PRODUCING NATURE LIKE SNOW IN A SUPERCOOLED CLOUD FOR LABORATORY EXPERIMENTS

Ursula Enzenhofer[1, 2], Michael Bacher[2,*], Sergey Sokratov[3], Christian Mahr[2], Johannes Müller[2], Ulrich Worthmann[1], Ingrid Reiweger[1]

[1]Institute of Mountain Risk Engineering, BOKU University of Natural Resources and Life Science, Vienna, Austria
[2]NEUSCHNEE GmbH, Austria
[3]Faculty of Geography, Lomonosov Moscow State University, Russia

ABSTRACT: We here introduce our cloud chamber which enabled us to grow snow crystals from water vapour under conditions similar to those in natural clouds. The snow crystals grew as a result of water vapour supersaturation as well as due to the interaction of ice crystals and water droplets within the cloud chamber. The cloud chamber, of cylindrical shape with a volume of about 2.7 m^3, was positioned in a cold room with regulated temperature ranging from −1 to −20°C. A fine mist of water droplets was fed into the cloud chamber and a short pulse of pressurized air triggered the nucleation. Observations of the size and shape distribution of the ice crystals as a function of temperature and supersaturation were consistent with literature values. Different crystal shapes – e.g. plates, columns, hollow columns, dendrites – were successfully formed at different conditions within the chamber. The produced snow was collected at the bottom of the cloud chamber and was used for further experiments and measurements.

KEYWORDS: ice crystals, snow formation, technical snow, supercooled cloud

1. INTRODUCTION

A number of techniques can be used to produce technical or artificial snow. The most common way to manufacture man-made snow e.g. for ski runs, is to create a spray of fine water droplets in sub-zero environment, which results in freezing droplets (e.g. Fauve et al., 2002). This technique produces ice droplets rather than snow crystals, which are of limited use for certain scientific purposes. For systematic studies of physical processes in natural or nature-like snow cover, artificial snow samples formed under regulated and reproducible laboratory conditions as well as independently of the season are very useful for snow related scientific experiments in the cold laboratory.

The most recent nature-like snow making devices introduced by Schleef et al. (2014) and Bones and Adams (2009) grow crystals by condensation of water vapour based on the idea of Nakamura (1978). Nakamura (1978) invented a machine which was able to produce nature-like snow grown on fixed nucleation points surrounded by supersaturated air.

We used a slightly different approach which aims at growing snow crystals in the air at conditions mimicking those in a natural cloud. We therefore built a cloud chamber (Schaefer, 1952 and Fig.1) which was able to produce nature-like snow crystals grown from the vapour phase under controlled laboratory conditions. The crystal growth process was similar to the process within a natural cloud and was based on water vapour supersaturation and interaction of neighbouring crystals and water droplets at a regulated temperature (e.g. Rauber and Tokay 1991).

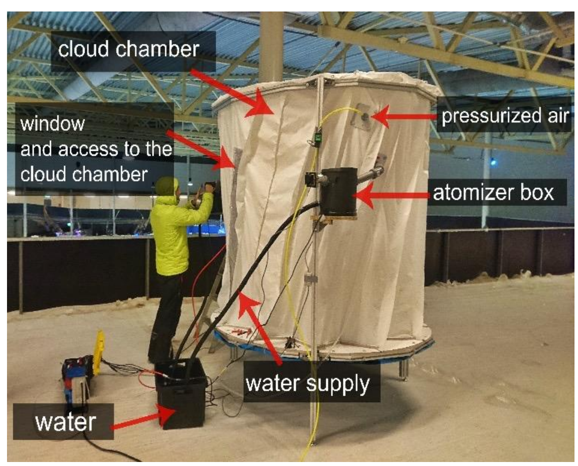

Fig. 1: Cloud chamber inside cold room.

Our cloud chamber was capable of producing crystals of different and predictable shapes – e.g. plates, columns, hollow columns, dendrites – as first depicted by Nakaya (1954).

* *Corresponding author address:*
Michael Bacher, NEUSCHNEE GmbH,
Hochstrasse 47, A-2380 Perchtoldsdorf, Austria
tel: +43 (0) 650 8090333;
email: michael.bacher@neuschnee.co.at

2. METHODS

The main component of our snow-making device was a chamber which was built from an aluminium supporting structure which was covered by a stretched polyethylene canvas, with a volume of 2.7m^3 (Fig. 1). This setup allowed free air circulation at atmospheric pressure. The temperature was regulated via the temperature regulation system of the old room.

