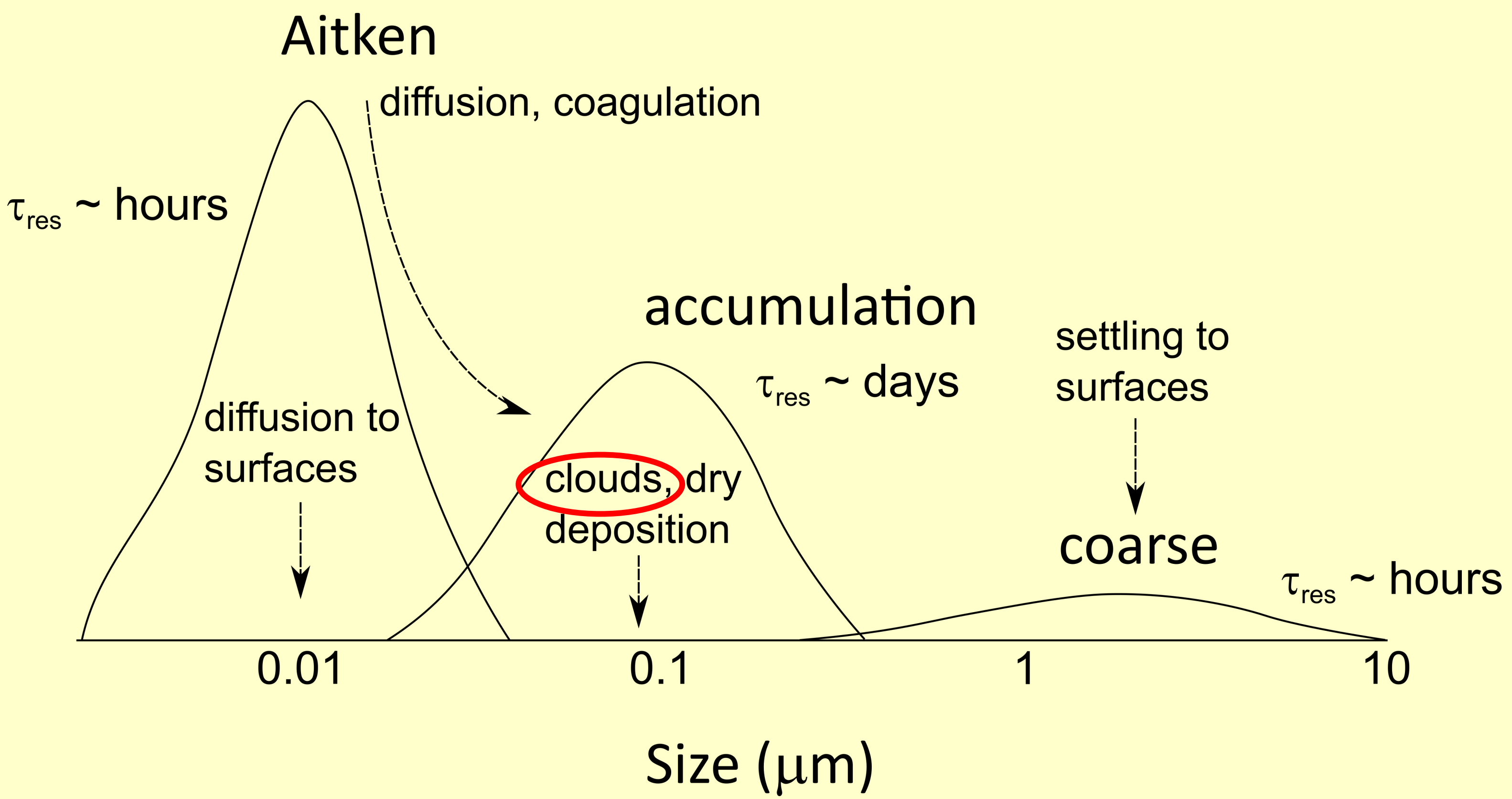
Laboratory Measurements of Aerosol Scavenging in a Cloudy, Turbulent Environment

Will Cantrell, Abu Sayeed Md Shawon, Prasanth Prabhakaran, Greg Kinney, Jesse Anderson, Claudio Mazzoleni, Raymond Shaw
Dept. of Physics and Atmospheric Sciences Program
Michigan Technological University

