A Miniaturized, Lower Cost Static Diffusion Chamber for Cloud Condensation Nuclei Measurements

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MOTIVATION and BACKGROUND

- Cloud condensation nuclei (CCN) have important impacts on precipitation, cloud microphysics and climate, but anthropogenic influence remains uncertain
- Emerging platforms such as tethered and free balloons, unmanned aerial vehicles and ground-based measurement networks are providing new opportunities for measuring atmospheric properties
- The research community lacks a compact, lightweight, low-power and accurate instrument for measuring CCN, despite their importance.
- Static thermal gradient diffusion chambers (STGDCs) are an established CCN measurement approach (e.g., Snider, et al., 2006; Engelhart et al., 2008), but have not seen significant development in recent years.
- Our Phase I project examines the potential for a miniature, low-cost STGDC based on the first commercial CCN instrument, the DH Associates Model M1 to meet the requirements for CCN measurements on unmanned vehicles and other platforms
- We leverage recent advances in electrical and computing hardware, which have led to widespread availability of low-cost, high-quality image sensors, cameras, computing platforms, as well as new software tools to improve CCN measurement capabilities for a likely 10x to 100x reduction in instrument cost compared to existing technologies.

MEASUREMENT PRINCIPLE

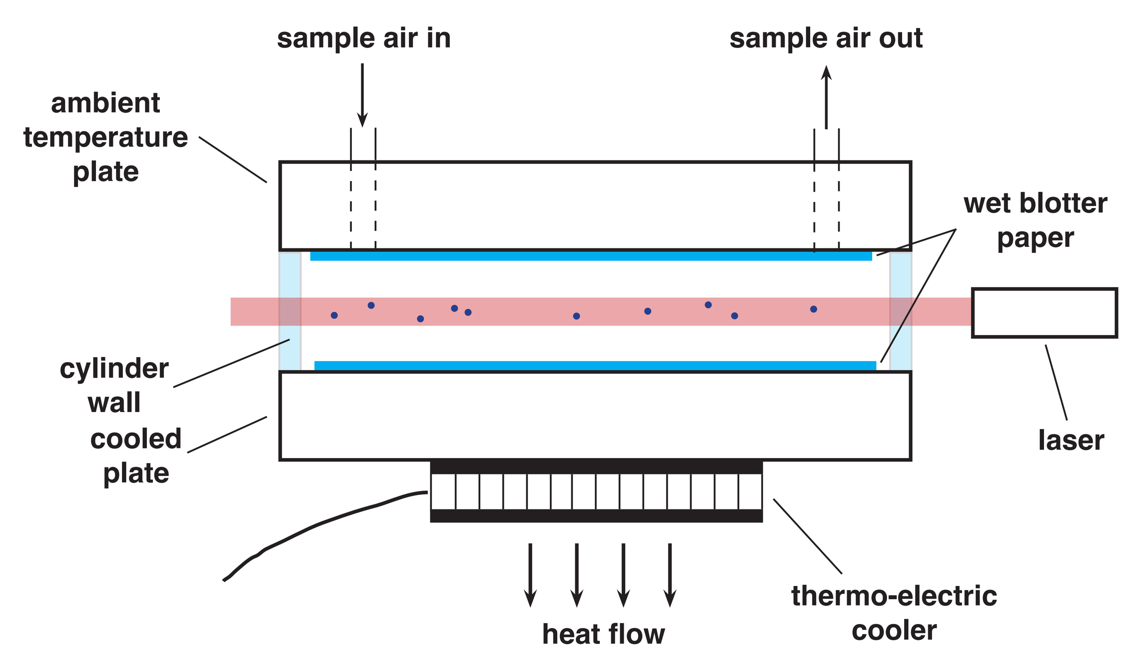

Figure 1. Basic schematic showing key components of a static thermal gradient diffusion chamber (STGDC). Sample aerosol are introduced between two moist plates with a known temperature gradient, which leads to a supersaturated region between them. CCN activate into large droplets that can be detected by a digital camera located perpendicular to the illumination laser beam.

INSTRUMENT SIMULATIONS

- We used a simple droplet growth model to simulate the measurement chamber and inform design decisions. It will also be used to evaluate laboratory data once it becomes available.

