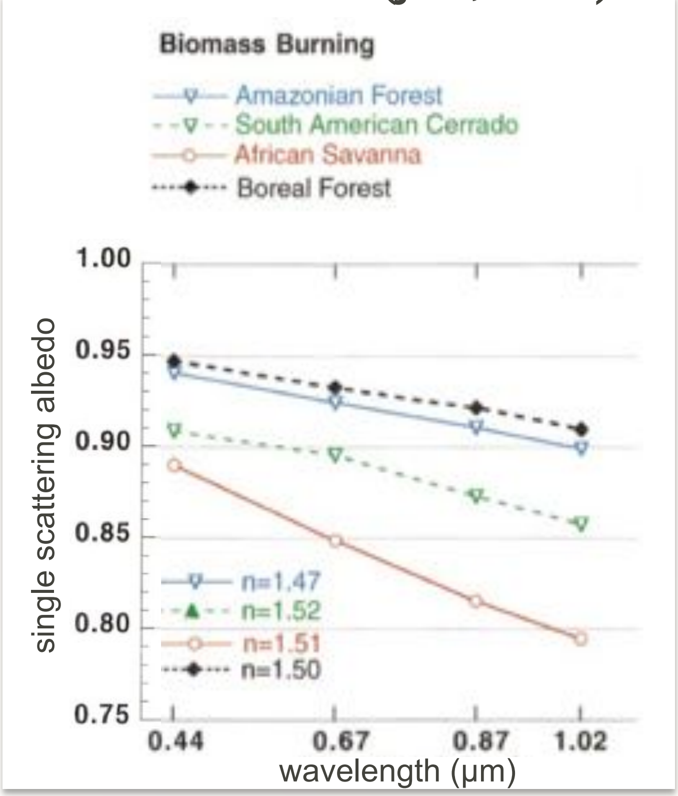
Thanks to the information about aerosol above clouds scattering, the total radiances at 490 and 865 nm from POLDER will lead to the evaluation of the aerosols absorption.



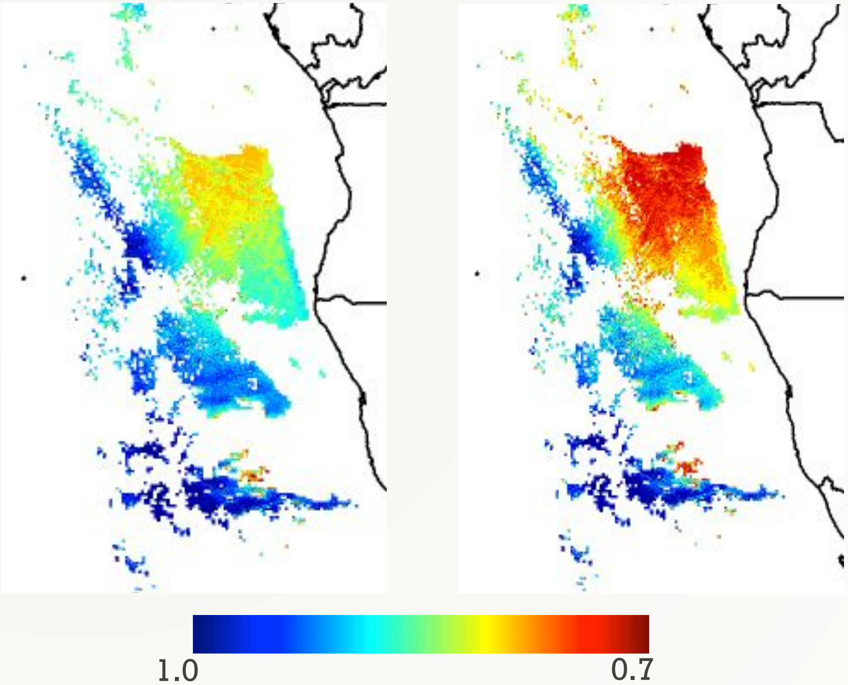
Case study : biomass burning aerosols above clouds off the coast of Namibia.
(04/08/2008 – preliminary results)

Aerosol absorption above clouds

Dubovik et al. (JAS, 2002)



