Microfluidic technology for atmospheric biological ice nucleating particle analysis

Polly Beth Foster
ee18pbf@leeds.ac.uk
School of Chemical and Process Engineering/School of Earth and Environment
University of Leeds, Woodhouse, Leeds LS2 9JT

University of Hertfordshire UH

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Introduction

Ice nucleating particles (INP) are a rare subset of aerosol that initiate the formation of ice crystals from water vapour or supercooled water. Known INP sources include desert dust, sea spray, terrestrial biological aerosol, and anthropogenic aerosol. This project aims to utilise novel developments in aerosol instrumentation to sample, analyse, and identify bioaerosol that acts as INP from agricultural sites in the UK.

The Importance of INP in the Climate System

- Mixed-phase clouds are a dynamic system made up of water vapour, ice crystals, and supercooled liquid water
- Mixed-phase clouds contribute to uncertainty in the magnitude of the cloud phase feedback
- Formation of ice impacts cloud lifetime, precipitation, and cloud radiative forcing [1]
- Increasing INP = positive climate feedback, amplified warming [1]
- Warming world = negative climate feedback, reduced warming [1]
- The contribution of bioaerosol, such as fungal spores, pollen, and lichen, to the atmospheric INP burden is less clear than the contribution from inorganic sources [1][2]

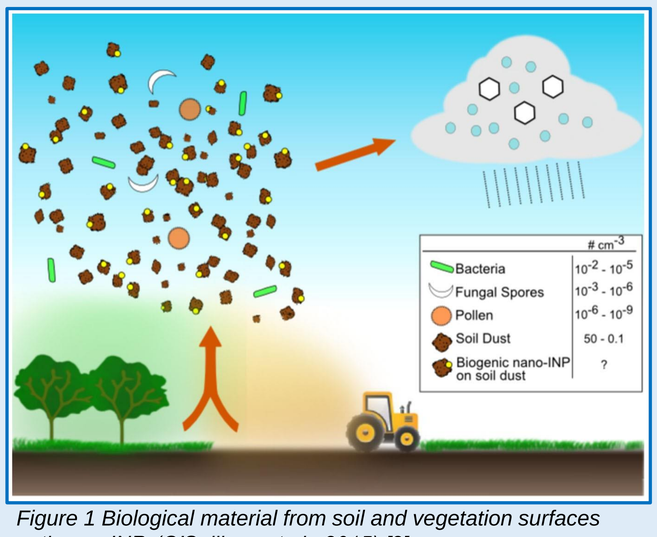
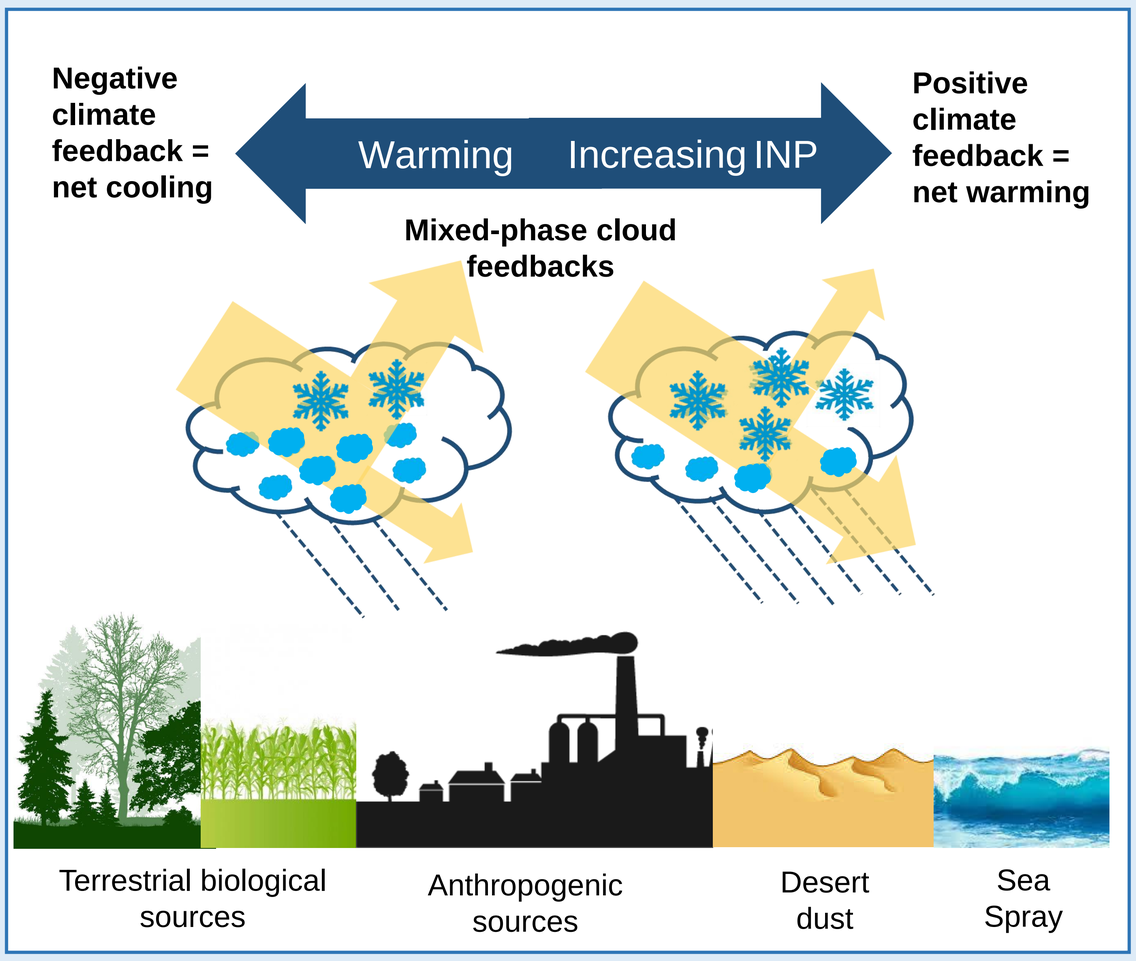


