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Sandia National Laboratories

# Developing and Characterizing an Inexpensive Tabletop Cloud Chamber

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# Presentation Outline

History of SNL Fog Measurements

Introduction and Motivation

MiniFog Design

Operating Procedures

Chamber Conditions During Measurements

Estimating Supersaturation

Next Steps

# A History of Fog Measurements at Sandia

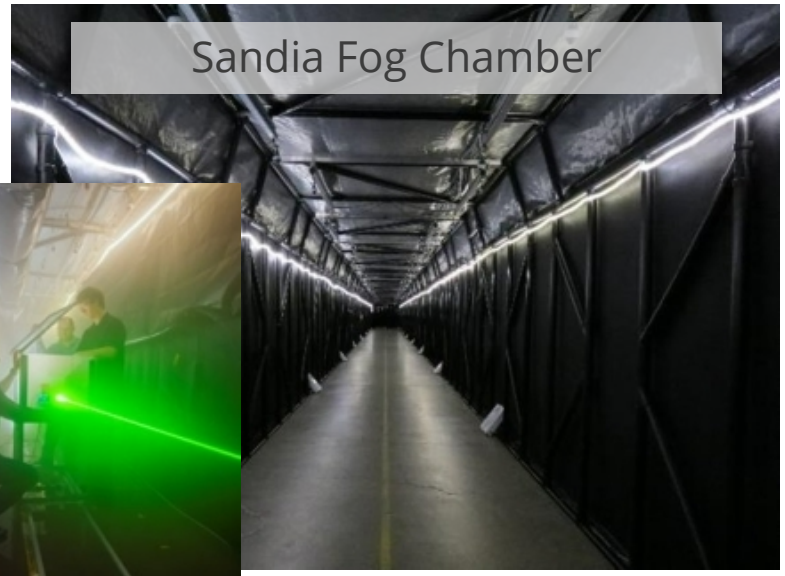
Fog creates visually degraded environments that impose…

- Transportation challenges
- Safety Risks
- Economic Impacts

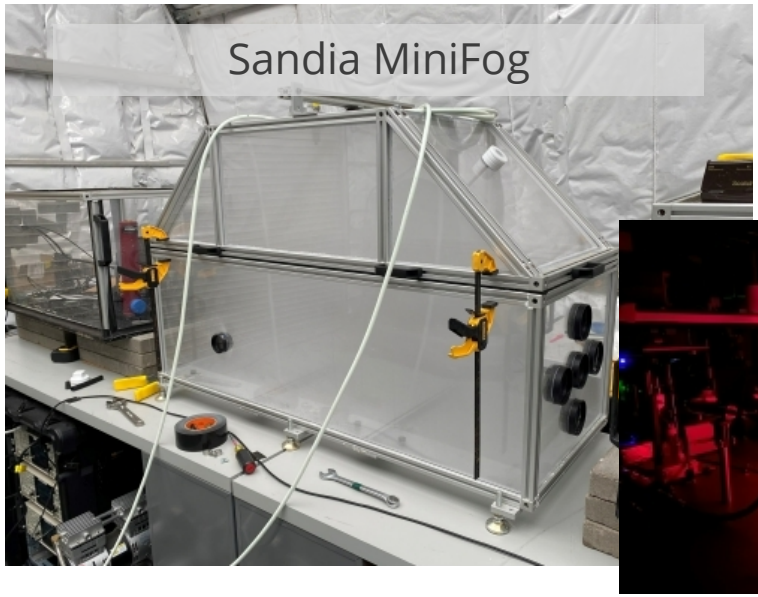

11 dead in helicopter crash off Florida Coast due to thick fog: WINK News, March 11, 2015