$\varpi_{0,490nm}$ $\varpi_{0,865nm}$



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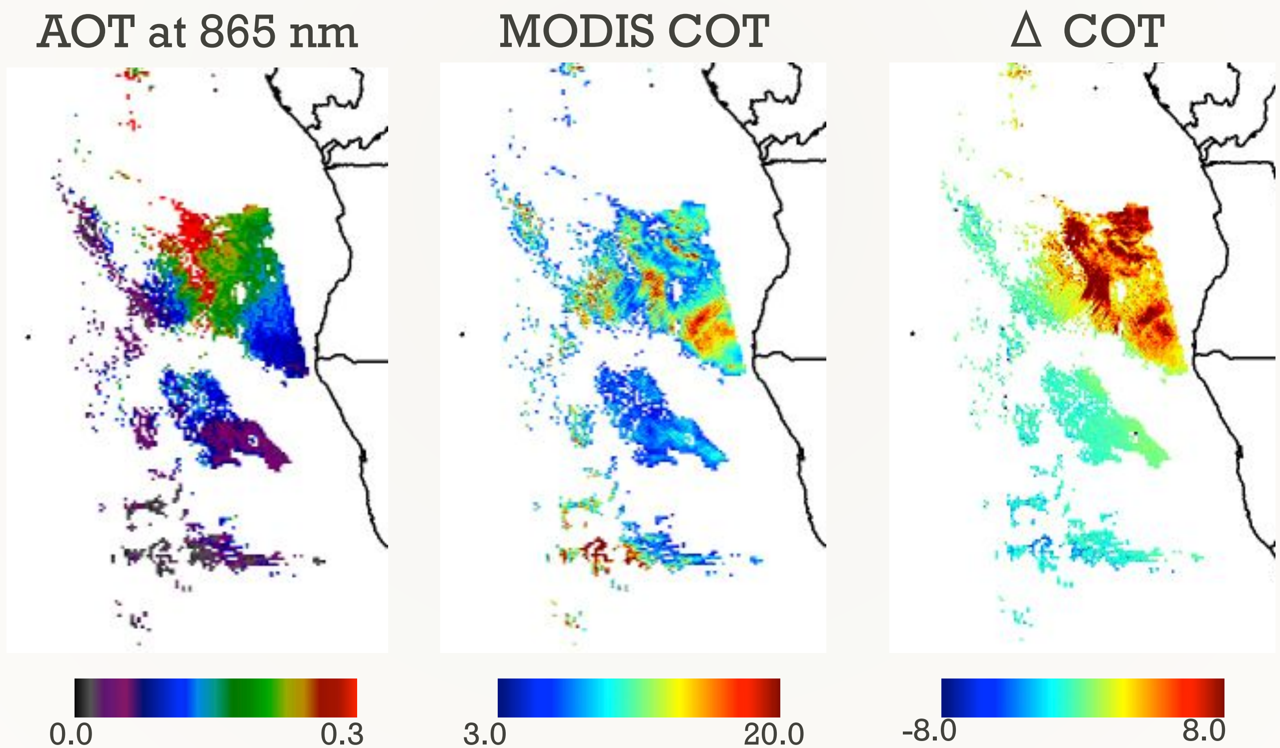
Aerosol absorption above clouds

The method will also provide an estimation of the error upon the retrieved cloud optical thickness (COT).



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Conclusions and outlooks

Detection of aerosols above clouds

- Polarization has shown sensitivity to detect aerosols above clouds.
- It enables the discrimination between aerosols from the fine mode (mostly anthropogenic) and those from coarse mode.

Global distribution of aerosols above clouds

- Taking into account aerosols above clouds increases the global AOT for the fine mode of ≈ 30% (cf. Waquet et al., GRL, 2013).
- ≈ 5 years of results from the operational algorithm (AOT and ångström) will be available from end of the year.
  (From 03/2005 to 12/2009)

Conclusions and outlooks

Evaluate the aerosols absorption

- The estimation of the aerosols absorption will lead to the correction of the extinction AOT.

- It will also allow to evaluate the error on cloud properties that are currently retrieved.

Constrain the direct radiative forcing

- Properties of aerosols above clouds may be used to constrain their direct radiative effect,
- as well as cloud corrected properties.

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