Motivation

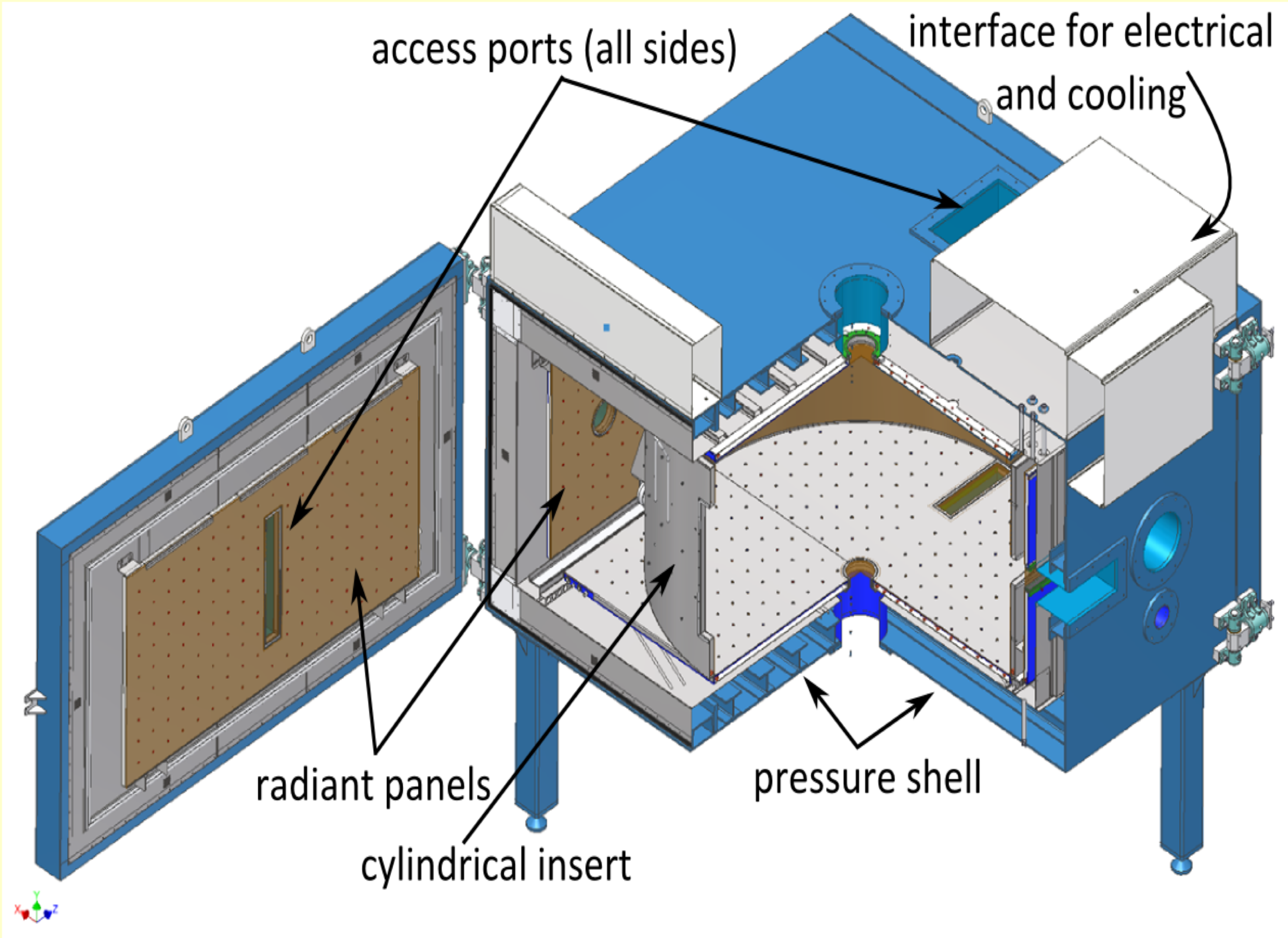
How are accumulation mode aerosol de-accumulated in the atmosphere?



Peak supersaturation, aerosol size and chemical composition are the canonical predictors of which aerosol particles will become cloud droplets.

Is that still true in a turbulent environment?

Cloud Chamber



Technical specifications

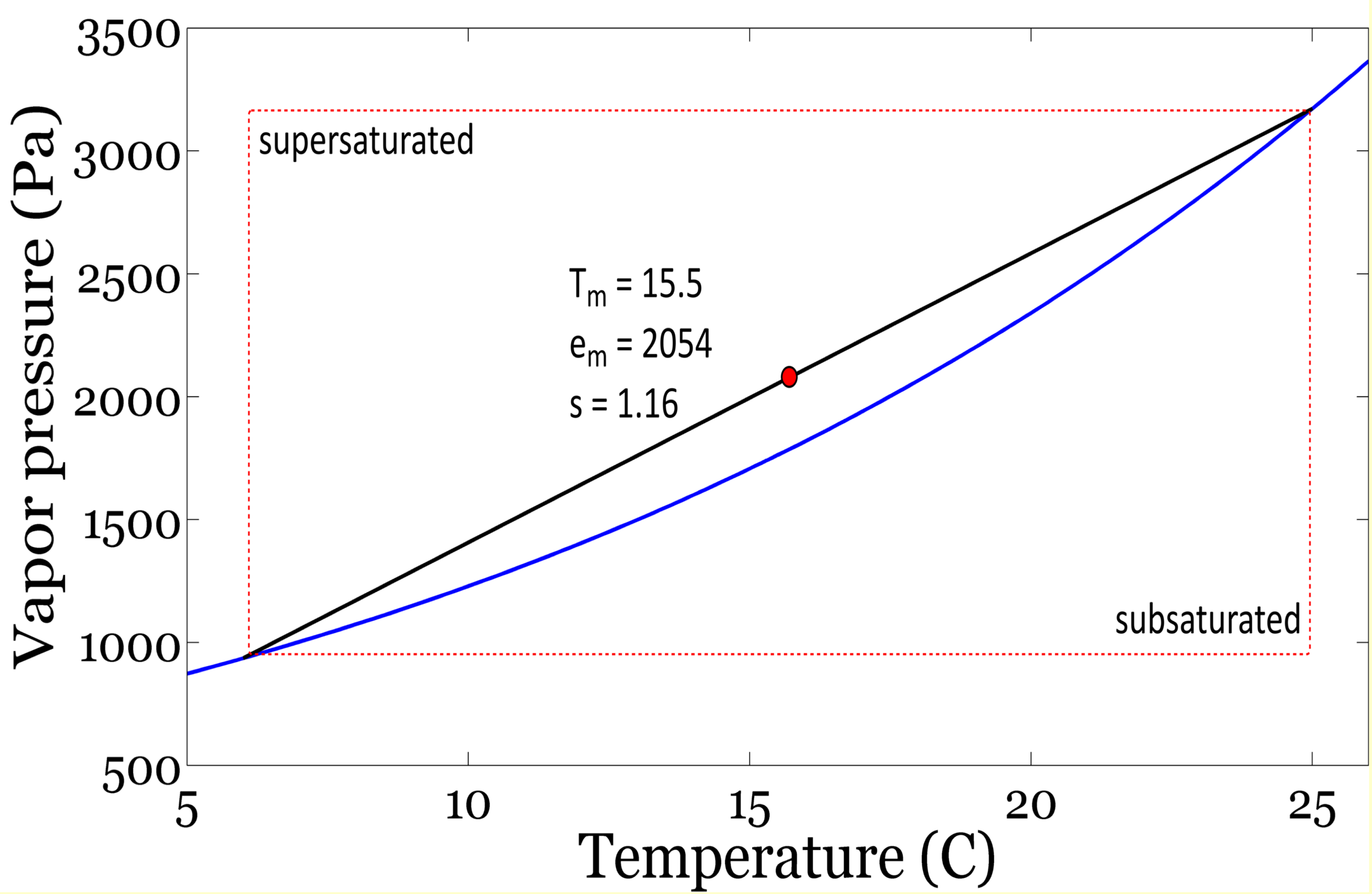
- T range: -55 to + 55 °C
- T control: ± 0.5 °C, dry bulb, measured at surfaces
- T gradient: ± 0.5 °C on surfaces, after stabilization
- T_{bottom}, T_{top}, T_{sides} independent
- dT/dt ~ -0.04 °C / sec
- Ra is 10^8 to 10^9