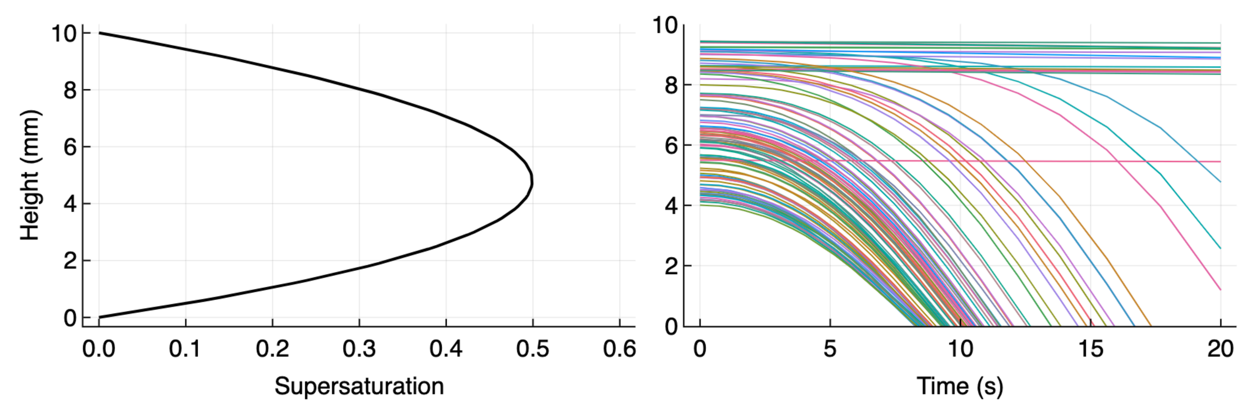

Figure 2. (left) Theoretical super-saturaiton profile for a an approximately 3.5 degree temperature difference between top and bottom plates. (right) Droplet trajectories predicted for a random distribution of particles seeded into the measurement chamber. Particles that do not activate remain suspended while activated droplets grow and fall to the lower plate. Trajectories for particles originating below 4 mm are not shown for clarity.

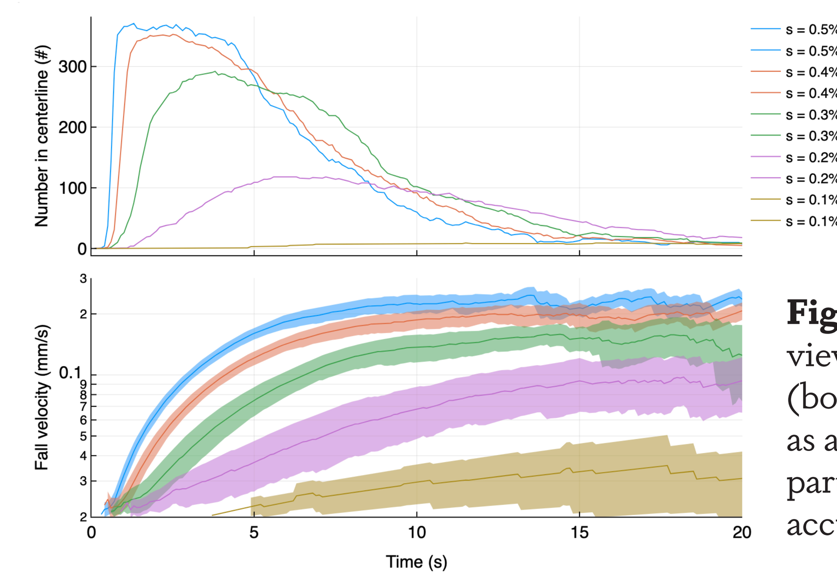

Figure 3. (top) Number of activated particles located within a 2 mm viewing region as a function of time and peak chamber supersaturation. (bottom) predicted fall velocities for a random distribution of particles as a function of time and supersaturation. At low supersaturations particles grow more slowly, requiring longer sampling times to be accurately counted.

BONUS: A Microfluidic Ice Nucleating Particle (INP) Counter for Continuous Measurements from Small Aerial Platforms

