3D Cloud Radiative Effects on Polarized Radiances

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Clouds and aerosols have a major importance in the climate budget and need to be better characterized. Remote sensing observations are a way to obtain either global observations of cloud from satellites or a very fine description of clouds and their variabilities from airborne measurements. More and more radiometers plan to measure polarized reflectances in addition to total reflectances measurements, since this information is very helpful to obtain information on aerosol or cloud properties. In a near future, for example, the Multi-viewing, Multi-channel, Multi-polarization Imager (3MI) will be part the EPS-SG Eumetsat-ESA mission. It will achieve multi-angular polarimetric measurements from visible to shortwave infrared wavelengths. An airborne prototype, OSIRIS (Observing System Including Polarization in the Solar Infrared Spectrum), is also presently developed at the Laboratoire d'Optique Atmospherique and had already participated at several measurements campaigns.

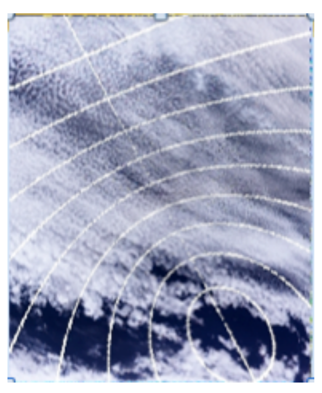
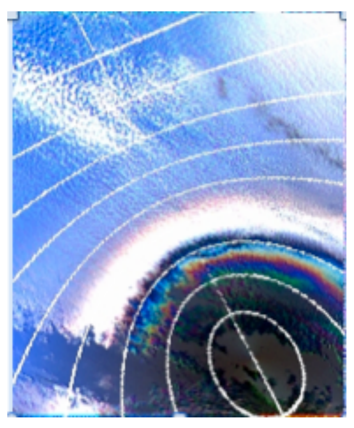
POLDER3/PARASOL – 3MI / EPS-SG

POLDER3/PARASOL 2005-2013:

- Sun-synchronous satellites part of the A-Train
- Multi-spectral measurements in SW range (443nm to 1020nm)
- Multidirectional measurements up to 16 directions
- Polarized measurements for 490, 670 and 865nm
- Initial resolution : 6 km X 7km

3MI /EPS-SG (Marbach et al., 2015) launch in 2021 similar to POLDER with:

- Extension to near-infrared with polarization (410 to 2130nm)
- Nominal resolution: 4kmx4km

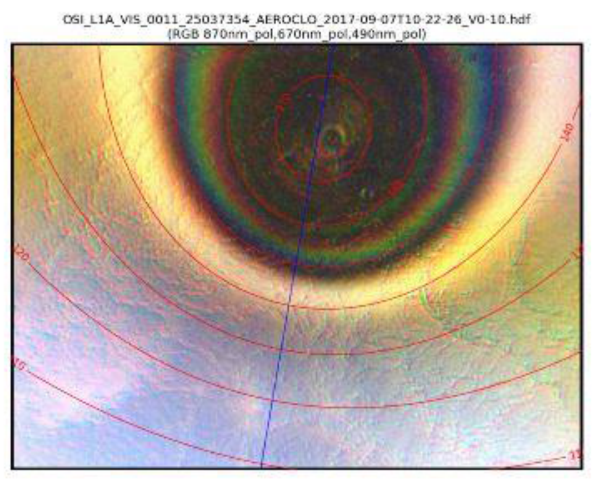
OSIRIS – Airborne radiometer

OSIRIS : Airborne radiometer for measurements of total and polarized radiances with two matrix :

- In the visible (440 to 940nm)
- In the SWIR (940 to 2200 nm)

OSIRIS participates to several campaigns and recently to AEROCLO-sA in the west coast of Namibia in September 2017

