Laboratory Measurements of Aerosol Scavenging in a Cloudy, Turbulent Environment

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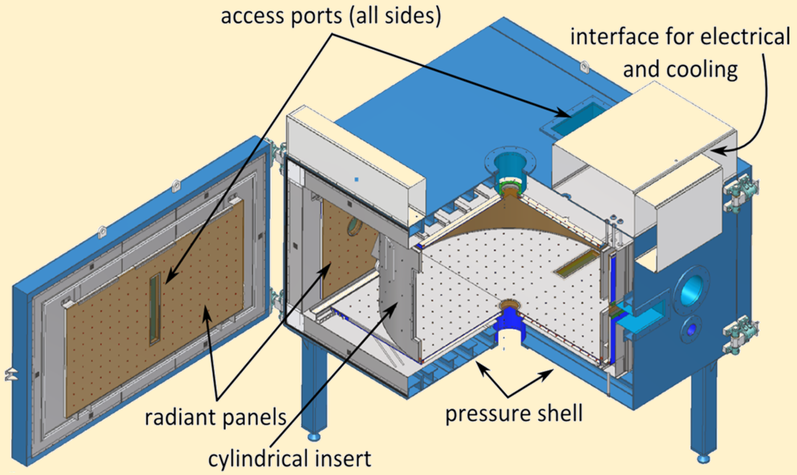
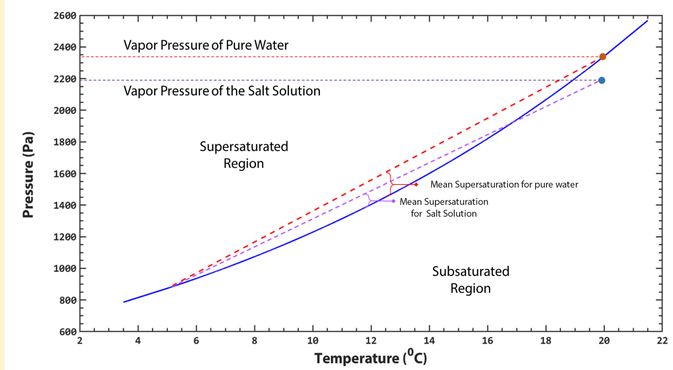
Abstract

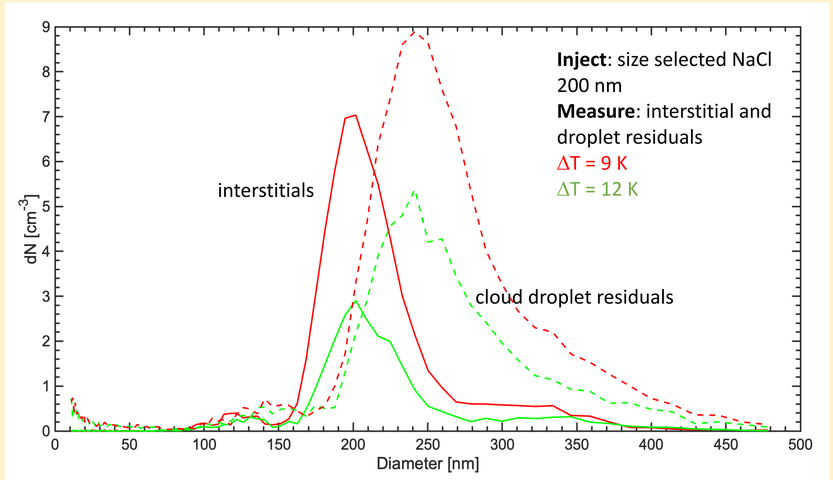
How are aerosol particles removed from the atmosphere? Those with diameters greater than a few microns have an appreciable negative vertical velocity and can be removed by settling. Particles smaller than few tens of nanometers have a high diffusivity and can be removed via diffusion. However, the in-between range of a few tenths of a micron has a small settling velocity and a low diffusivity, which produces a bottleneck in removal. As a consequence, this size range is frequently called the "accumulation mode" because particles in it accumulate in the atmosphere. The primary removal mechanism for the accumulation mode is cloud processing, because those particles readily serve as cloud condensation nuclei. The probability that an aerosol particle activates is traditionally understood to depend upon size and chemical composition, described in Köhler theory.

