How Does Ice Start in Clouds?

Pure water can stay liquid far below freezing. Most cloud droplets do exactly that: they sit at several degrees below zero and still do not freeze, until something gives them a place to start. That something is a tiny particle, a speck of desert dust or a bacterium on a leaf, and scientists call it an ice-nucleating particle.

Why does it matter? How much of a cloud is ice and how much is liquid changes how much sunlight it reflects and how long it lasts, which is one of the big uncertainties in climate models. It also matters for cloud seeding, where silver iodide is sprayed into clouds to start ice on purpose. A 2024 US GAO report put the extra precipitation from seeding anywhere between 0% and 20%, with weak or missing efficacy data. And it matters for farms, because some bacteria on leaves can trigger frost damage at only a few degrees below zero.

What did we do? We have no laboratory, so we asked a different question: what could a simple home-freezer experiment actually tell apart? Using computer simulations, we found three things.

- A small test (two runs of 30 droplets) can probably tell feldspar dust from plain water, but struggles to detect quartz dust.
- How fast the freezer cools can shift the freezing temperature by about 1 °C, enough to create false differences between surfaces.
- The kind of dust matters as much as the amount: ten times more dust warms the freezing threshold by about 2.5–2.8 °C, and so does ten times more feldspar within the dust.

What did we not do? We ran no real experiment, so none of this is laboratory evidence. A molecular simulation of freezing water did not produce a confirmed crystal, and one key assumption (the base of a logarithm in a published formula) could not be verified. Our results depend on it.

What is next? A real pilot with a household freezer, a sensor under every surface and a record of the cooling rate, then a check of that assumption against the original paper.

Everything here is simulation and sensitivity analysis, not an experimental result.