# PhD in Geo-Atmospheric Science:
# Mineral dust particles as the seeds of ice in clouds

**Supervisors:** Dr Ben Murray (SEE), Prof. Liane Benning (SEE)

**Contact:** Ben Murray (b.j.murray@leeds.ac.uk)

**Project synopsis**

Ice formation in clouds remains one of the least well understood cloud processes. In this laboratory project you will quantify the role that mineral dusts play in the formation of ice in clouds. This novel and exciting project is on the interface between atmospheric science and geochemistry. Ice nucleation is a fast moving and growing field with a network of researchers across the world in both academia and industry with many opportunities post-PhD.

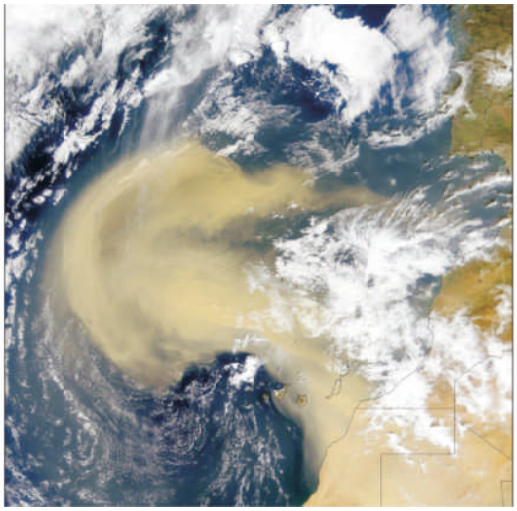

Fig.1. Saharan dust storm swirling over the Atlantic. Northern Africa is a major global source of dust, but there are many questions remaining regarding its ice nucleating properties.

**Background**

Ice formation in clouds is of central importance to life on Earth since it is a key process in the formation of precipitation and strongly influences the radiative properties of clouds. Despite its importance, the formation of ice remains one of the least well understood aspects of cloud formation. It is well known that ice melts at 0°C, but it is less well understood that cloud water droplets can supercool to temperatures approaching -36°C unless as special particle type is present. This special particle type, known as an ice nucleating particle (INP), can trigger or seed droplet freezing at much higher temperatures, but only about 1 in a million aerosol particles in the atmosphere is capable of serving as an INP. It is this inherent rarity that makes INP's and ice formation such an exciting and challenging field.

Fig.2. A convective cloud towering out of a dust laden lower atmosphere over the Sahel.

The ice nucleation community has identified a range of aerosol types as INP including desert dusts, pollen grain, fungal spores, volcanic ash, bacteria and soot amongst others. Of these, mineral dusts from deserts are thought to be one of the most important. We have recently discovered that one particular component of desert dust is most important for its ice nucleating ability (Atkinson et al., Nature, 2013). We showed that feldspars, which are a very common framework silicate in Earth's crust, and not the clay minerals as previously thought, are the most efficient ice nucleating minerals. Through collaboration with the GLOMAP global aerosol modelling team in ICAS we were able to show that feldspars are one of the most important atmospheric ice nuclei in the Earth's atmosphere. This paper was a major step change in our understanding of atmospheric INP, but many questions remain. In particular, there is some evidence that the ice nucleating ability of feldspars varies with feldspar composition. Because feldspar mineralogy and composition varies substantially in different desert source regions this might be very important for ice

nucleation in the atmosphere (see Fig. 3 for the range of possible feldspars). In this project you will quantify the ice nucleating ability of a series of well-characterized natural feldspars but also synthesise various feldspars with defined composition yourself in the Cohen Geochemistry Laboratories. This way you will be able to quantitatively establish which feldspars are best at nucleating ice.

**Objectives**

1. Synthesis and characterise feldspar minerals with varying composition and crystal structure.
2. Quantify ice nucleating ability of a range of natural feldspars and the synthesised well-defined feldspars.
3. Parameterise the ice nucleation results in a form suitable for use in atmospheric models.

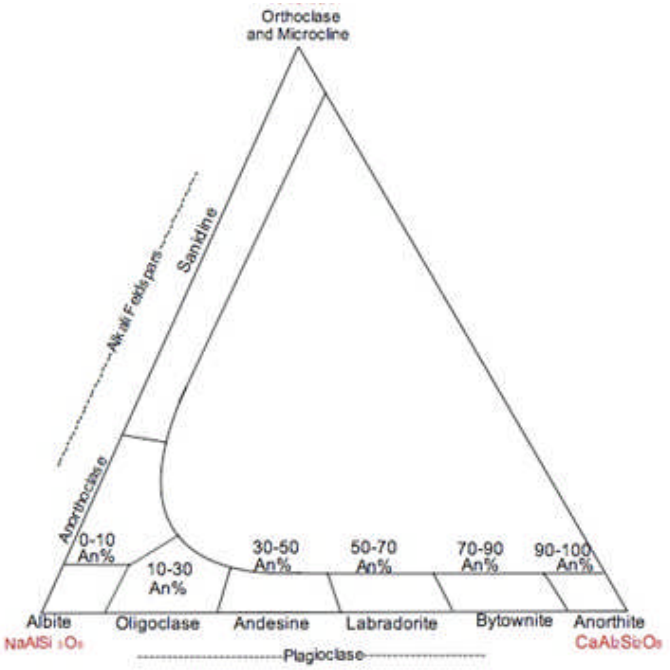


Fig.2. Minerals in the feldspar series. So far we have only studied ice nucleation by albite and microcline.

**Potential for high impact outcome**

Ice nucleation remains a major limitation in our quantitative understanding of clouds in the climate system. New understanding of which atmospheric aerosol types nucleate ice and how efficiently they do so is critical to addressing this problem and this project aims to do just that.

**Suitable candidates and Training/support**

You will benefit from working within an active and multidisciplinary group of scientists within Murray's and Benning's teams.

Murray's team is made up of people with a range of backgrounds (Physics, Chemistry, Environmental science) all of whom bring different skills and expertise while Benning's team will provide the links to a strong mineralogy and mineral synthesis and characterization team within the Cohen Geochemistry Laboratories where you will synthesise feldspar minerals. In Leeds you will learn how to use our bespoke equipment for quantifying ice nucleation as well as learning how to use a variety of analytical tools including X-ray diffraction, Raman microscopy and electron microscopy.

There will be opportunities to attend various training schools including the NCAS Atmospheric Measurement summer school and the INUIT ice nucleation summer school.

Suitable academic backgrounds include (but are not limited to) Environmental science, Physics, Chemistry, geological sciences and other physical sciences.

**Further reading**

- Nature news and views piece on our Nature article here.
- Nature paper on feldspar ice nucleation (Atkinson et al., 2013) and there is a freely available version here.
- More information on Murray's research and group can be found on his webpages and Benning's research group info can be found here.