- P range: site level (~ 1 bar) to ~ 100 mbar
- P control: ± 2 kPa
- dP/dt ~ 2.5 mbar / sec

- Humidity is monitored, not controlled (source is wet filter paper on top and bottom plates)

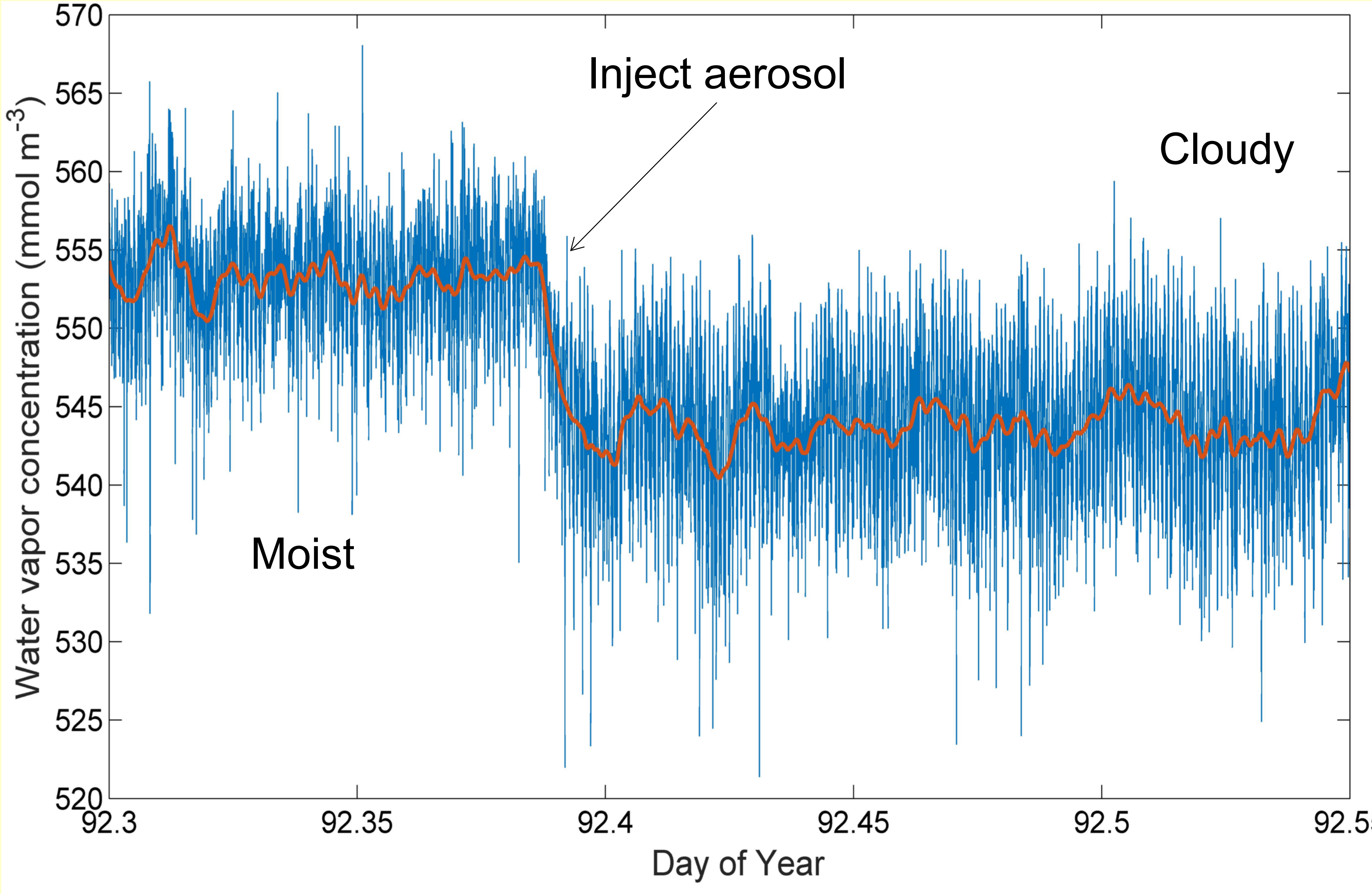
Cloud formation

Turbulent mixing: cold wet air at the upper surface falls toward warm, wet air rising from lower surface. Mixing event results in supersaturation.