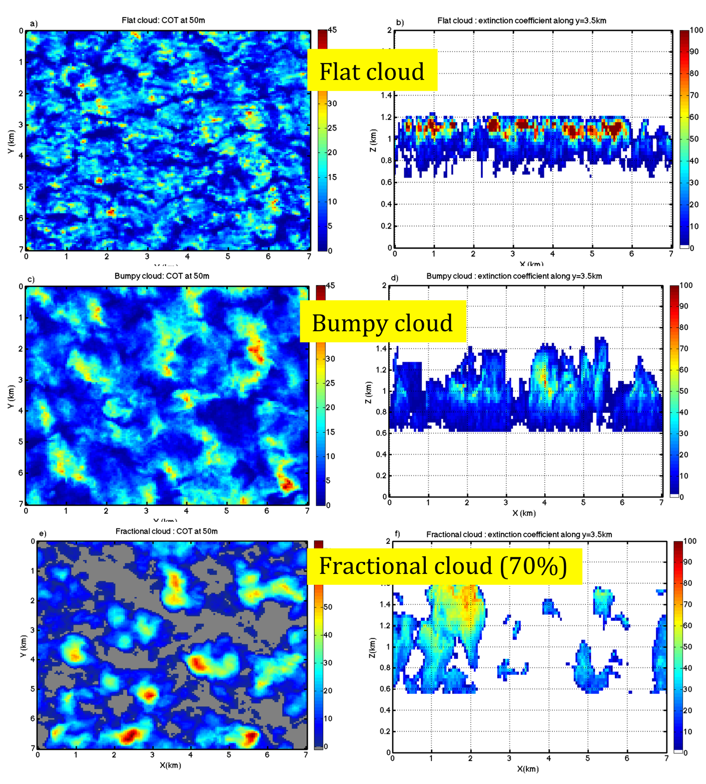




3D Clouds

3DCLOUD model (Szczap et al., 2014) : COT=10

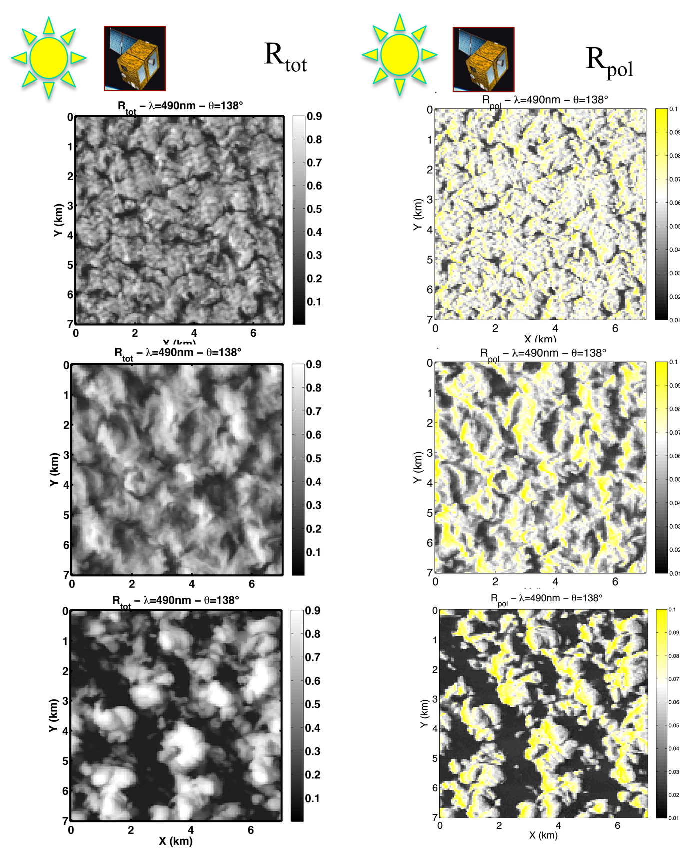
A simplified dynamical thermodynamical stochastic cloud model



