# Influence of air parcel history on the thermodynamic phase of Arctic clouds

Supervisors: Quentin Coopman, Jérôme Riedi
Laboratoire d’Optique Atmosphérique, Université de Lille

The Arctic is warming faster and more intensely than lower latitudes, but climate models remain uncertain and disagree about the magnitude of this so-called « Arctic amplification ». The uncertainty is mainly due to the radiative impact of clouds on the surface and in particular because of their complex interactions with aerosols. These later act as ice nucleating particles and facilitate the freezing of cloud droplets to ice crystals: without aerosols, cloud droplets freeze at -40˚C, through so-called homogeneous freezing, but with aerosols, freezing can occur up to ~0˚C through heterogeneous freezing. The temperature at which a cloud droplet turns into an ice crystal and the effect of aerosols on this process are still poorly understood. The Arctic region does not contain important sources of aerosols, but can nonetheless be highly polluted by lower latitude aerosols reaching the Arctic after being transported over long distances. The physicochemical properties of the aerosols change during transport, making the particles more or less efficient in forming ice crystals. However, these changes have not been considered in the study of aerosol-cloud interactions. Clouds can also remain in a metastable state where ice crystals and liquid droplets coexist, called mixed-phase clouds. The representation of mixed-phase clouds in models, which contradicts observations, leads to large uncertainties in climate predictions.

This PhD project aims to understand the influence of aerosols on the spatial distribution of the thermodynamic phase of Arctic clouds and the glaciation temperature. The influence of different types of aerosols from anthropogenic and natural sources will be investigated. Satellite observations from the passive instruments Polarization and Directionality of the Earth's Reflectances (POLDER-3) and Moderate-Resolution Imaging Spectroradiometer (MODIS) will be used to characterize the thermodynamic phase at the cloud top and infer cloud microphysical properties. A particular focus will be on the description of mixed phase clouds. The same information will be obtained from the active instruments Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) and the space-based radar on CloudSAT to determine the vertical profile of the cloud phase. Back trajectories initialized on cloud observations will be linked to understand the path taken by the air parcels and the possible processes that took place prior to cloud formation. Aerosol information from the reanalysis from Copernicus Atmosphere Monitoring Service (CAMS) will be co-localized with the back trajectories to understand the nature of the aerosols and the mixing of the air parcels. Different statistical tools will be considered to analyze the data set from classical to machine learning methods. Ultimately, the thesis will identify aerosols that have an impact on the cloud glaciation temperature, quantify this impact as well as their influence on the spatial distribution of the cloud thermodynamic phase, distinguishing between the different types of transport having an impact on different processes.

key words: aerosol-cloud interactions, polar regions, remote sensing, aerosol aging
Contact: quentin.coopman@univ-lille.fr

**Requirements:**

- Master's degree in Physics, remote sensing or atmospheric sciences.
- Analytical skills working on scientific data
- Proficiency in programming/scripting languages (e.g., Python)
- English language skills, written and spoken

**Position Duration:** 3-year fellowship starting from October 2024.

**Location:** The candidate will be based at the Laboratoire d'Optique Atmosphérique in Villeneuve d'Ascq, France.

**Application Requirements:**

- A detailed CV, including the email and phone number of two references.
- A brief cover letter explaining the applicant's relevant experience and motivation for the position.

For additional details and application submission, please contact Quentin Coopman at quentin.coopman@univ-lille.fr.