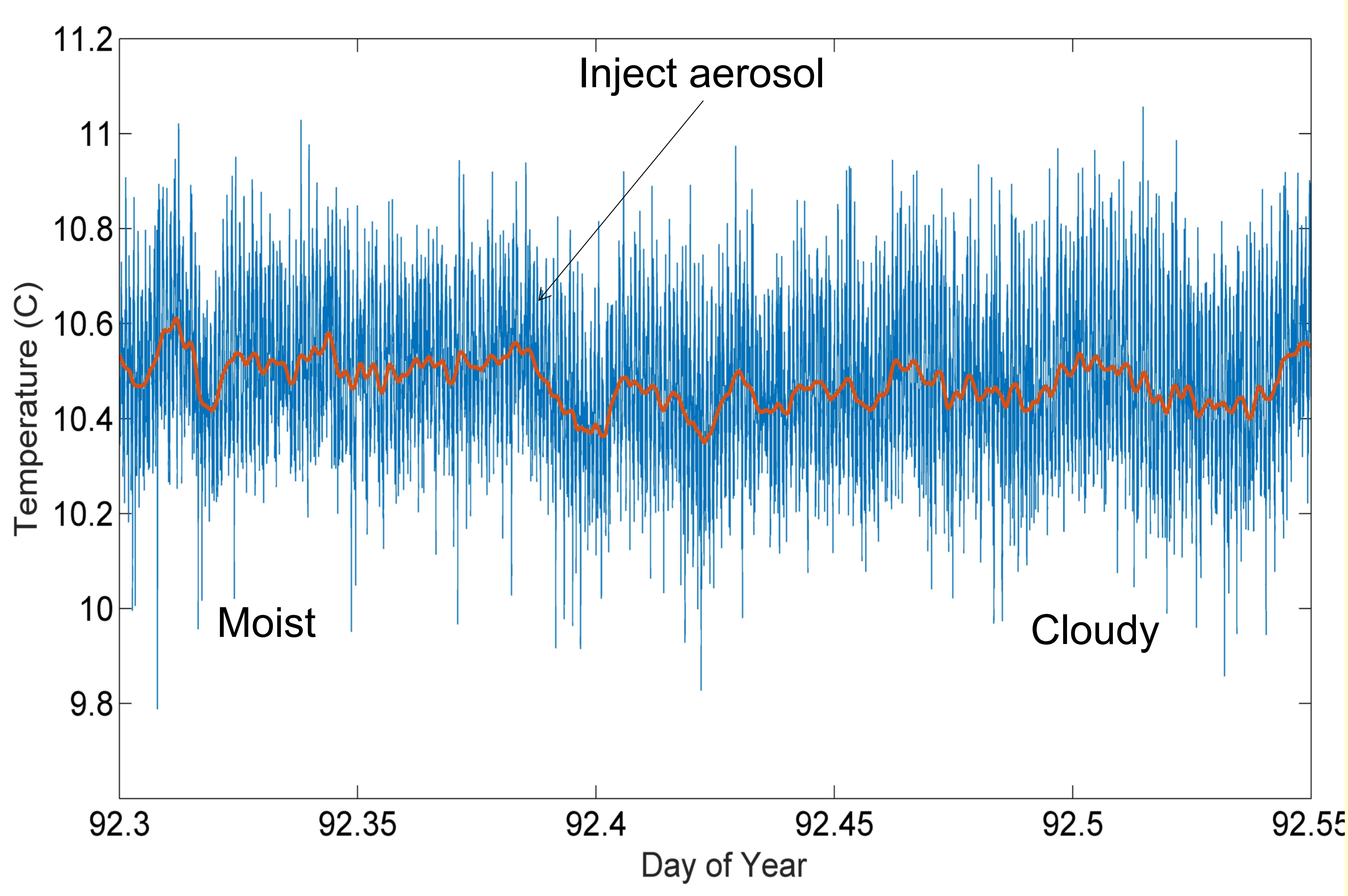
Fluctuating quantities

Water vapor



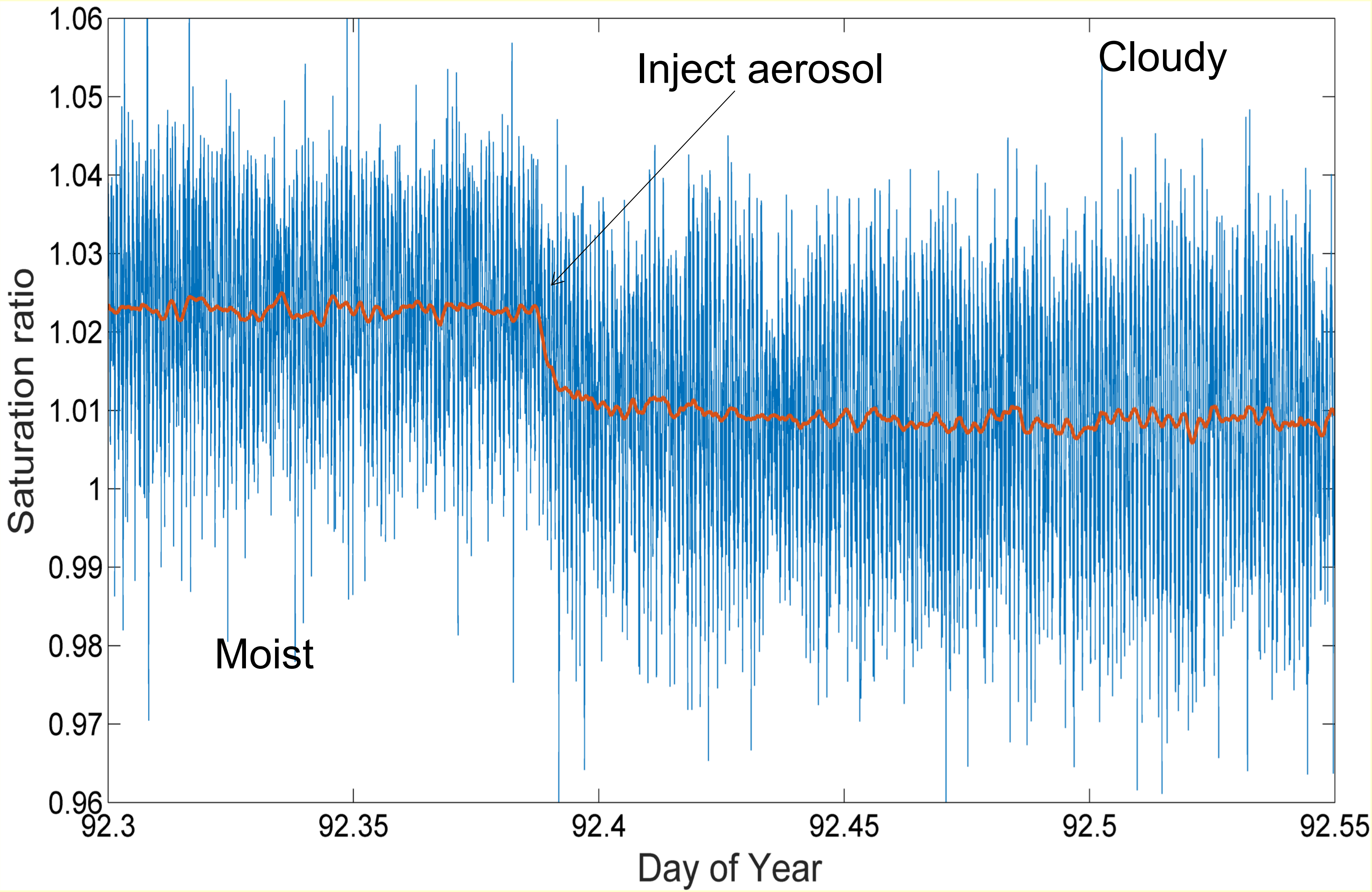
Fluctuating quantities

Temperature

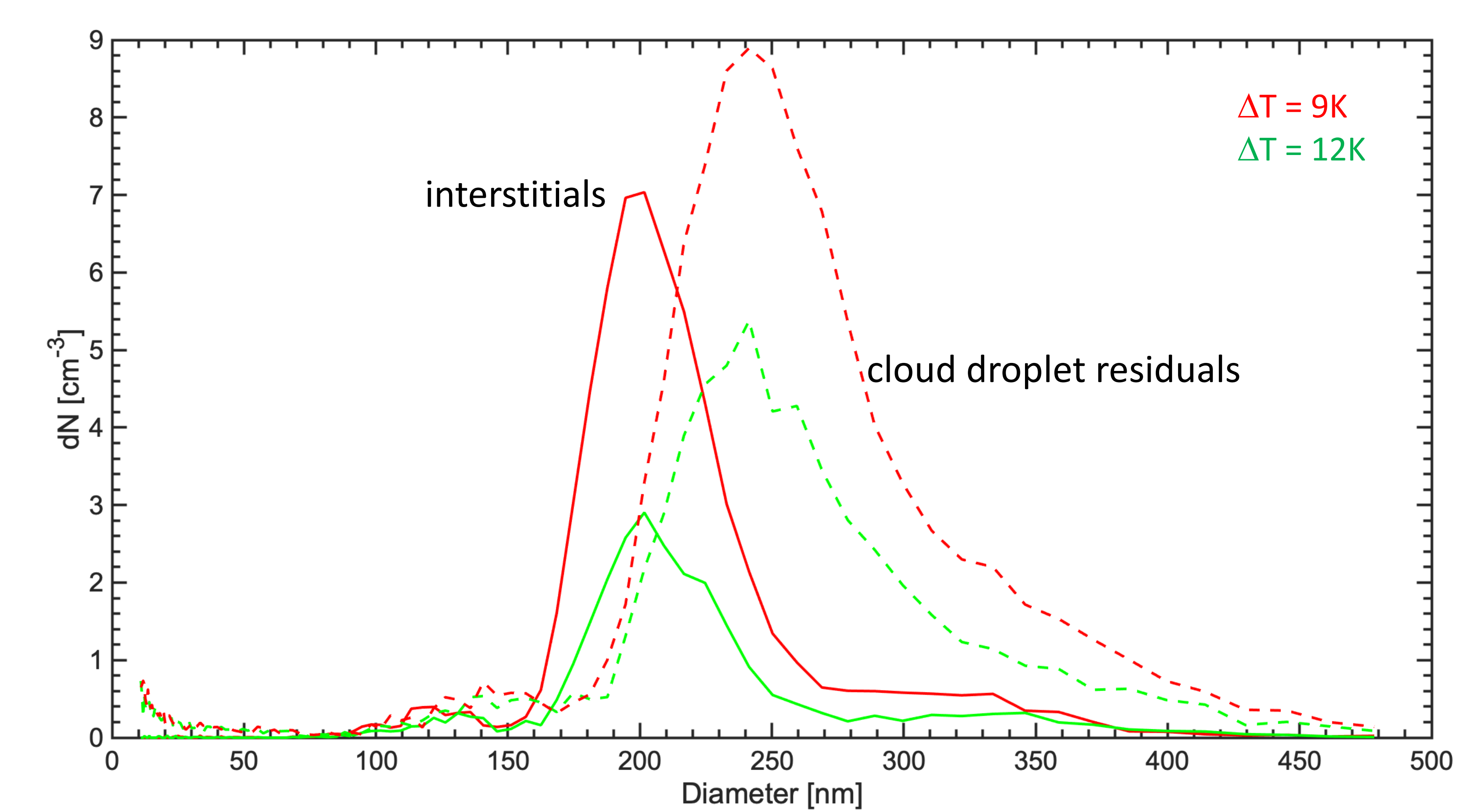


