University of Reading
UNIVERSITY OF SURREY
Scenario
DOCTORAL TRAINING PARTNERSHIP
UKRI Natural Environment Research Council

Snowflake dynamics: in the lab, and in the atmosphere

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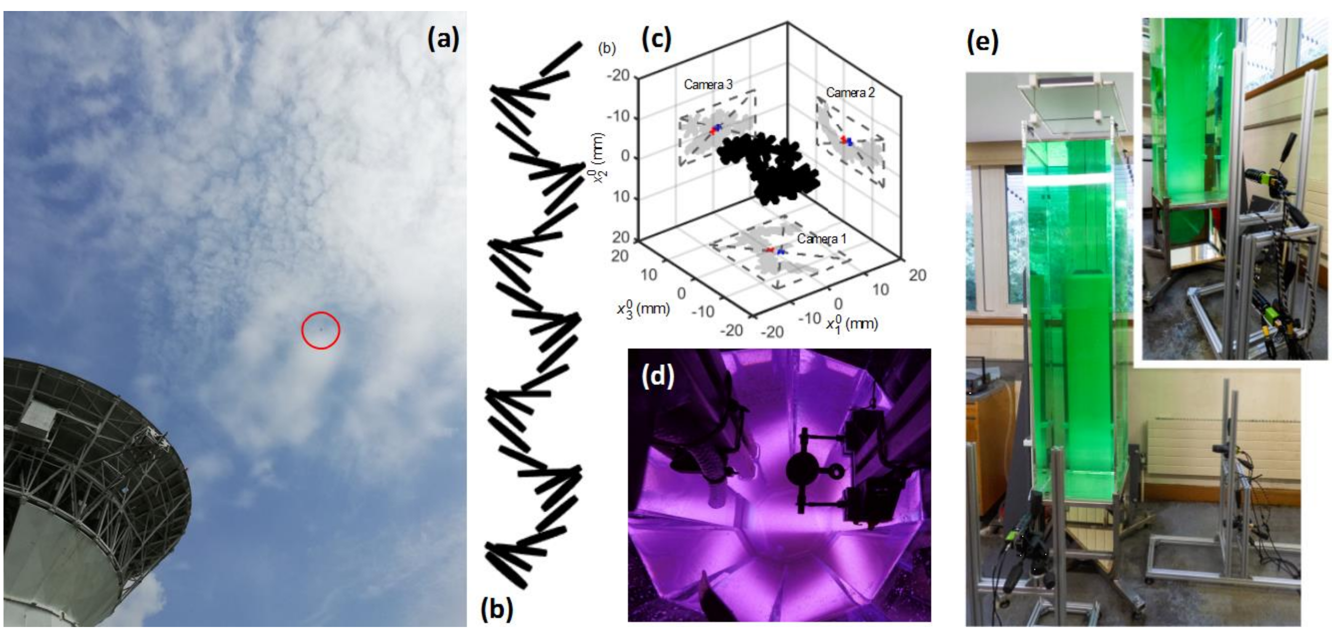
Snowfall is an important but poorly quantified component of the earth's hydrological cycle. Meanwhile, the rate at which snow falls out of high-altitude clouds is considered highly uncertain, yet in model experiments has shown to be a critical parameter controlling the earth's radiation budget in climate simulations.
One of the most important ways in which we can observe these processes, and test numerical simulations of them, is using remote sensors, such as radar. These techniques are rapidly advancing, utilitising multiple wavelengths to probe different parts of the size distribution, multiple polarisations to diagnose the types and orientations of the snowflakes, and Doppler information to diagnose the distribution of particle fall speeds and hence the distribution of particle sizes in the cloud. Exploitation of these techniques relies on a detailed understanding of the dynamics of falling snowflakes – how fast they fall, the orientation they adopt, and their trajectories (which may be unsteady, e.g. fluttering, tumbling). Unfortunately, our understanding of this is currently very limited.



(a) The Chilbolton Advanced Meteorological Radar's 25m antenna, tracking the FAAM research aircraft during PICASSO; (b) reconstructed fluttering trajectory of a plate snowcrystal 3D-printed analogue (c) illustration of reconstruction process for a more complex cluster of ice crystals; (d) fluorescent seeding particles in fluid tank; (e) fluid tank rig in the lab at Reading

In this PhD you will perform new experiments, observations, data analysis and numerical calculations to resolve these issues. In the laboratory, you will use 3D-printed and micro-machined snowflake "analogues" to develop our fundamental understanding of how ice particles fall, and what properties control this, observing the fall motion using multi-view cameras and particle tracking codes to reconstruct the trajectories and orientations of the particles. You will then apply this new knowledge and understanding to interpreting data from the atmosphere, exploiting data from a recent field project ("PICASSO") at the Chilbolton Observatory comprising state of the art remote-sensing measurements, in which data on the shapes, sizes, fall speeds and orientations of the particles are encoded, along with complementary in-situ measurements of particles from the FAAM research aircraft. By connecting the results from the laboratory and numerical methods to model the corresponding radar Doppler spectra and polarimetric observations, we will gain a deeper understanding of how to interpret such data, and the opportunity to improve retrievals of ice properties (such as those planned for the EarthCARE satellite mission). Finally, working in collaboration with the larger PICASSO project team, the student will be able to apply the new understanding from these results to the improvement of how microphysical processes should be represented in models.

Training opportunities:

The student will be embedded within the "remote sensing, clouds and precipitation" research group, which is made up of 3 faculty, along with a number of PhD students and postdoctoral researchers. We anticipate that the student will have the opportunity to experience operation of the remote-sensing instrumentation at Chilbolton, and to take part in a research flight on the FAAM aircraft. It is envisaged that the student would spend a period of time visiting the University of Manchester, benefiting from their expertise in in-situ measurement techniques and being exposed to other cutting edge research in cloud physics (e.g. experiments with the Manchester Ice Cloud Chamber, state of the art microphysics modelling, and other activities). It is possible that there will be opportunities to take part in new field work during the PhD.

The student will attend a biennial workshop on snowfall, as well as a suitable international conference, and other smaller meetings to become familiar with the field, and present their work.

References:

McCorquodale and Westbrook (2020a) TRAIL: a novel approach for studying the aerodynamics of ice particles. *Q. J. R. Meteorol. Soc*. (in press)
McCorquodale and Westbrook (2020b) TRAIL part 2: a comprehensive assessment of ice particle fall speed parametrisations. *Q. J. R. Meteorol. Soc.* (in press)
Barrett, Westbrook, Stein and Nicol (2019) Rapid ice aggregation process revealed through triple-wavelength Doppler spectrum radar analysis, *Atmos. Chem. & Phys.*
Stein, Westbrook and Nicol (2014) Fractal geometry of aggregate snowflakes revealed by triple-wavelength radar measurements *Geophys. Res. Lett.*