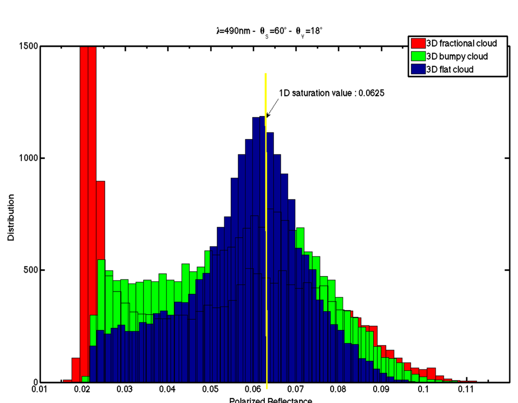
Cloud heterogeneity effects at small scale (50m) for θs=60° (Cornet et al., 2017)

3D sun illumination effects…

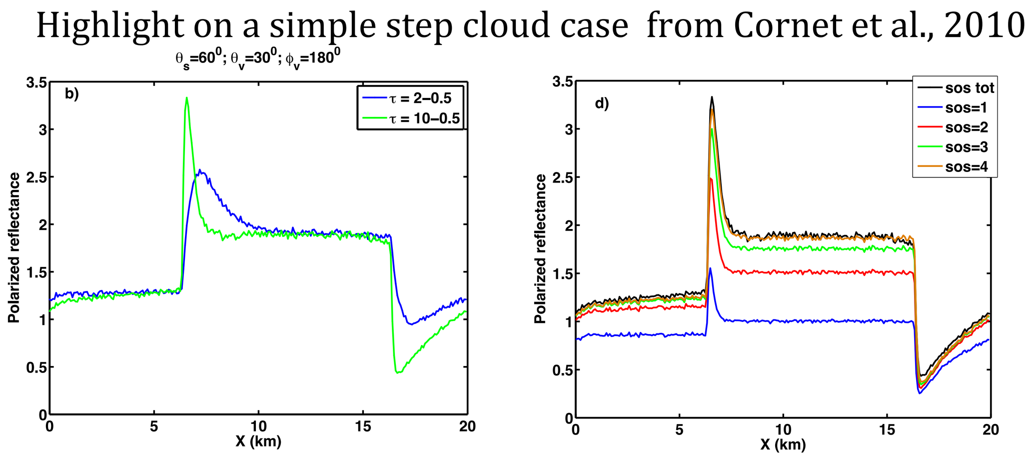
θ_s=60° , θ_v=18°, φ_v =180° => Cloubow view , Θ = 138°



At 50m scale, as for total reflectances, **sun illumination effects** lead to polarized reflectance values higher than values predicted by 1D homogeneous cloud model