Fluctuating quantities

Saturation ratio ≡ $n_v/n_{v,sat}$



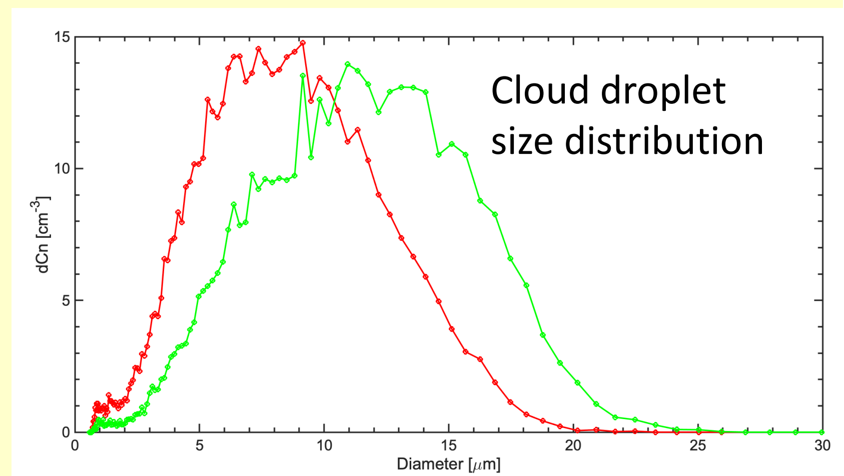
Compare interstitials to cloud droplet residuals for cloudy, turbulent conditions