A fog consisting of a fine spray of water droplets, created inside an atomizer box, was blown into the cloud chamber via bended tubes, using a small fan. The fan controlled fog density and wind speed and provided cold air from the environment. During operation the fog was continuously introduced into the cloud chamber forming a supercooled cloud which followed a spiral trajectory due to the tangent injection of the air flow.

For producing the fog water was fed into the atomizer box from a low-lying reservoir (20 litres). The atomizer contained an ultrasonic atomizer, with an atomization rate of approximately one litre per hour. The water level above the atomizer was kept constant with a spillway.

The formation of ice particles within the supercooled fog in the cloud chamber was triggered by a short burst of pressurized air which was directed into the cloud chamber. These ice particles acted as condensation nuclei to encourage condensation of water vapour in order to form snow crystals.

3. MEASUREMENTS INSIDE THE CLOUD CHAMBER

We installed four type K thermocouples to derive a vertical temperature profile inside the cloud chamber. In addition we measured the relative humidity of the air within the cloud chamber as well as water temperature.

After different time periods of crystal growth the ice crystals were collected at the bottom and at the top of the cloud chamber and were immediately photographed under a microscope.

We used an optical microscope with an adapter for a single lens reflex camera. By applying a microscopic scale we were able to derive the size of the individual ice crystals. We used standard classifications of ice crystals (Nakaya, 1954) to organize and classify our observations. Snow density was measured by weighing a known volume of collected snow.

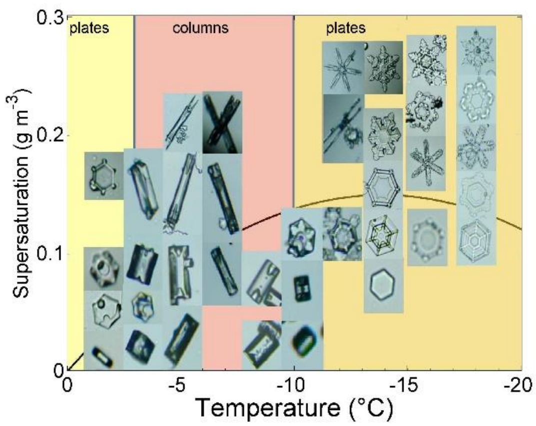

Fig. 3: Snow crystals from our cloud chamber as a function of measured temperature and estimated supersaturation (Lettner, 2012).

4. RESULTS AND DISCUSSION

A summary of the produced crystals is shown in Fig. 3. The diverse crystal shapes were formed successfully at different controlled conditions within the cloud chamber. Measurements of snow crystal sizes showed that the largest snow crystals were found at temperatures between −12°C and −16°C.

First systematic observations of the size and shape distribution of the ice crystals as a function of temperature and supersaturation were consistent with the other literature data. (e.g. Libbrecht, 2005)

We could determine a vast difference in the shape of the snow crystals growing in our cloud chamber (Fig.3). We observed large ice crystals inside the cloud chamber when we performed longer test runs and took samples at the end of the test period. At the start of the test run we measured crystal sizes of about 0.001mm and 0.002. Afterwards the crystals were growing slowly, but in the final growth phase the crystal size was increasing fast (Figs.4 and 6). Fast increase of snow crystal sizes might be explained by the fact that close to the end of the test run only a small amount of ice crystals remained in the cloud but still the same amount of water vapour was available. On the other hand the increasing size of the individual ice particles provided more surface for free water molecules to deposit on the crystalline surface.

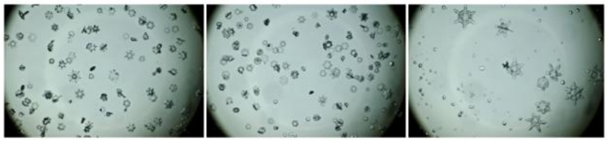

Fig. 4: Snow crystals taken from the cloud chamber 3, 6, and 11 min after injection of compressed air. The temperature within the cloud chamber was −14°C. The width of each image corresponds to 1.2 mm (Lettner, 2012).

Even though the snow crystals grew fast at the end of the growth period, we observed that the air temperature had a greater impact on the crystal size.

Results from the tests carried out in early 2016 showed that producing exactly reproducible homogenous snow samples had only limited success. It was still not possible to fully control the ventilation and supersaturation inside the cloud chamber over a period of more than one hour.

The production rate of lightweight snow in our cloud chamber set-up depended on the amount of atomized water per time unit and laboratory temperature. For a cold room temperature of -15°C and usage of one atomizer box it was possible to produce about 10 litres of snow per hour.