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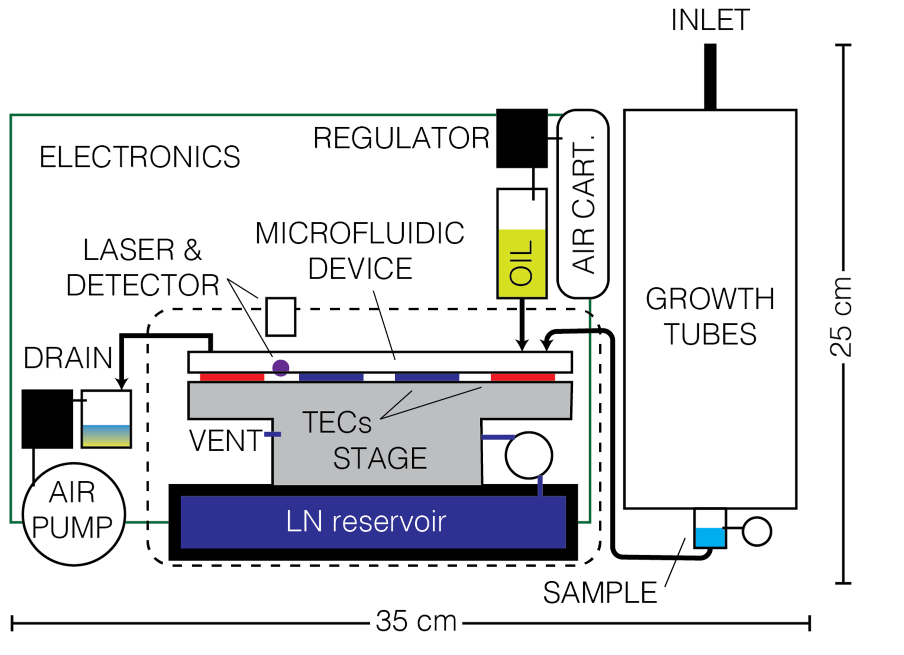
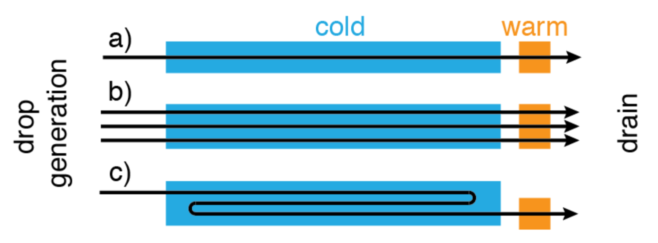
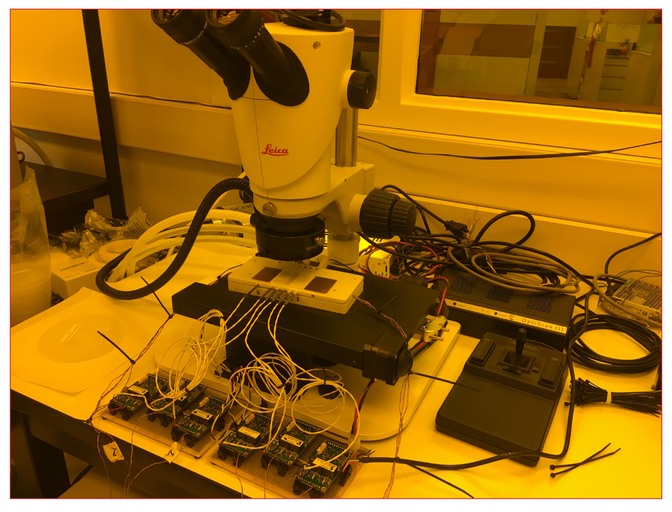
- Ice nucleating particles INP have important impacts on clouds, precipitation and climate, but are still poorly understood.
- One limitation to improving understanding is limited measurement capabilities
- Existing approaches are either labor intensive and have poor time resolution (e.g., filter-based methods), or are labor intensive and require large physical footprints for instruments (e.g., CFDC)
- Microfluidic technology offers the potential for a new approach to continuously measuring INP with a much smaller instrument footprint, enabling measurement capabilities for unmanned and other aerial platforms (e.g., Stan et al., 2009).
- Phase I established a continuously flowing microfluidic channel could provide reliable measurements of INP for selected materials
- Phase II will continue characterizing the microfluidic device in the laboratory AND develop an integrated, compact prototype suitable for field deployments.