Inject size selected (200 nm, NaCl) aerosol into chamber.

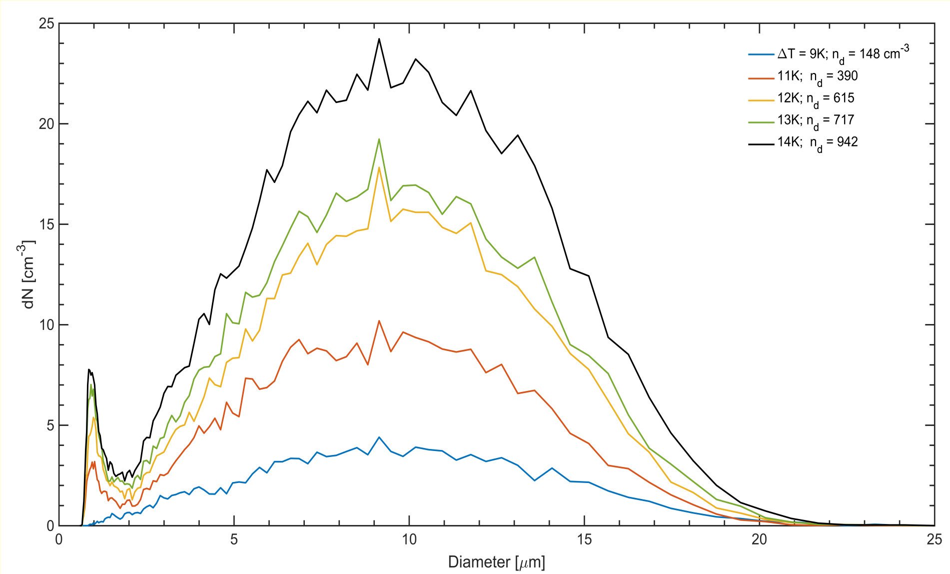
Measure interstitials, cloud droplet residuals, and cloud droplet number distribution.

Note aerosol of same size in both distributions.

