A 3D polarized Monte Carlo spaceborne LIDAR system simulator for investigating cirrus inhomogeneity effects on retrieved optical properties

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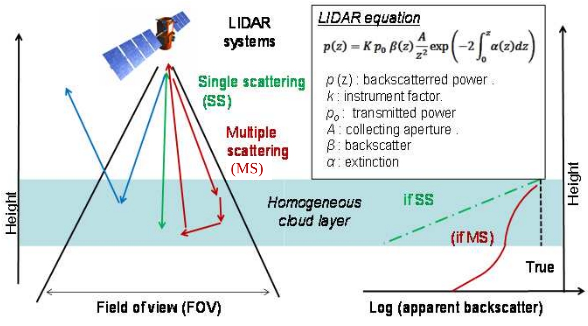
Scientific context :

LIDAR is a powerful tool for deriving the cirrus properties, but the main difficulty to overcome is the significant extinction of the LIDAR beam in its path through the cloud, and one must take into account multiple scattering (Hogan, 2008, Hu et al., 2001).

The cirrus properties are also assumed to be horizontally homogeneous at each level into and around the LIDAR system "footprint" or field of view (FOV).

Our objective is to quantify the effects of cirrus inhomogeneities, corresponding to 3D spatial fluctuations of extinction, on the apparent backscatter and the apparent depolarization ratio as measured by CALIOP/CALIPSO on the A-train.



Methodology :

We developed a 3D polarized LIDAR simulator (3DMCPoLid) based on 3DMCPol (Cornet et al., 2010), a forward Monte Carlo radiative transfer model using the local estimate method and variance reduction methods (Buras et al., 2010) which allows the computation of the Stokes vectors $S=(I,Q,U,V)$

3DMCPoLid computes the apparent backscatter and the apparent depolarization ratio as a function of z, *z* is the height above ground, as "seen" by CALIOP/CALIPSO.

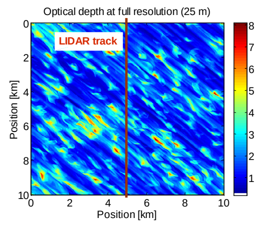
3D cirrus scenes are provided by the thermodynamic/stochastic cloud generator (3DCLOUD) which is able to constrain the cloud invariant scale properties, the mean optical depth, the distribution of the extinction and the amplitude of the cloud inhomogeneity.

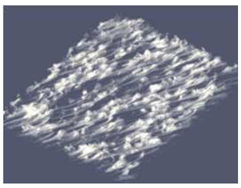
Conditions of simulation

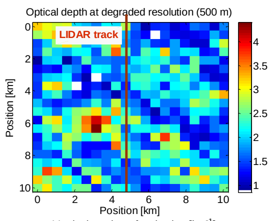
- *LIDAR system parameters*
- Laser beam divergence = 0
- Linearly polarized laser
- λ_{laser} = 352 nm
- FOV = 130 µrad
- Footprint ≈ 100 m
- $D_{telescope}$ = 1 m
- Height = 1000 km
- Vertical resolution = 20 m

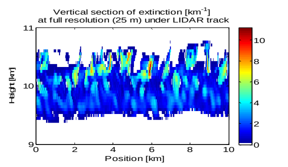
- *Atmospheric properties*
- No sun (Night)
- No ground albedo
- Gaz optical depth from Hansen and Travis (1974)
- Gaz depolarization factor (90°) = 0.0275
- Gaz phase function : Rayleigh theory
- Cloud phase function : Rough plate ice crystals, R_{eff} = 25 µm , aspect ratio = 0.2, gamma distribution ,IGOM, Yang and Liou (1996)

- *Inhomogeneous cirrus cloud parameters*
- Mean optical depth = 2
- Base and top height ≈ 9 and 10 km
- Inhomogeneity parameter (standard deviation / mean of IWC) = 1
- Slope of 1D power spectrum of IWC = -1.66
- Gamma distribution of IWC
- Horizontal extension = 10 km
- Pixel number : *Nx* = *Ny* = 400, *Nz* = 90
- Horizontal (vertical) resolution = 25 (50) m