5. OUTLOOK

In the future we aim to test our cloud chamber also for outdoor conditions (Fig. 5). We therefore built a larger version of our laboratory cloud chamber and installed it in a ski resort in Obergurgl, Tyrol, Austria. In a future project we want to test the feasibility of using a cloud chamber to produce artificial snow for ski runs.

Fig.5: Outdoor testing of the cloud chamber in a in the ski resort in Obergurgl, Tyrol, Austria.

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APPENDIX

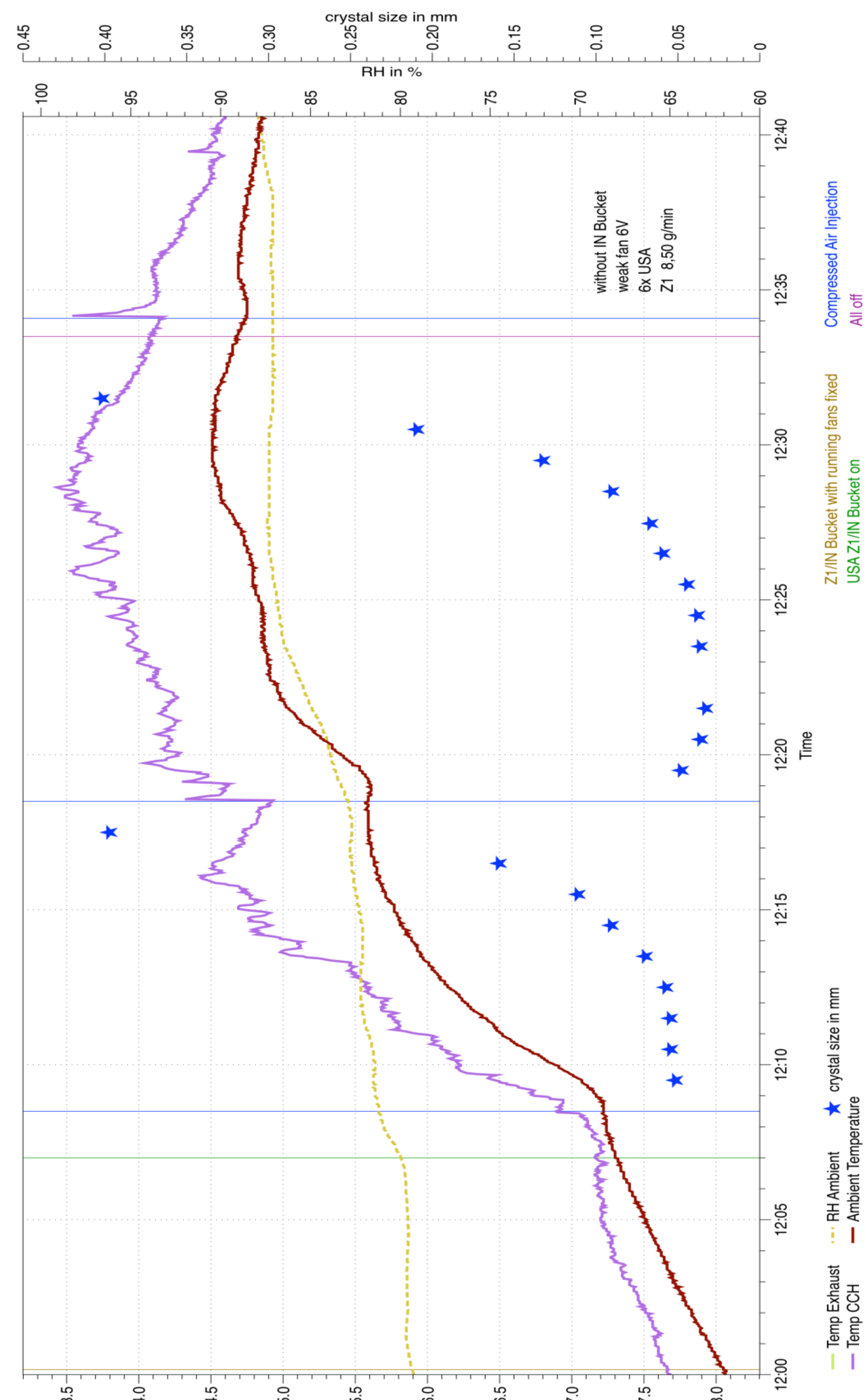

Fig. 6: Observed crystal sizes (blue stars), temperature within cloud chamber (purple line), ambient temperature (res line), and relative humidity (yellow dashed line) over time (Burkart, 2012).