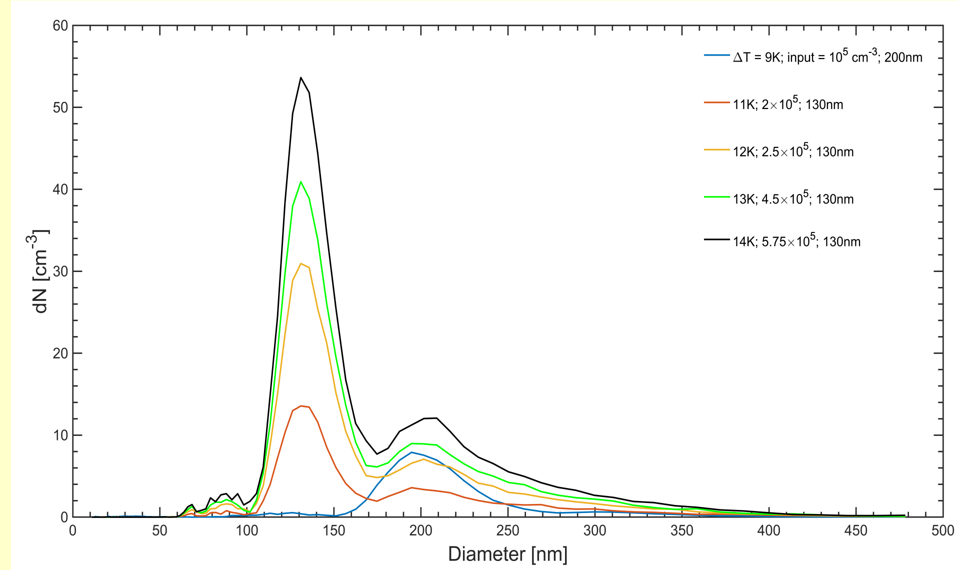


Come by poster for more details…

Scavenging by activation, another perspective



Cloud droplet size distribution



Interstitial aerosol size distribution (dry)

Budget in the chamber

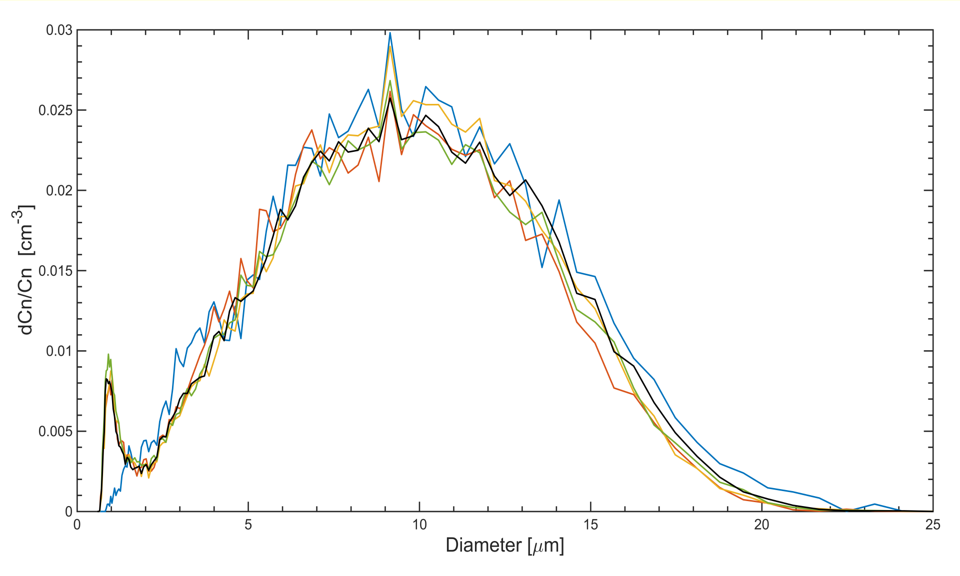
$$\frac{dn_{aerosol}}{dt} = \frac{dn_{injection}}{dt} - \frac{dn_{activation}}{dt}$$

$$\frac{dn_{droplets}}{dt} = \frac{dn_{activation}}{dt} - \frac{n_{droplets}}{\tau_{residence}}$$

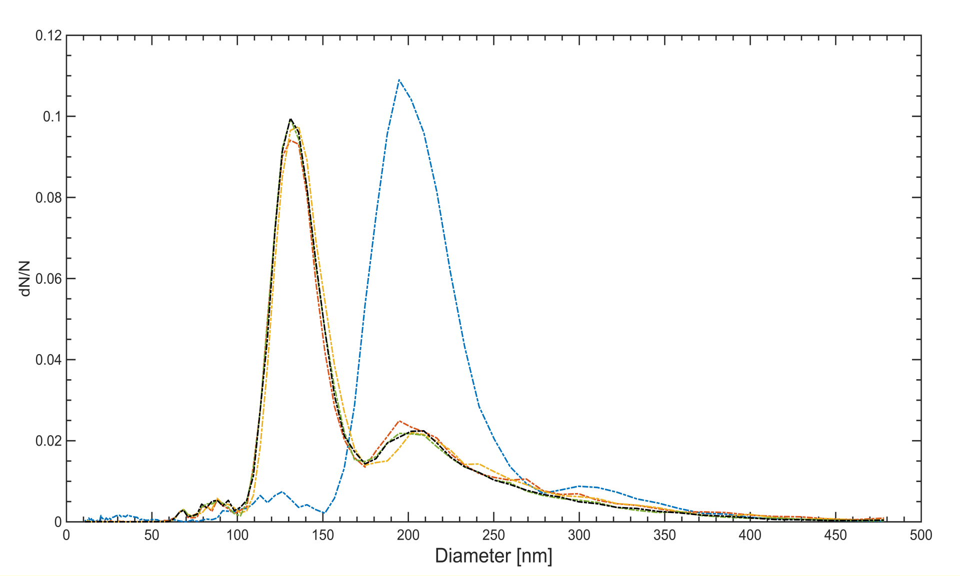
In steady state (for both droplets and aerosol):

$$\frac{dn_{injection}}{dt} = \frac{dn_{activation}}{dt} = \frac{n_{droplets}}{\tau_{residence}}$$