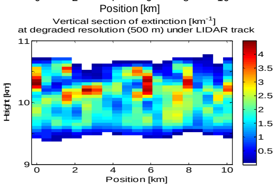
3DMCPoLid simulations

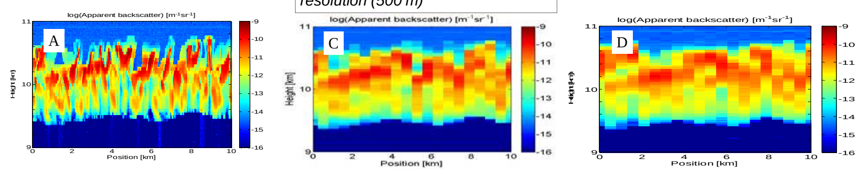
Case A : 3D LIDAR at full resolution (25 m)

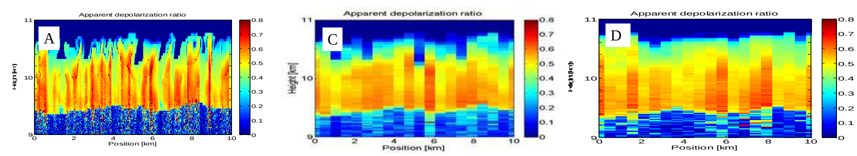
Case B : 1D LIDAR at full resolution (25 m) (not shown)

Case C : 3D LIDAR at full resolution (25 m) and averaged at degraded resolution (500m)

Case D : 3D LIDAR at degraded resolution (500 m)

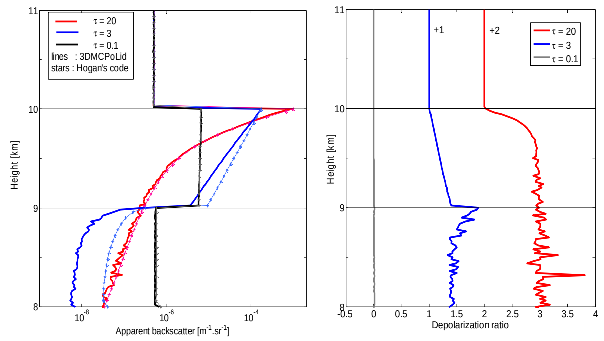






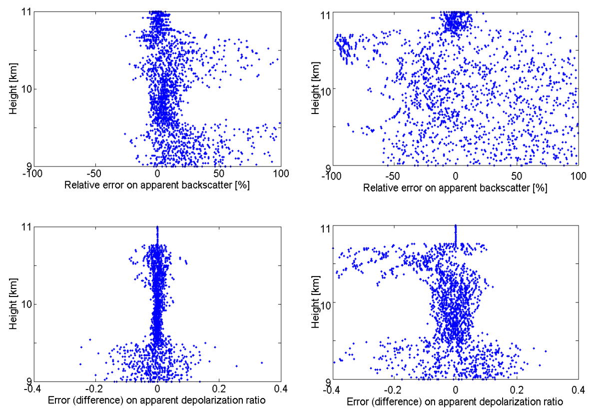
3DMCPoLid vs Hogan's LIDAR code (Homogeneous cirrus)

Spherical ice crystals, R_{eff} = 10 µm, lognormal distribution, Mie theory



Effects of cirrus inhomogeneities inside the LIDAR FOV (≈100) at degraded resolution (500m)

Effects of cirrus inhomogeneities at the degraded resolution (500m)



Early results

- Good agreement between 3DMCPoLid and Hogan's codes for small and large optical depth, but not for optical depth close to 3.
- 3D cirrus inhomogeneities effects are not negligible for space LIDAR systems and can provide large relative error on backscatter (100%) and on depolarization ratio (25% to 100%), especially on cirrus top, even for an averaging scale of 500 m, close to CALIOP resolution (333m)

Perspectives

- In order to generalize these early results, sensitivity tests must be carried out with others realistic fluctuations of cirrus extinction and with other ice crystals shapes.
- To take into account laser beam divergence.
- To investigate 3D cirrus inhomogeneities on retrieved optical depth by LIDAR system.
- To develop a 3D polarized RADAR simulator

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