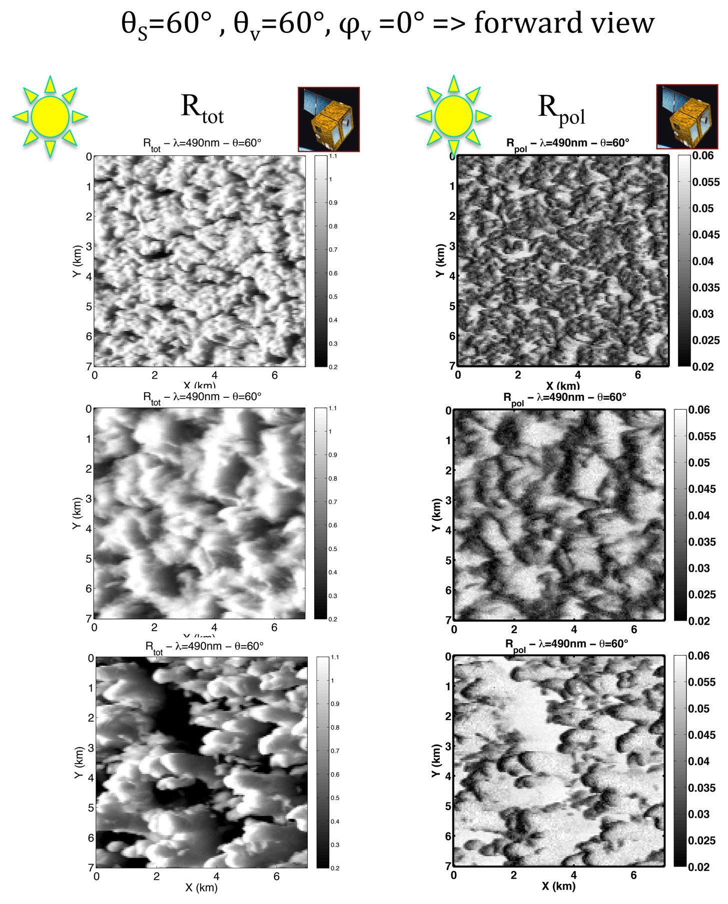


Highlight on a simple step cloud case from Cornet et al., 2010

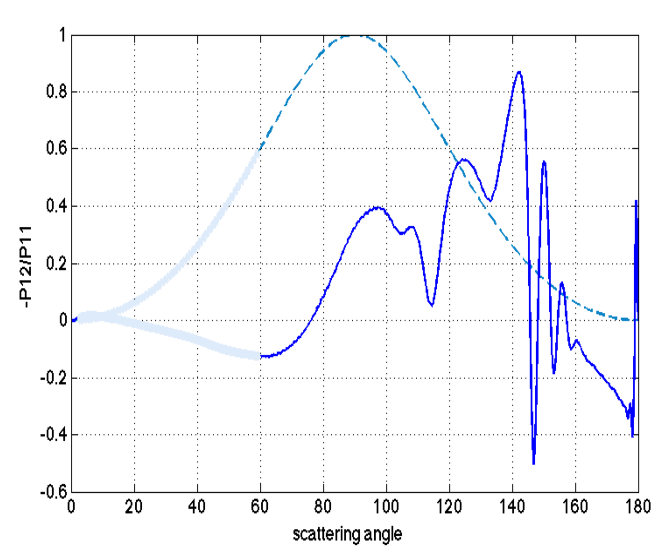


… and 3D cloud shadowing

θ_s=60° , θ_v=60°, φ_v =0° => forward view

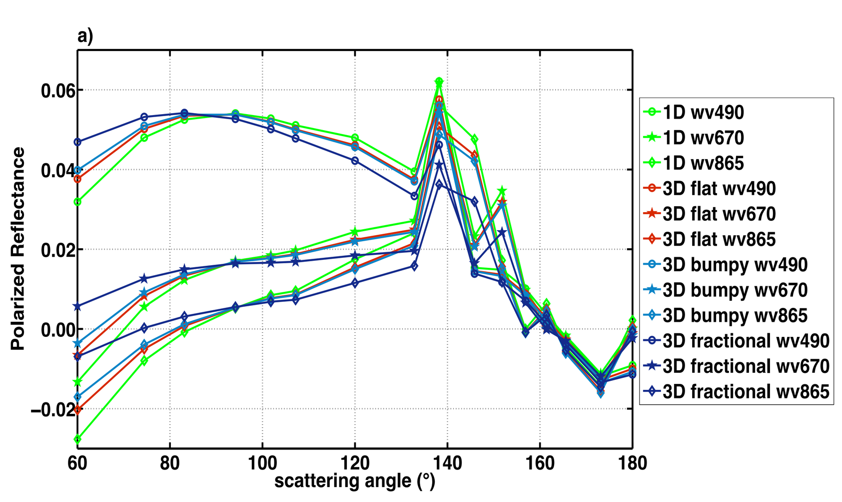


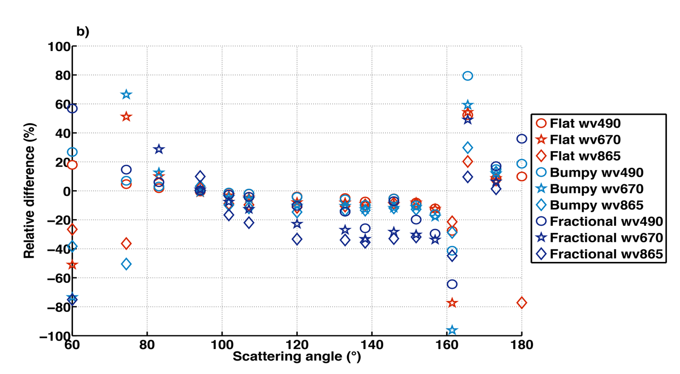
At 490nm, molecular scattering increase polarized reflectances in **shadow region**