30 to 40 vehicles crash on stretch of foggy Texas interstate Dec 19, 2018


Tenerife Airport Disaster –Fog a major contributor- 583 dead March 27,1977



Sandia Fog Chamber



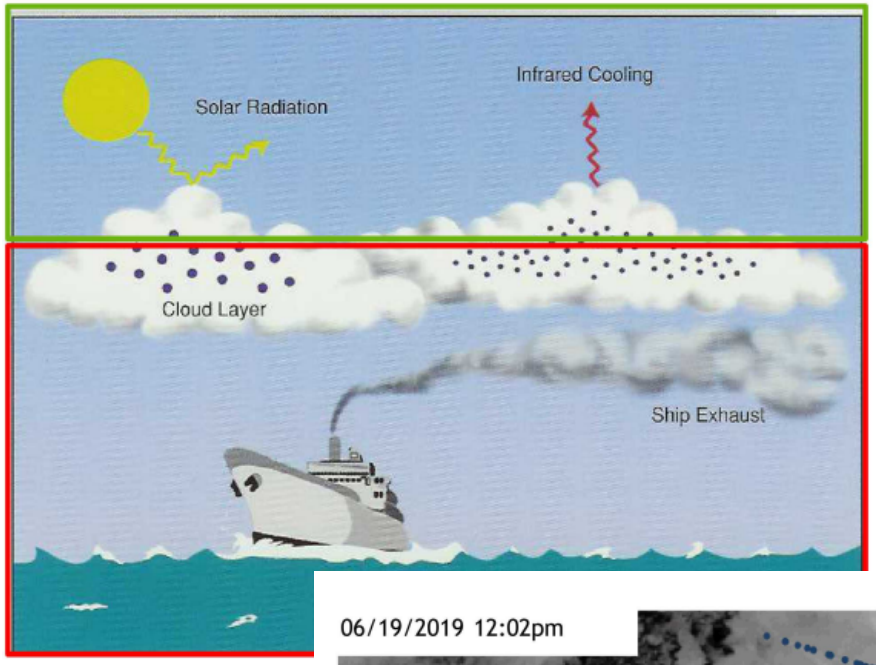
Sandia MiniFog

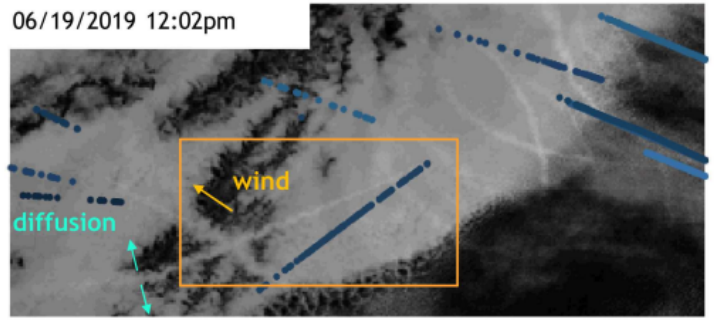
# Background and Motivation

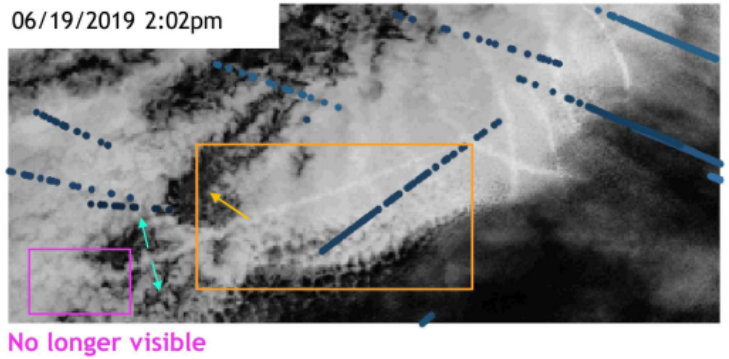
**Motivation:**

How does ship exhaust change the optical properties of clouds?

→ Improve accuracy of satellite imagery dispersion estimates. (SNL Internal Funding)




**Potential Limitations:**

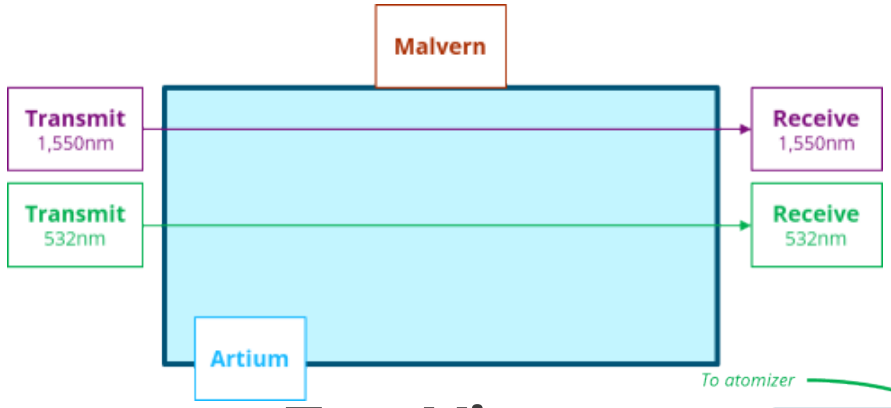
- Controlling and characterizing chamber conditions
- Isolating the impact of different forcings
- Truncated size and time scales
- Relating simplified conditions to a complex atmosphere

