Ecole Doctorale des Sciences Fondamentales

Title of the thesis: Ice crystals formation in convective cloud systems: properties and impacts.

Supervisor: Wolfram Wobrock
Laboratory: Laboratoire de Météorologie Physique (LaMP)
University: Université Clermont Auvergne
Email and Phone: Wolfram.WOBROCK@uca.fr / 04 73 40 73 64

Possible co-supervisor: Céline Planche (celine.planche@uca.fr)
Laboratory: Laboratoire de Météorologie Physique (LaMP)
University: Université Clermont Auvergne

Summary:

Significant gaps exist in our current understanding of aerosol-cloud interactions which are reflected in the large uncertainties in weather forecasts and climate projections. One key aspect that is poorly understood is the role of the ice phase and the aerosol particles on which atmospheric ice crystals form. Whether a cloud is predominantly composed of water or ice strongly influences cloud properties and feeds back into the cloud life cycle, precipitation formation, and radiative energy balance. Both the impact of the aerosol particles on the formation of the ice crystals and the ice crystal evolution, are suspected to play a dominant role in determining the physical properties of clouds.

Ice crystals can be formed in clouds at temperatures lower than 0°C via different processes. One process, which is called heterogeneous nucleation, involves the presence of aerosol particles known as ice-nucleating particles (INPs). The ability of aerosol particles to act as INPs is strongly dependent on both their physical and chemical properties. The other way to form ice crystals is via the homogeneous nucleation process. In contrast to the heterogeneous nucleation, the water freezes without the presence of INPs at temperatures below around -36°C.

Cloud systems under different climatic conditions have been observed thanks to in-situ aircraft microphysics probes or remote measurements during several experiments: for tropical conditions with the HAIC campaigns (2014 at Darwin, Australia and 2016 at Cayenne, French Guyana), and for the mid-latitude Mediterranean conditions with the HyMeX (2012) and the EXAEDRE (2018) campaigns. Using the bin resolved microphysics module DESCAM (developed at the lab LaMP) within a three dimensional dynamic frame of a cloud model, significant differences in the number concentration between observed and modeled spectra of ice particles have been found at altitudes within the temperature range of 0°C to -20°C. In this temperature range, heterogeneous nucleation is a key process for the formation of ice crystals.

However, secondary ice production processes (such as the rime splintering or the breakup of the freezing droplet) may occur and lead to a substantial enhancement of the number concentration of the ice population.

This PhD thesis will be a step towards a better understanding of the ice phase formation in different convective clouds. A main focus will be given to the role of the secondary icemultiplication and heterogeneous nucleation processes and their consequences for cloud particle spectra. Fulfilment of this objective will be based on the analysis of airborne cloud measurements and detailed microphysical modelling.

Using the DESCAM bin microphysics scheme, the candidate will simulate idealized cases with contrasted atmospheric conditions for updating the representation of the heterogeneous ice nucleation process and for implementing an explicit representation of the secondary ice multiplication mechanisms. In subsequent work steps, statistical comparative analyses between modelling results and observations, with a focus on either the heterogeneous nucleation or the secondary ice production will be conducted to adjust, if necessary, each ice formation mechanism (such as efficiency, ice particles properties: concentrations and sizes) to actual atmospheric conditions observed during the different campaigns.

Directeur : Pr Yanick HEURTEAUX
tél. 04.73.40.50.64
E-mail : yanick.heurteaux@uca.fr

Secrétariat : Lucie NAUD
tél. 04.73.40.53.76
E-mail : edsf.drv@uca.fr