PHD Project

Microfluidic instrumentation for studying the ice-forming properties of aerosols. Application to marine environments

Context

The oceans cover more than two-thirds of the Earth's surface and dominate the Southern Hemisphere. As a result, the marine atmosphere is a key component of the Earth's climate system. Marine aerosols are produced by wave action through the bursting of bubbles at the air–sea interface, generating sea spray aerosols (SSA) that remain suspended in the atmosphere. These particles influence climate both directly, by interacting with incoming solar radiation, and indirectly, by acting as cloud condensation nuclei (CCN) and ice nucleating particles (INPs).

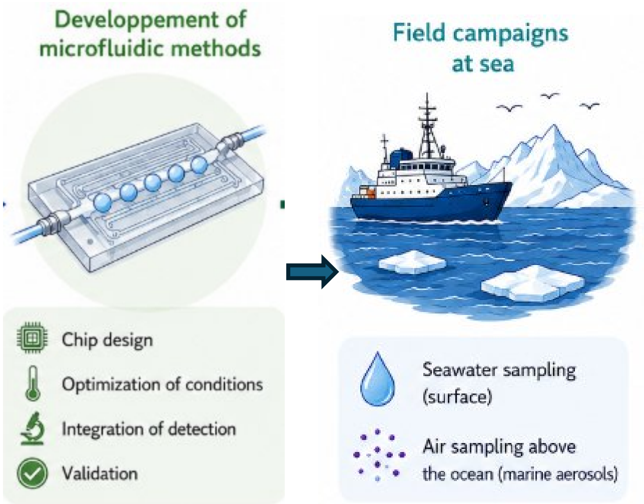
The phase of clouds (liquid, mixed-phase, or ice) strongly influences their radiative properties, lifetime, and ability to produce precipitation. However, ice crystal formation through heterogeneous nucleation remains one of the largest uncertainties in climate models, particularly at relatively "warm" temperatures (0 to –20 °C), where INP concentrations are extremely low and difficult to quantify. This issue is especially critical over the Southern Ocean, a key region for the Earth's radiation balance, where cloud properties remain poorly represented in climate models. Current measurement techniques suffer from important limitations. Online methods are generally restricted to temperatures below approximately –15 °C, whereas offline techniques require sample collection, storage, and transport, potentially introducing significant artefacts.

The overall objective of this PhD project is to **investigate the links between marine biogeochemistry and the formation of ice nucleating particles** in the Southern Ocean. To achieve this goal, the project will involve the **development and subsequent deployment of an instrument based on microfluidic technologies**. This miniaturized and portable instrument will enable the quantification of ice nucleating particles in seawater and, ultimately, in marine aerosols generated aboard research vessels.

Work Plan

The PhD project is structured around two complementary research themes. The first component will focus on the completion of the instrument development, the validation of an existing prototype, and its optimization for the detection of biologically derived INPs expected at extremely low concentrations to evaluate the microfluidic technique in the laboratory alongside existing ice nucleation measurement methods. Beyond prototype validation, the project will explore new instrumental developments aimed at measuring additional variables using microfluidic technologies, either through functionalization of the microfluidic chip or through the integration of complementary detection techniques (e.g. fluorescence), in order to better characterize the contribution of biological compounds to the observed ice nucleating activity.

The second component of the PhD will focus on deploying the instrument to measure INPs—and potentially biological indicators—directly aboard research vessels, with the aim of obtaining the first identification of the biogeochemical factors controlling the occurrence of INPs in seawater and their spatial variability. The ambition is to deploy the instrument during the ASOLAS expedition in 2028 aboard the R/V Polarstern in the Weddell Sea as part of the Antarctic-InSYNC initiative.



This project is based on a highly interdisciplinary collaboration between the Laboratoire de Météorologie Physique (LaMP), providing expertise in atmospheric chemistry, aerosol–cloud interactions, and ice nucleation measurements; the FEMTO-ST Institute, specializing in microfluidic technologies; and DT-INSU, contributing expertise in the design and engineering of scientific instrumentation. Thesis under joint supervision LAMP (Karine Sellegri / Evelyn Freney) and FEMTO-ST (Jean-François Manceau / Franck Chollet).

Scientific challenges

- How do marine biogeochemical properties influence the concentrations of ice nucleating particles (INPs) in seawater?
- What mechanisms control the transfer of these ice nucleating particles from the ocean to the atmosphere ?
- How can microfluidic technologies be adapted for the development of autonomous instruments for atmospheric measurements ?
- How can the detection and characterization of ice nucleation events be automated for extremely low concentrations of ice nucleating particles ?
- Can these approaches be extended to characterize other variables relevant to climate, atmospheric aerosols, or marine ecology ?

Expected qualifications for the PhD candidate:

- Applicants should hold a Master's degree (or equivalent) in Atmospheric Sciences, Environmental Sciences, Physics, Engineering, or a closely related discipline.
- This project has a strong experimental component and will be particularly well suited to candidates interested in instrument development, environmental measurements, and the deployment of novel sensors during field campaigns in challenging environments.
- Ideally, candidates should have a background in engineering (mechanical engineering, electronics/instrumentation, thermal engineering, microtechnology, etc.).
- Experience or skills in microfluidics and microfabrication would be considered an asset.

Work place : LAMP (Clermont-Ferrand) and FEMTO-ST (Besançon)

Expected start date : nonmember, 1st, 2026

To apply : Send CV, a motivation Lette and one or more referees to evelyn.freney@cnrs.fr