# Sandia Mini Fog Chamber

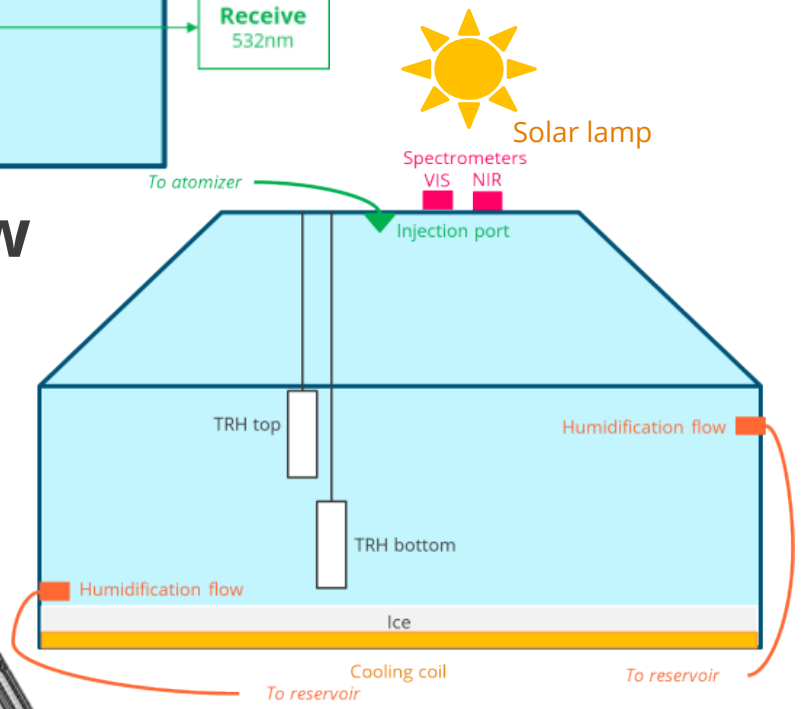
## Design
- Insulation, cooling, and humidification
- Dry CCN generation

## Instrumentation
- Malvern Spraytec
- Three-wavelength Transmissometer
- SMPS ( 10 to 480 nm)
- Reflectivity Instrumentation
- Phase Doppler Interferometer
- T/RH Probes

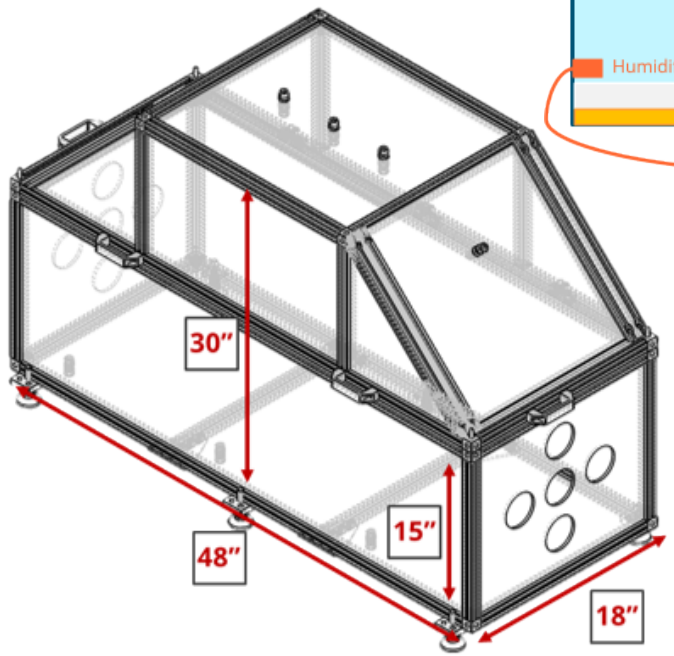
## Measured Parameters
- Droplet size distribution
- Transmission coefficients
- Dry particle conc. and size distribution
- Cloud albedo
- Droplet vertical velocity




