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Cloud from a chip: Quantifying the activity of ice-nucleating particles in microfluidic droplets

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To improve the precision of climate models, it is paramount to accurately quantify the probability of ice formation under conditions (e.g., temperatures and cooling rates) that closely resemble those in the atmosphere. In recent years, microfluidic approaches have emerged as a new tool in atmospheric research. Polydimethylsiloxane (PDMS) microfluidic chips have been used to study the ice nucleation behavior of aqueous drops containing ice nucleating particles. However, PDMS readily takes up water, which compromises the stability of droplets for prolonged times. Additionally, careful temperature calibration has been required due to significant temperature gradients that arise between the bottom area of the chip that is cooled and the location of the droplets. In contrast to past work, our generated droplets are stored in fluoropolymer tubing that is impermeable to water and is immersed in an ethanol bath. Such a design has two main advantages: (i) small aqueous droplets are stable in the structure for extended periods of time beyond those possible in PDMS chips; and (ii) immersion in a liquid bath reduces the temperature gradient between droplets and chip-bottom since cooling instead occurs over all exposed surfaces. These benefits impart an ability to study individual droplets with diameters that approach the sizes of cloud droplets over several freeze-thaw cycles. Herein, we present our instrument design (with an automated droplet-freezing image detection algorithm) and report data on the nucleation of ice in pure water droplets and in aqueous suspensions of ice-nucleating particles. This work will be used as the basis for future investigations in atmospheric ice nucleation that aim to better constrain the influence of ice-nucleating particles on cloud optical properties and precipitation formation.