Ecole Doctorale des Sciences Fondamentales

Title of the thesis: Influence of environmental conditions on Arctic mixed phase cloud microphysical and radiative properties

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Summary :

Polar regions are more sensitive to climate change than any other region of the world. The Arctic is warming at twice the global mean rate (i.e. Arctic amplification phenomenon) and shows acute visible signs such as the retreat of summertime sea-ice. Low-level mixedphase clouds (MPCs) have a major impact on the Arctic surface energy budget and hydrological cycle due to their persistence and peculiar microphysical properties (mixture of liquid droplets and ice crystals). The distribution of these clouds, their precise radiative impact and precipitation frequency are poorly understood due to the limited availability of *in situ* measurements and the difficult identification of the mixed phase from remote sensing techniques. The life cycle of MPC results from a complex web of interactions between local microphysical, radiative, dynamical processes and larger scale environmental conditions (surface type, air mass origin, meteorological conditions). MPCs are challenging to model from local to global scales, and strong assumptions in the representation of the microphysical processes are required. The predictive capability of the Arctic to respond to climate change is therefore severely hampered by a lack of understanding on key processes related to clouds and their interactions with atmospheric aerosol particles. Since 2017, the LaMP *in situ* probe payload (PMA) has been deployed during three airborne campaigns in the vicinity of the Svalbard Archipelago to characterize the microphysical and optical properties of MPCs under a variety of environmental conditions. An unprecedented dataset of cloud measurements was collected during ACLOUD in the end of spring 2017 (Arctic CLoud Observations Using airborne measurements during polar Day), AFLUX in early spring 2019 (Joint Aircraft campaign observing FLUXes of energy and momentum in the cloudy boundary layer over polar sea ice and ocean) et MOSAiC-ACA in summer 2020 (Multidisciplinary drifting Observatory for the Study of Arctic Climate). The analysis of these measurements combined with collocated remote sensing observations (mainly radar/lidar) and radiative fluxes performed during these campaigns should increase our process-level understanding of ice microphysics, phase partitioning and their role in the sustenance and radiative impact of MPCs.

The main objective of this PhD thesis will be to investigate how environmental conditions impact the microphysical and radiative properties of Arctic mixed phase clouds. A first step will be to analyze the cloud *in situ* data (liquid and ice water content, number concentration, hydrometeor size, scattering properties) to characterize their horizontal and vertical distributions with respect to the air mass origin (linked to aerosol loading), surface type (open ocean, marginal ice zone, sea ice) and thermodynamical conditions. The small scale variability of cloud microphysical and optical properties as well as the fluctuations of the liquid/ice partitioning will also be assessed for different meteorological conditions. In a second step, the candidate will develop parametrizations of the ice crystal number concentration and liquid/water distribution as a function of aerosol properties, cloud top temperature and humidity for different surface conditions. Relationships between the ice/liquid water contents, extinction coefficients and radar reflectivity will be established to evaluate remote sensing retrievals. Finally, the aim of the third step will be to deliver representative estimates of cloud radiative effect for selected environmental conditions. The candidate will run the 3DCLOUD cloud simulator constrained with *in situ* observations to compute the radiative properties (fluxes, vertical profiles of heating rates) of the target MPC cases with a 3D radiative transfer solver (SHDOM). Special focus will be placed on the radiative impact of cloud phase spatial inhomogeneities.

This subject lies within the framework of previous studies on Arctic cloud microphysics conducted by the supervisors (*Mioche et al.*, 2017 ; *Mioche and Jourdan*, 2018 ; *Szczap et al.*, 2014) with this time a focus on the influence of large scale environmental conditions as well as on the radiative impact of MPCs. The expected results will contribute and fit to the objectives of the already funded projects IPEVMPC^{2}EA and CNES-EECLAT as well as the (MPC)^2 project submitted to the ANR in 2020. The candidate will also benefit from the scientific expertise of the (AC)^3 research institutes (DLR, IGM Univ. Cologne, LIM univ. Leipzig) that funded the aircraft activities in Svalbard.

References :

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