Figure 1 Biological material from soil and vegetation surfaces acting as INP. (O'Sullivan et al., 2015) [2]



Collection

Figure 2 Handheld electrostatic precipitator and box containing collection slides

Thematic Broadening Sabbatical

- Aerosol measurement techniques
- Personal aerosol sampler developed at University of Hertfordshire [3]
- Handheld electrostatic precipitator (ESP)
- Aerosol particles collected onto a removable hydrophobic surface
- Collecting polystyrene latex (PSL) spheres of different sizes
- Fluorescence microscopy to analyse collected particle count
- Collection and recovery efficiency:

$$\eta_c = \frac{quantity\ collected}{quantity\ sampled}$$

$$\eta_r = \frac{quantity\ recovered}{quantity\ collected}$$

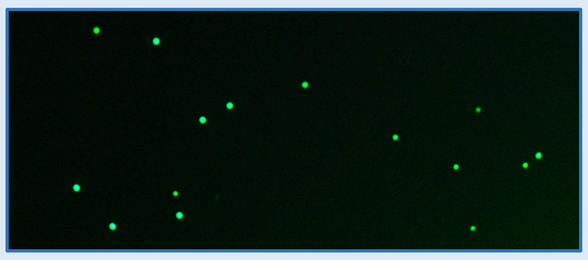


Figure 5 Fluorescence micrograph of 2 micron particles collected by the ESP

Analysis

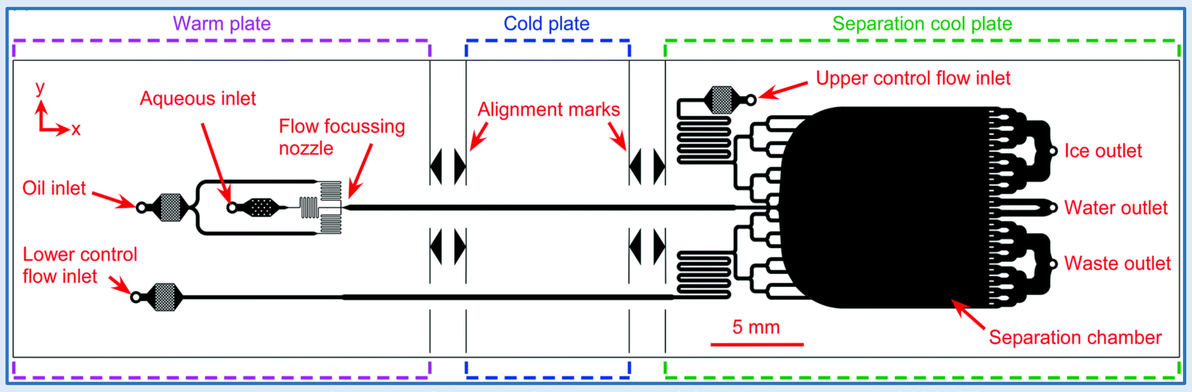


Figure 3 Design of the microfluidic chip in LOC-NIPI. (Porter et al., 2020) [5]

Lab-on-a-chip Nucleation by Immersed Particle Instrument (LOC-NIPI)

- Water-in-oil droplets freeze in continuous flow [4]
- Freezing events are recorded and used to calculate fraction frozen and number of INPs per litre of sampled air [4]
- Frozen and unfrozen droplets are separated by a density sorting system [5]

