RESULTS FROM THE ZUGSPITZE EXPERIMENT: AN IN-SITU CLOUD-DROPLET PARTICLE-TRACKING EXPERIMENT

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It is well-known that rain formation has four phases: nucleation, condensation, turbulent coalescence, and gravitational coalescence. Condensation is effective for droplet sizes of up to $\sim 20\,\mu\mathrm{m}$, whereas gravitational coalescence is effective for droplet sizes larger than $\sim 100\,\mu\mathrm{m}$. Turbulence is responsible for bridging the gap between these two, but how exactly it does this, is not known.

One of the first to study the effect of turbulence on rain formation were Saffman & Turner [6]. While beautiful in its simplicity, their theory has some shortcomings: it doesn't take droplet clustering (e.g. [1]) or the sling effect (e.g. [2]) into account. Many studies have tried to resolve these issues. To keep the problem tractable many theoretical studies assume droplets are monodisperse and/or neglect gravity (e.g. [4, 8]). This makes the results of limited relevance to clouds. Numerical and experimental studies (e.g. [3]) are often limited to low Reynolds numbers, and hence cannot faithfully reproduce cloud conditions. To avoid these issues, one must measure inside clouds.

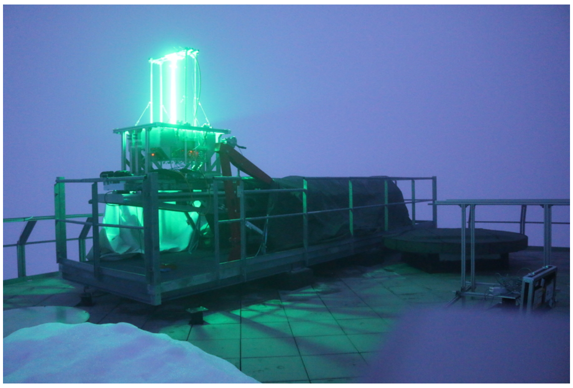
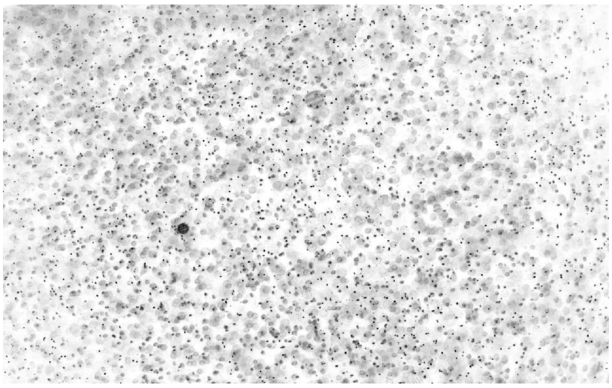

Figure 1. Left: the experimental setup. Most of the rail is covered by a tarp. Right: single camera image; brightness is inverted and enhanced for ease of viewing.

Here we present an in-situ cloud-droplet tracking experiment. The experiment (Fig. 1, left) is located on top of the environmental research station Schneefernerhaus, at $2650\,\mathrm{m}$ altitude, just below the peak of Mt. Zugspitze in the German Alps. At this location clouds occur close to the ground [5], which obviates the need for planes or helicopters.

At the heart of the experiment are three high speed cameras, capable of recording $1\,\mathrm{Mpx}$ at $10\,\mathrm{kHz}$. They are pointed at a small volume, approximately $(2.5\,\mathrm{cm})^3$ in size, illuminated by a $75\,\mathrm{W}$ green laser. The cameras are mounted on rails and can be moved by a linear motor, in order compensate for the mean wind. Images are processed with an in-house particle tracking code, that is remniscent of the Shake-The-Box algorithm [7]. The code is particularly suitable for processing low light imagery (Fig. 1, right), in which many droplet images are out of focus.

We report measurements of the radial distribution function (RDF) for separations of $0.1\,\mathrm{mm}$ to $20\,\mathrm{mm}$. Furthermore we can estimate relative radial velocities (RRV), and condition both quantities on approximate droplet size.

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