Top View




Side View

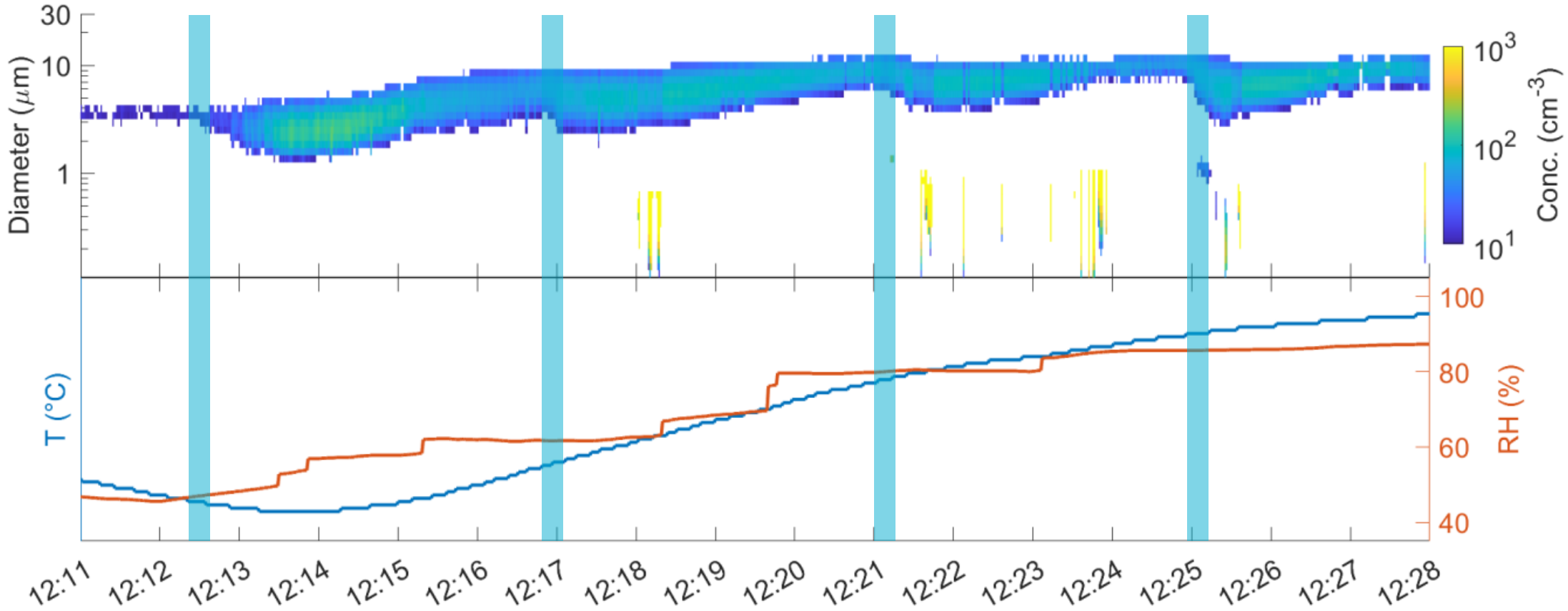


# General Operating Procedures and Observations

Control over:

