Ecole Doctorale des Sciences Fondamentales

Title of the thesis: Study of the effect of the spatial variabilities of the Earth's cloudy atmosphere and the simple scattering approximation on the measurements of high spectral resolution lidar and Doppler radar systems and on the retrieved cloud products

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Summary :

Aerosols and clouds play a major role in the hydrological and radiative balance of the Earth's climate system and the cloud feedback is still very uncertain (IPCC report, 2013). In addition, remote sensing from space provides remarkable useful observations for studying cloud propertiesat a global scale. Since 2006, observations of the CALIOP lidar and the CPR radar of the A-train mission have made it possible for the first time to carry out studies on the vertical structure of clouds at a global scale. These observations, coupled with numerical models, allowed significant advances in understanding the mechanisms involving clouds and aerosols and to improve their representation in numerical simulations (Bony et al., 2006, Sherwood et al., 2013, Stephens et al., 2018).

Following on from this success, several other active spatial remote sensing projects have emerged or are in preparation, with the aim of studying the atmosphere with new technologies, in particular high spectral resolution (HSR) or the Doppler effect (ADMAeolus, ESA report, 2016; EarthCARE, Illingworth et al., 2015; ACCP / MESCAL, NASA / CNES project). These new technologies will provide new measurements from space such as wind speed and will improve the characterization of the vertical profile of aerosols and clouds.

However, clouds remain complex structures that exhibit large variability in three dimensions with geometric, microphysical and optical properties atdifferent scales.. Atmospheric dynamics also exhibit significant variability at different scales. These variabilities are still poorly taken into account in numerical models, as well as in signal processing and in lidar and radar remote sensing algorithms. In addition, simplifying assumptions such as single scattering regime are often used in operational algorithms to optimize computation times.

Since HSR technology is now present on (future) lidars in space, it therefore becomes very important to assess the impact of these hypotheses and to quantify the uncertainties both on future active remote sensing observations (direct problem) and on retrieved cloudy products (reverse problem).

To answer these questions, numerical simulation tools are particularly well suited. They make it possible to study cloud-radiation interactions from a theoretical point of view. They are therefore excellent tools for improving our understanding of the physics of measurement of such remote sensing systems, for preparing and interpreting current and future observations.
In this context, the Monte Carlo McRALI radar/lidar simulator has been developed at LaMP (Alkasem et al., 2017; Szczap et al., 2020). Coupled with high spatial resolution stochastic cloud models such as 3DCLOUD (Szczap et al., 2014), it is a very powerful tool for understanding the physics of measurements of active remote sensing instruments and cloud-radiation interactions.

The thesis work will consist in finalizing the code developments that will make McRALI a end-to-end HSR lidar and Doppler radar simulator (implementation of a sea surface model, a Brillouin scattering model, a generation model of noise, filter / interferometer models), to finalize the development of the 3DCLOUD code (generation of wind fields, of 3D mixed phase clouds) and also to develop rendering algorithms to determine cloud products. Once these developments will be validated, the objective will be to use McRALI to assess the impact of cloud heterogeneities and to quantify the effects of the single scattering approximation in the signal processing of ground, airborne and space lidar and radar observations. This will allow to estimatethe error on the retrieved products such as cloud optical thickness or extinction coefficient, lidar ratio and wind speed.

The thesis will be done within the framework of the TOSCA / CNES EECLAT project and a PNTS project led by the LaMP and will have applications in the TOSCA / CNES SEA2CLOUD (LaMP), DYCECT (LATMOS) and IMOTEP (CNRM) projects.

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