Molecular (dashed line) and cloud (solid line) polarized phase function. P12/P11 coefficient

Cloud heterogeneity effects at the POLDER scale (7kmx7km)





Comparing to homogeneous (1D) reflectances :

- Plan-parallel bias : Lower 3D polarized reflectances in cloudbow (Θ = 140°)
- Shadowing effects (Θ = 60°)
  - higher 3D polarized reflectances at 490nm
  - lower absolute 3D polarized reflectances at 865nm

- In the cloudbow, relative error
  - relative error between -5 and -30%
- In the forward direction, relative error
  - between 20 and +50% at 490nm
  - between 20 and 80% at 865nm.

3D cloud effects in the solar principal plane

From IPRT : International Polarized Radiative Transfer group

(Emde et al., 2015, Emde et al., 2017, http://www.meteo.physik.uni-muenchen.de/~iprt)

Case 2 of the intercomparison: cubic cloud illuminated with a solar zenith angle t to 40°

In the solar principal plane :
1D RT => U=0 and V=0
No more true for 3DRT !! => U≠0 and V≠0

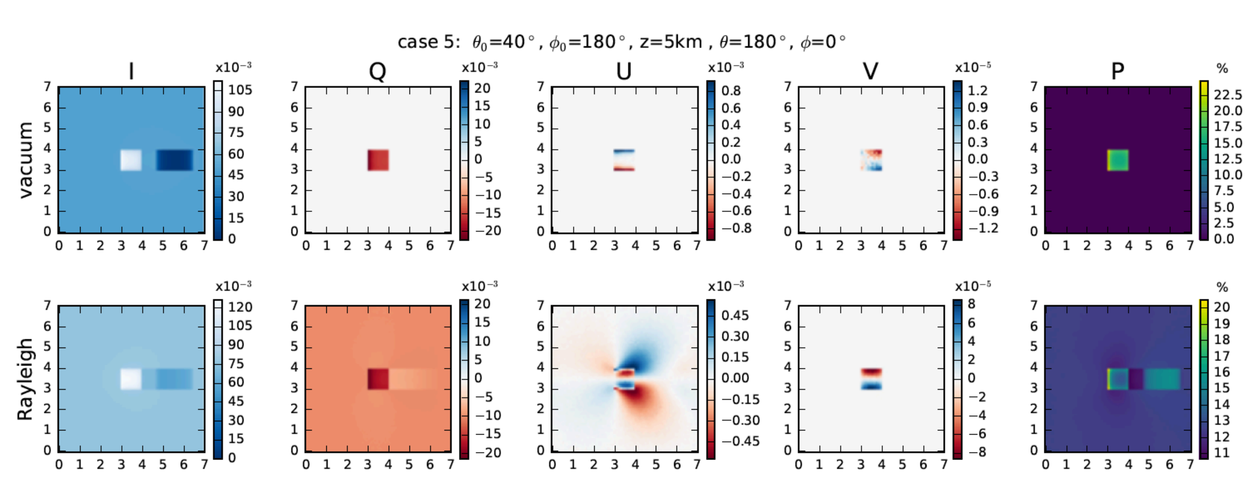


Figure 10: Results for scenario C2 (cubic cloud), case 5, for an observer at the top of the model atmosphere. The viewing direction is nadir and the sun position is $(\theta_0, \phi_0) = (40°, 180°)$. Upper panels: Cubic cloud is in vacuum. Lower panels: The cloud is embedded in a Rayleigh scattering layer. The labels on the x- and y-axes correspond to kilometers.

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