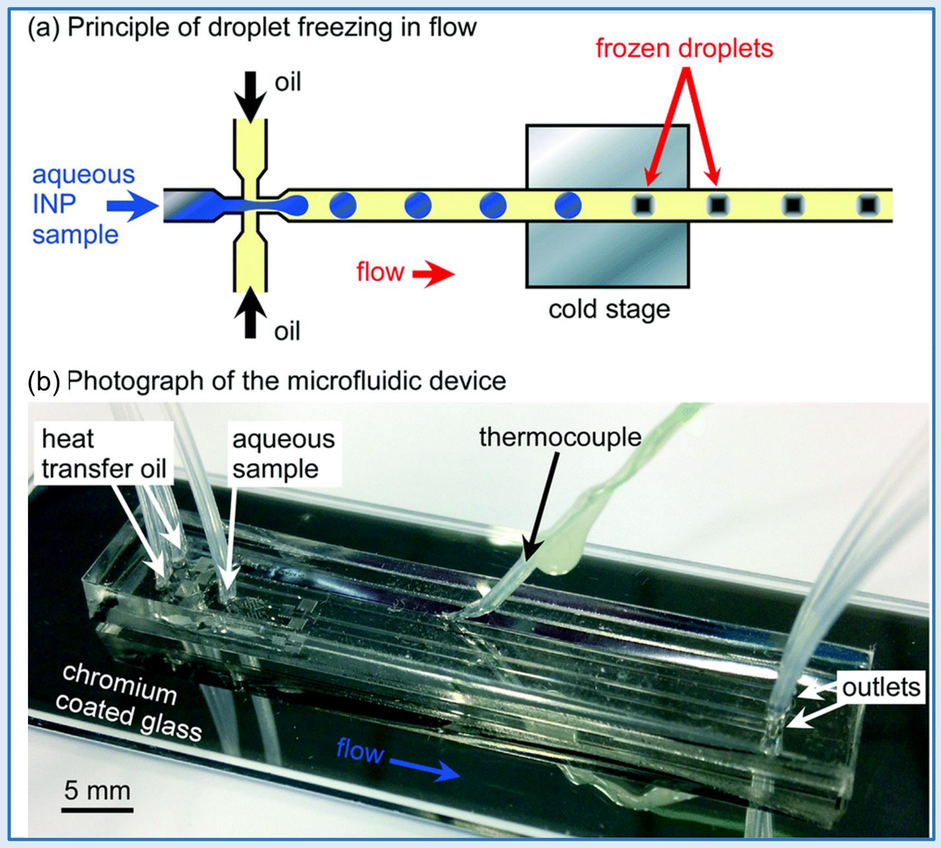


Figure 6 (a) Droplet freezing in flow. (b) Photograph of LOC-NIPI. (Tarn et al., 2020) [4]

Identification

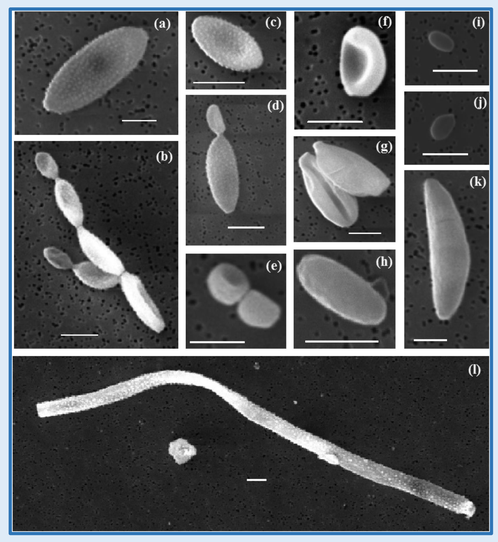


Figure 4 Primary biological aerosol particles in SEM imaging. (Sanchez-Marroquin 2021) [6]

Identification methods

- Scanning electron microscopy (SEM)
- Fluorescence microscopy
- Culturing
- Polymerase Chain Reaction (PCR)

Placement with Rothamsted Research

- PCR to identify material in frozen droplets
- Collecting biological aerosol samples from various locations
- Establish relationship between wind and INP production in a wind tunnel

Future work

- Instrument development to analyse full range of concentrations and activation temperatures of atmospheric INP
- Bioaerosol sources, sinks, and distribution
- **Autonomous micro total analysis system: collection to identification**

References
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[2] O'Sullivan, D. et al. (2015) 'The relevance of nanoscale biological fragments for ice nucleation in clouds', Scientific Reports 2015 5:1. Nature Publishing Group, 5(1), pp. 1–7. doi: 10.1038/srep08082.
[3] Foat, T. G. et al. (2016) 'A prototype personal aerosol sampler based on electrostatic precipitation and electrowetting-on-dielectric actuation of droplets', Journal of Aerosol Science. Pergamon, 95, pp. 43–53. doi: 10.1016/J.JAEROSCI.2016.01.007.
[4] Tarn, M. D. *et al.* (2020) 'On-chip analysis of atmospheric ice-nucleating particles in continuous flow', *Lab on a Chip*. Royal Society of Chemistry, 20(16), pp. 2889–2910. doi: 10.1039/D0LC00251H.
[5] Porter, G. C. E., Sikora, S. N. F., Shim, J. U., et al. (2020) 'On-chip density-based sorting of supercooled droplets and frozen droplets in continuous flow', Lab on a Chip. Royal Society of Chemistry, 20(21), pp. 3876–3887. doi: 10.1039/D0LC00690D.
[6] Sanchez-Marroquin, A. et al. (2021) 'Mineral and biological ice-nucleating particles above the South East of the British Isles †'. doi: 10.1039/d1ea00003a.

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