- CCN Concentration
- Temp and RH

**Increase in RH → Increase in droplet growth rate**

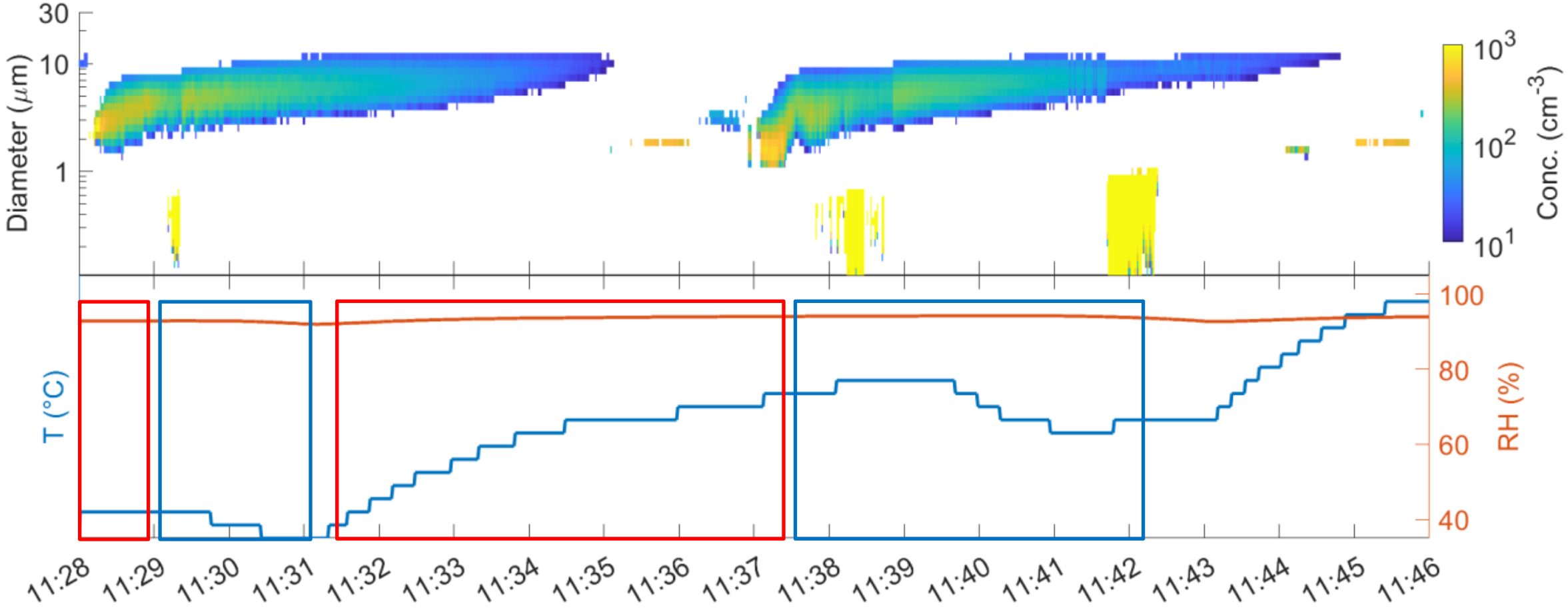


# Chamber Conditions - Temperature

Chamber temperature responds to latent heating and cooling effects