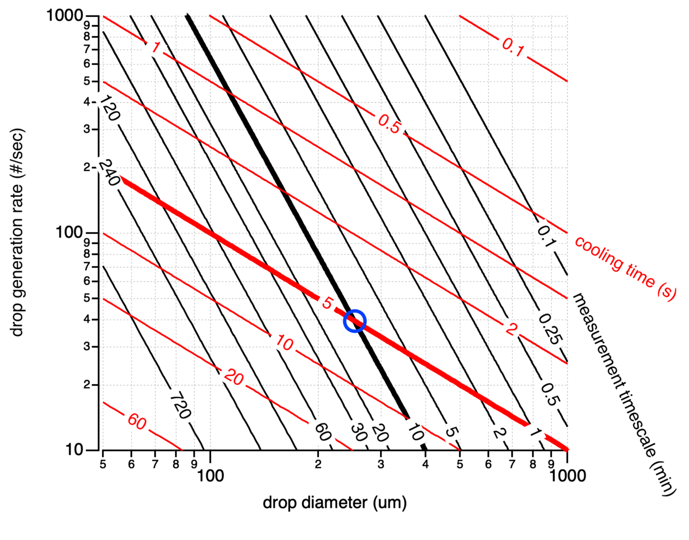


Figure A. (clockwise from top) Diagram showing major components of integrated system; potential microfluidic flow pathways to be tested; range of sample volume and cooling times that can be achieved; photograph of preliminary system during Phase I testing.

INITIAL DEVELOPMENTS

- Work performed to date includes the design, manufacture and assembly of a prototype measurement chamber, identification and procurement of digital camera and temperature control systems, design and assembly of electronic prototype circuit boards, and software development.

Figure 4. Screencapture showing activated droplets in an early version of the CCN measurement chamber with glass walls.

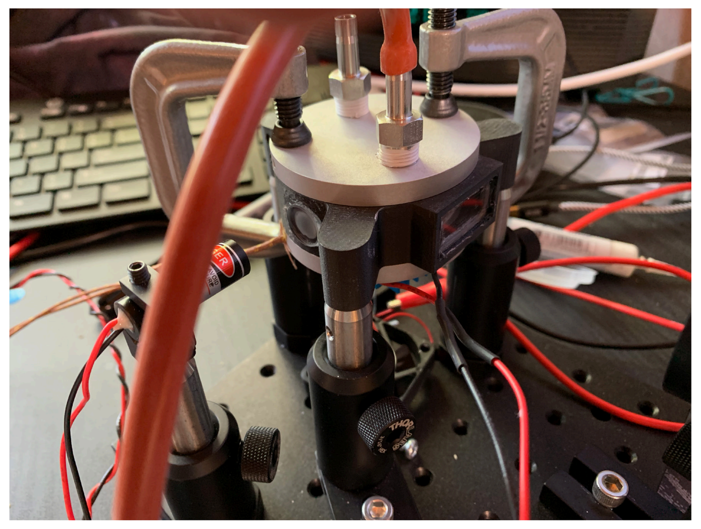


Figure 6. Photograph showing measurement chamber mounted to an optical breadboard. Visible are the windows for the illumination laser (left) and window for viewing droplets by the digital camera (off-screen, right). The chamber measures approximately 2 inches in diameter by 1 inch high.

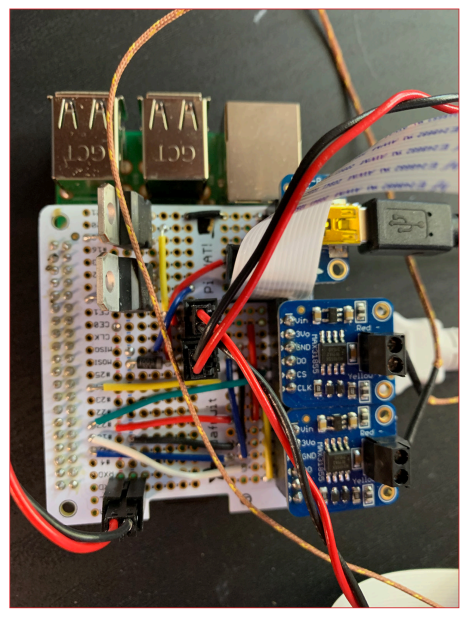


Figure 5. Photograph showing newly developed electronics for operating the CCN chamber, including temperature measurement and control. The board is designed for easy integration with a Raspberry Pi single-board computer.

REMAINING PHASE I WORK

- Laboratory evaluation of measurement chambers will begin by the end of June and will involve size-selected measurements of ammonium sulfate.
- Comparisons with the DMT CCN-100 instrument are planned for July/September.
- Environmental testing and calibration stability will be investigated concurrently with multiple testbed systems.

REFERENCES

- Engelhart, G. J., et al., ACP, 8, 3937-3949, 2008.
- Snider, J. R., et al., JAOT, 1323-1339, 2006.
- Stan, C. A., et al., Lab on a Chip, 9, 2293-2305, 2009.

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