Ecole Doctorale des Sciences Fondamentales

Title of the thesis: Ice crystal morphology and growth mechanisms by water vapour deposition, aggregation growth, and riming: towards a better understanding of cloud physics and improvements in aviation safety

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Summary:
Physical properties (dimension, shape, phase, concentration…) of ice crystals are key parameters for a better representation of the ice phase in atmospheric models (cloud process models, mesoscale models, GCM) and in radiative transfer calculations. Improved understanding of ice microphysics and more sophisticated cloud model microphysical parametrizations of the onset and development/growth and precipitation of the ice phase will also help validating retrievals from cloud remote sensing instruments (cloud radars and radiometers on aircraft and satellites).
Also research progress with respect to cloud ice phase is particularly needed for the aviation industry. For example, high concentrations of small ice particles (HAIC project) have been recognized as a threat to commercial aviation, causing hazardous icing conditions for aircraft engines and Pitot probes. Likewise, a better comprehension of snow properties is needed for future designs and certification work of aircraft and helicopters (ICE GENESIS project).
Within this thesis we want to promote the quantitative morphological analysis of ice crystals, which has not been a primary focus within past studies. Based on existing ice crystal datasets and newly developed convolutional neural network software for most sophisticated automatic ice crystal classification at the laboratory, we want to demonstrate statistically the link between complex crystal morphology and ice crystal growth regimes which are active in space and time during the entire cloud life cycle. Among growth processes we generally distinguish between growth by water vapour diffusion, aggregation growth, and riming. Observed crystal morphology is more often impacted by varying contributions of different growth regimes as a function of time (and space in the cloud). This thesis work is planned within a few national and international research projects (e.g. HAIC (FP7) and ICE-GENESIS (Horizon 2020) both led by Airbus Industry and e.g. the French national project ANR EXAEDRE (dedicated to better understanding of cloud electrical phenomena).

Within the above projects (including numerous worldwide measurement campaigns in 2014-2021, and beyond) the LaMP research laboratory operated the French Airborne Measurement Platform PMA, thereby using individual crystal imagery (from small crystals to large hydrometeores and up to snowflakes) and complementary measurements in order to document ice particle microphysical

properties, fall speed, mass, and density of individual hydrometeors, also properties of supercooled water droplets, which are eventually co-existing with ice particles.

			
PMA cloud instruments on F20 (SAFIRE): HAIC, EXAEDRE, others…	…. on A340 flight tests Airbus) : HAIC	…on helicopter H160 (Airbus Helicopters) : H160 project, ICE GENESIS	…on ATR-42 (SAFIRE) : ICE GENESIS

Useful links:

- Ice crystal icing in aviation / deep convection in the Tropics ○ HAIC: https://insu.cnrs.fr/fr/cnrsinfo/haic-high-altitude-ice-crystals-2014
- Ice crystal icing from snow ○ ICE GENESIS : https://www.ice-genesis.eu/
- Deep convection in mid latitudes and cloud electricity :
  - EXAEDRE : https://www.hymex.org/exaedre/
- PMA project / instrumental payload :
  - https://lamp.uca.fr/recherche/instruments-modeles/plateforme-de-mesuresaeroportees

Laboratory:

The PhD candidate will be hosted at LaMP. Based in Clermont-Ferrand (France), this laboratory (≈ 35 scientists and engineers and 10 Master/PhD students) is the leader in France and a reference in the world for cloud in-situ microphysics measurements and modelling.

Qualification

We are looking for a motivated PhD student to investigate above scientific questions. The candidate should hold a Master of Science or equivalent in a field relevant to the proposed research field (e.g. Environmental Sciences, Applied Mathematics, or Statistics). We expect the candidate to be proficient in a programming language (Python, Matlab, etc.…). Proficiency in English is a prerequisite.