Condensation/ Heating in **Red**

Evaporation/Cooling in **Blue**

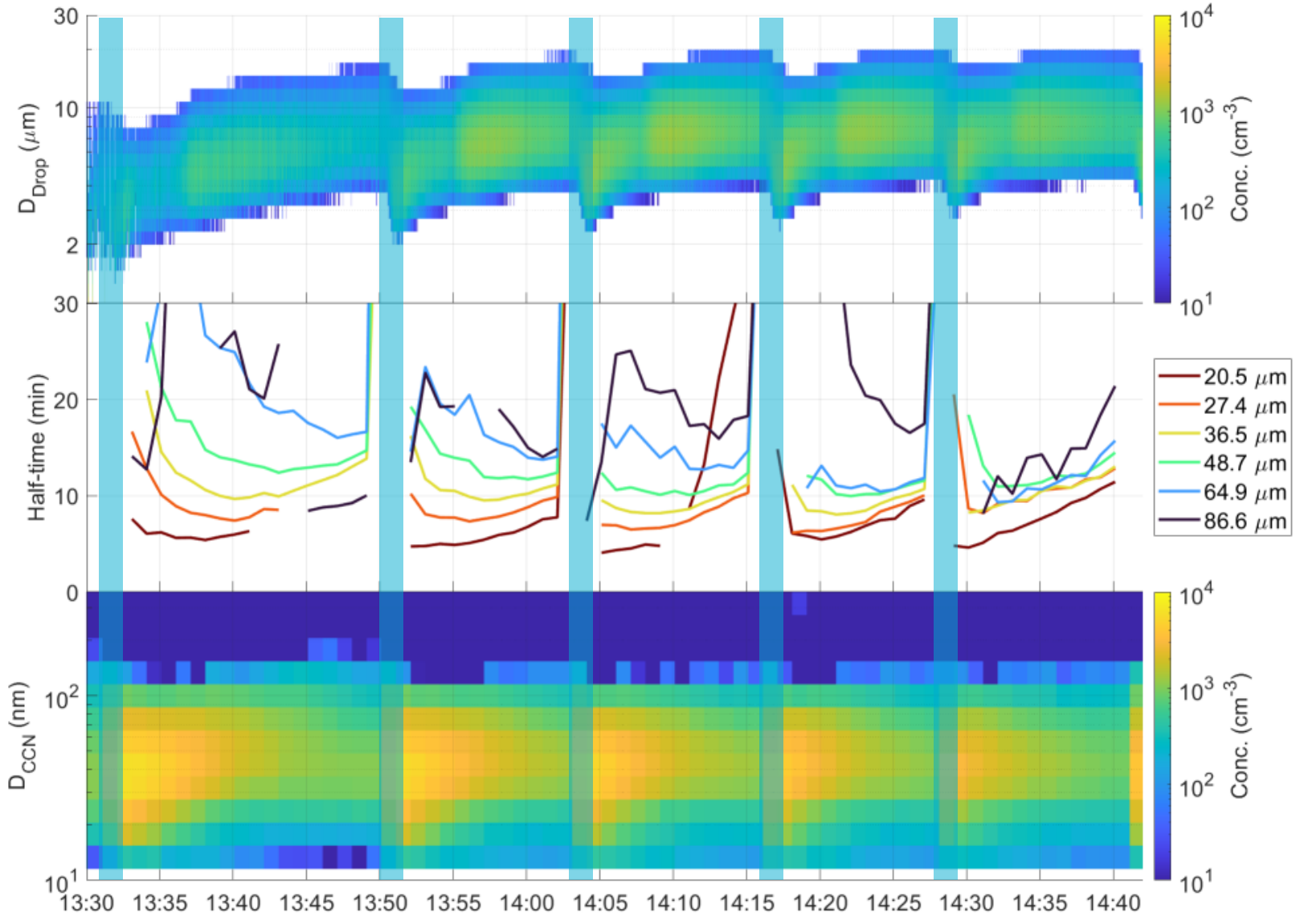


# Chamber Conditions – Residence Time

Residence time is dependent on:

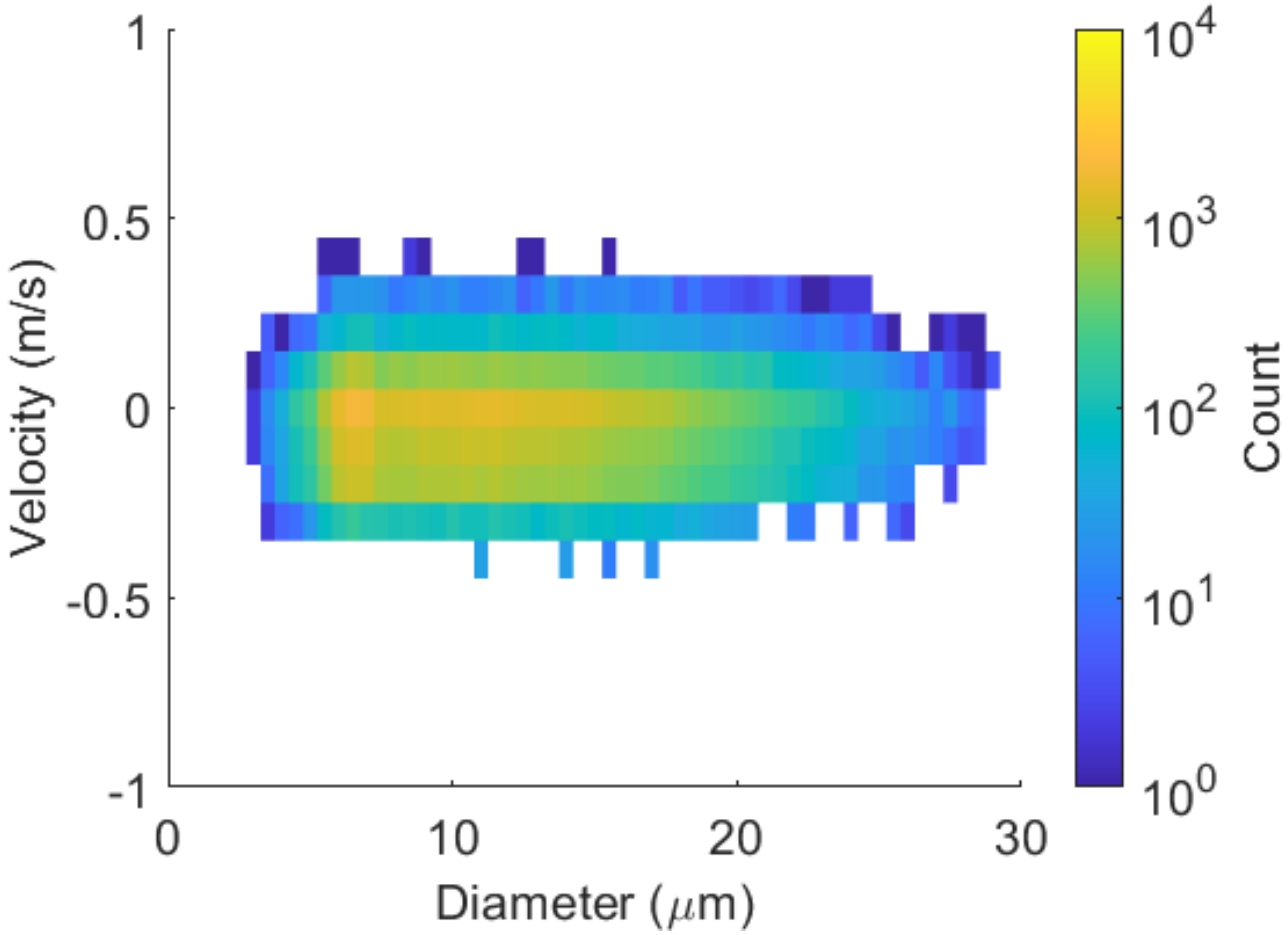
- Particle/Droplet size
- CCN concentration

