Supplement

Direct evidence for secondary ice crystals formed around -15 °C in mixed-phase clouds

by Claudia Mignani et al.

Further details of the custom-built stage

Cooling (and heating) of the cold stage is achieved with a Peltier element (13 mm x 12 mm x 2.75 mm, -40 °C to +80 °C; model TE-65-0.6-1.5P, TE Technology Inc., Traverse City, MI, USA). Temperature is measured with a thermistor (0.9 mm diameter, 5 kOhm at 25 °C; model MP-3176, TE Technology Inc., Traverse City, MI, USA) located in the centre of the cylinder just below the surface. Surface temperature can be adjusted within a range from +10 °C to -30 °C. It is set via a single-board microcontroller (Arduino, https://www.arduino.cc/) with a touchpad and a LCD display (control unit). The display shows the actual temperature of the stage, the set-point temperature, cooling rate, and other instrumental parameters. The heat formed during cooling is discharged through a ventilated heat-sink (Figure S1). Power is supplied to the stage and the control unit from a 12 V, 4.5 Ah $LiFePO_4$ battery (model V-LFP-12-5, Vision Group, Shenzhen, China) lasting about four hours at ambient temperatures a few degrees below 0 °C. The cold stage, control unit, and other items necessary for the analysis of single crystals fit onto a small area (approximately 30 cm x 30 cm; Figure S2). Together with the macro camera used to document the crystals, the equipment fits into case the size of a piece of hand luggage allowed inside an aircraft. Its total weight is roughly 10 kg.

We validated the temperature of the cold stage by detecting the melting point of ice. For that purpose, a thin frost layer was grown on the cold stage surface. We then increased the temperature of the cold stage in 0.1 °C steps, starting from -0.2 °C. Melting of the frost layer occurred between the temperature readings of 0.0 °C and 0.1 °C. In addition, we conducted a surface temperature test with a commercial thermometer (model RDXL4SD, sensor type K, Pt100 Ohm, Omega Engineering Inc., Norwalk, CT, USA) in the temperature range of interest from -12 °C to -25 °C with a cooling rate of 3 K min^{-1}. For this test we greased the sensor of the thermometer with petrol jelly and pressed it with Styrofoam onto the surface of the cold stage. When the control unit of the cold stage indicated -12 °C the thermometer indicated -12.1 °C. When the cold stage gave a reading of -17.0 °C the thermometer indicated -16.4 °C. At -25.0 °C the offset of the thermometer had increased to 0.9 °C. This difference might be due to an imperfect contact between sensor of the thermometer, which is a bead of about 1 mm diameter, and cold stage surface. Or, it could be due to heat diffusion through the wires of the temperature sensor. Overall, the difference is too small to matter in the context of our study.

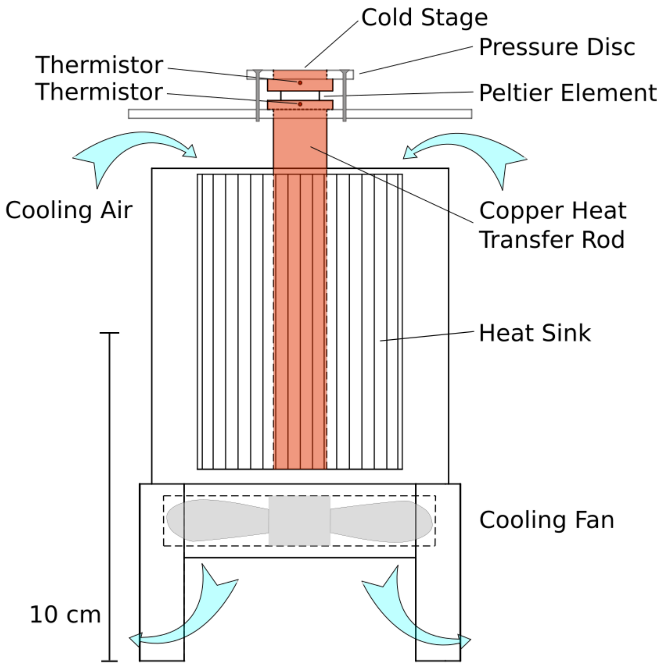

Figure S1. Technical drawing of the cold stage apparatus.

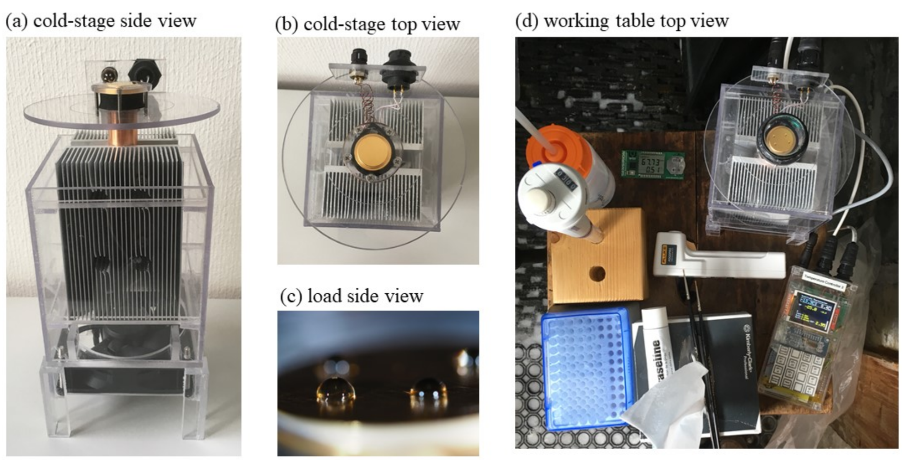

Figure S2. Photographs of the cold-stage (a) from the side and; (b) from the top; (c) a close-up view of the stage loaded with droplets; (d) view from the top onto the working table during operations on Jungfraujoch.