Scavenging by activation, another perspective



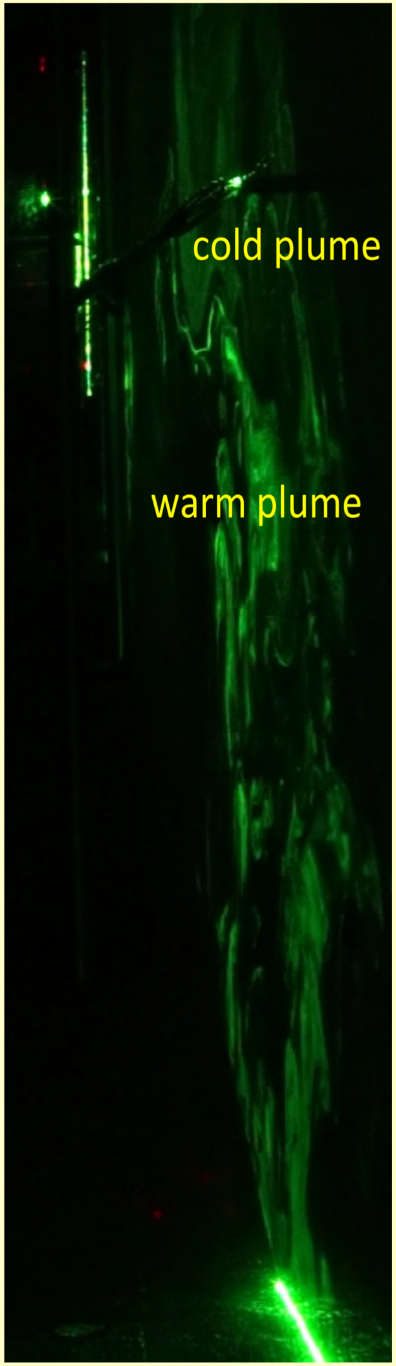
Cloud droplet size distribution (normalized)



Interstitial aerosol size distribution (dry, normalized)

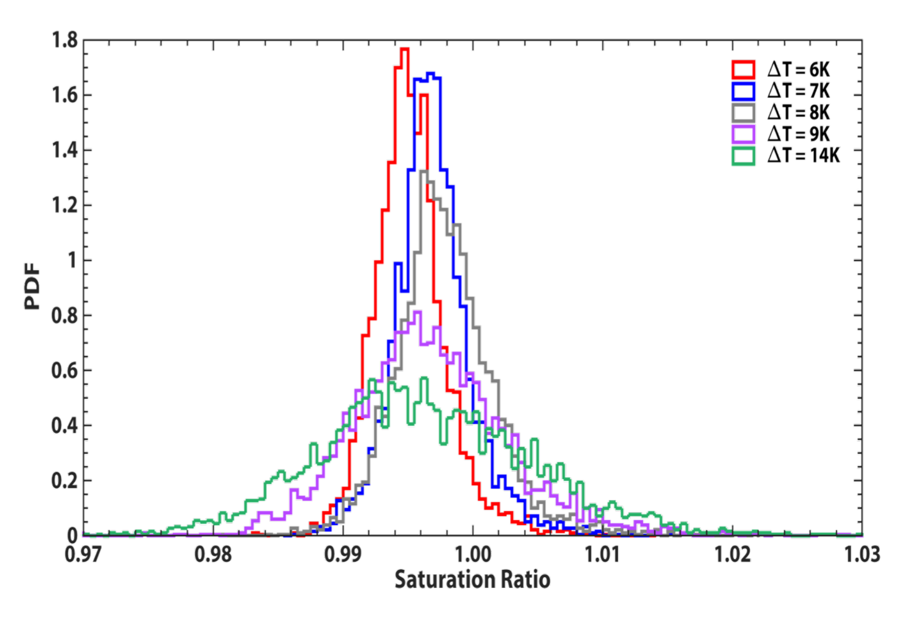
$\Delta T_{chamber}$	Droplet concentration (cm^{-3})	Activation rate ($cm^{-3}\ min^{-1}$)	Activated fraction
9 (200 nm)	148	48	0.70
11	390	99	0.70
12	615	143	0.63
13	717	215	0.60
14	942	275	0.61

Take home message… (preliminary conclusions)



- Aerosol size and chemical composition are indicators of which aerosol particles will become cloud droplets, but turbulence blurs distinction between those that activate and those that do not.
- Turbulence plus cloud properties (e.g. in-cloud supersaturation) govern activation / removal.

- Come by my poster to discuss efforts to de-couple turbulence and supersaturation.



The Π Chamber was developed through an MRI from NSF.
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