**Droplets activated by smaller CCN grow more rapidly when CCN conc. is lower.**



# Chamber Conditions – Vertical Velocity

- Mean velocity is slightly negative
- Turbulent and normally distributed
- No clear dependence on size



# Quantifying Supersaturation

Approach [a]:

Droplet Size Distribution Change Over Time | Diffusional Growth | Sedimentation Loss | New Droplet Activation

Governing Equation:

$$\frac{\partial v(r)}{\partial t} = -\frac{\partial}{\partial r}\left(\xi \frac{v}{r}\right) - v\frac{u}{h} + A(r)$$

At Steady-State:

$$0 = -\frac{d}{\mathrm{d}r}\left(\xi \frac{v}{r}\right) - v\frac{k_1}{h}r^2$$

Solution:

$$C^{1/4} = \frac{\sqrt{2}}{\sqrt{\pi}}\frac{\Gamma(\frac{3}{4})}{\bar{r}}$$

where, $\xi = \dfrac{S-1}{F_k + F_\mathrm{d}}$

and, $\dfrac{1}{C} = \dfrac{\xi h}{k_1}$

[a] Adapted from Krueger, S.K., 2020. Equilibrium droplet size distributions in a turbulent cloud chamber with uniform supersaturation. *Atmospheric Chemistry and Physics*, *20*(13), pp.7895-7909.

# Supersaturation (Cont.)

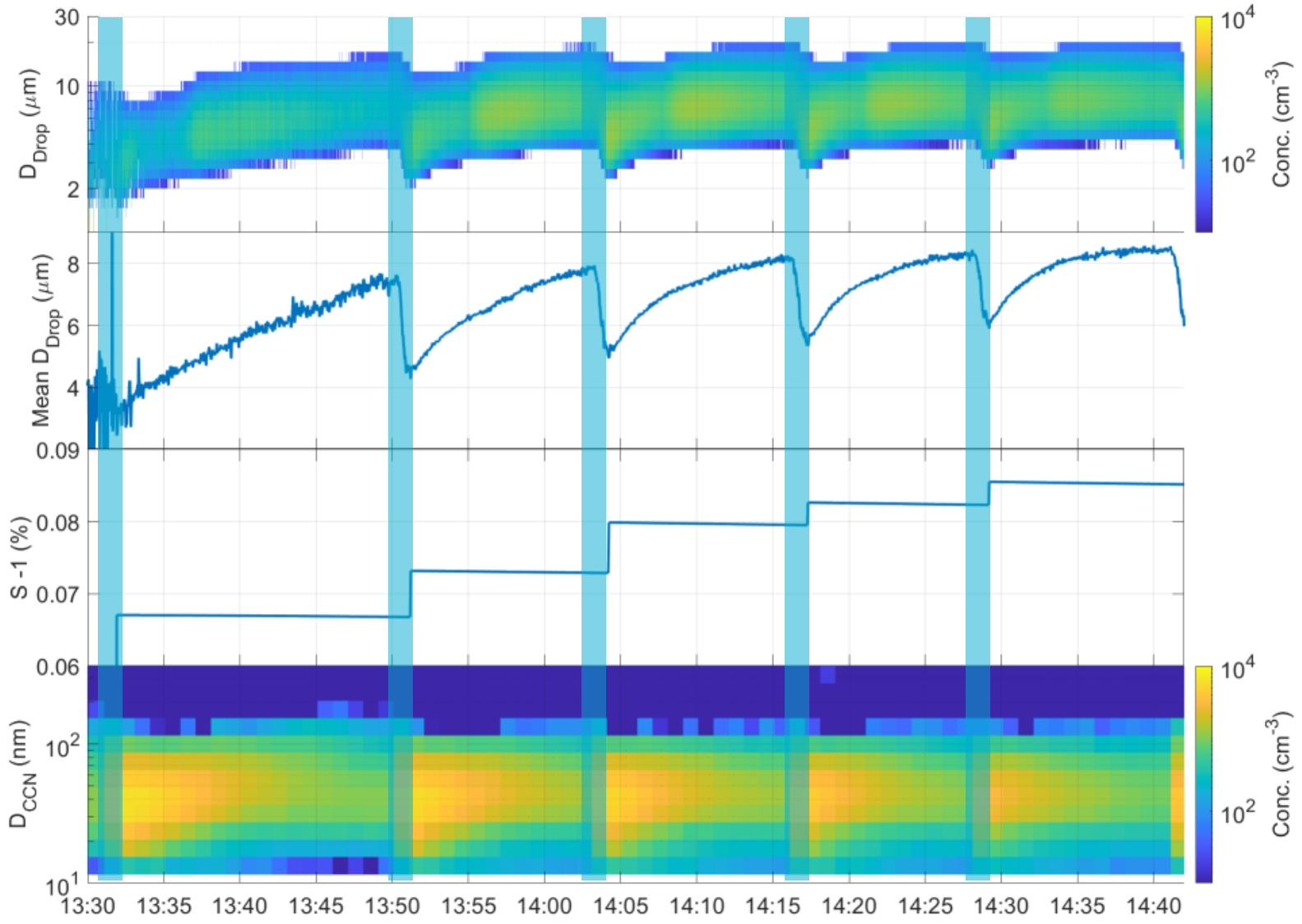
**Experiment Description:**

Sequential injections with decreasing concentrations.

The same humidification settings were used across all samples.

**Observation:**

Increasing supersaturation as CCN concentration decreases.



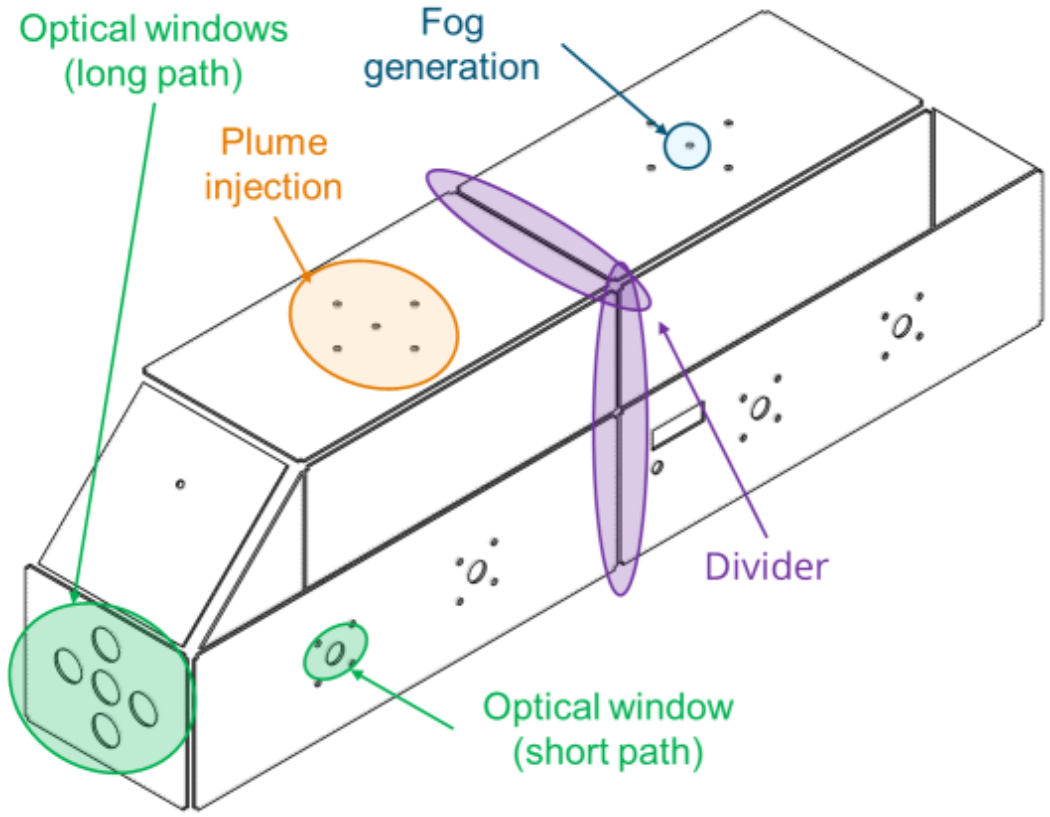
# What's next?

Continued MiniFog development and testing

Diagnostic and Predictive Modeling of Supersaturation

MesoFog development and testing

SNL Fog Chamber testing



# Questions?