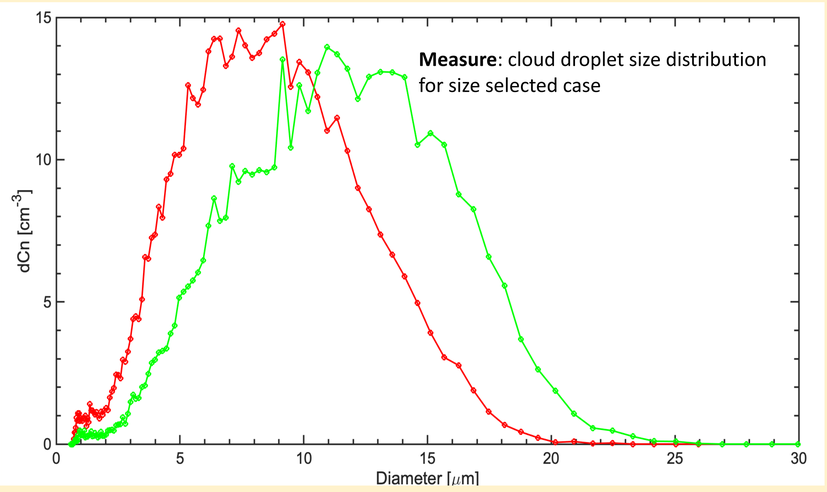
But, turbulent fluctuations in the scalar fields which couple aerosols and cloud droplets (i.e. temperature and water vapor) must also be considered. Measurements from Michigan Tech's turbulent mixing chamber (the Pi Chamber), show that, in the presence of turbulent fluctuations, the correspondence between size and activation is not clearly defined. In steady-state, turbulent cloud conditions a comparison of distribution of interstitial aerosol to the distribution of cloud droplet residuals shows that some aerosol particles are just as likely to remain as interstitial as they are to be activated, a result of fluctuations in the saturation ratio.

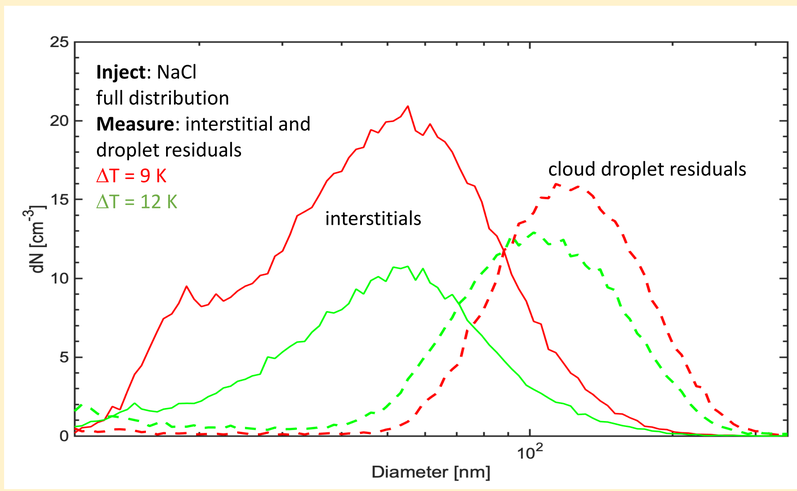
The Π Chamber

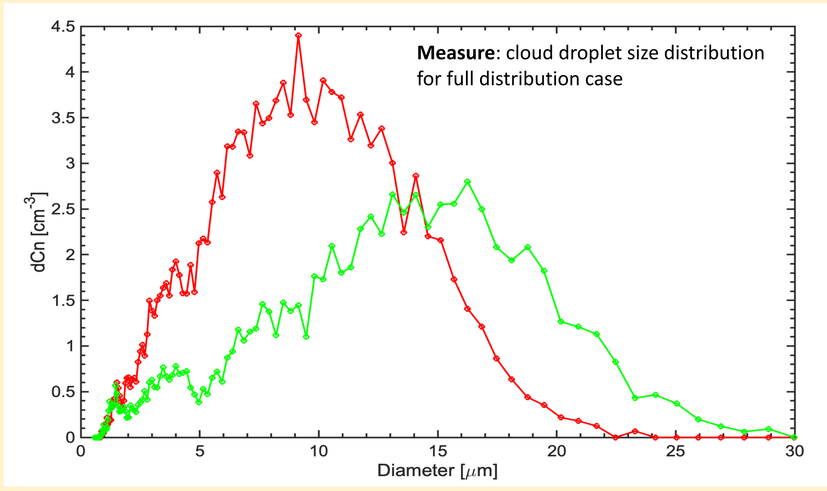










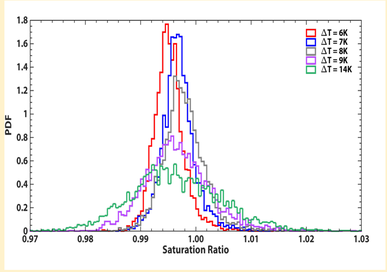


Procedure: Inject NaCl aerosol into a turbulent, cloudy environment and let both cloud and aerosol properties come to steady state.
Measure cloud droplet number distribution with Welas optical particle counter.
Measure distribution of interstitial aerosol (dry size) with Scanning Mobility Sizer (SMPS).
Measure distribution of cloud droplet residuals (dry size) with pumped counterflow virtual impactor (p-CVI) + SMPS.

Results: For the same injection rate, steady-state supersaturation (in cloud) is higher for higher temperature difference between the plates (ΔT). Note shift in cloud droplet size distribution.
Particles of the same dry size (same critical supersaturation) are found in both interstitial and residual distributions.
Larger particles are preferentially found in the residuals, smaller ones in the interstitials (see especially injection of full distribution).

Take home message

In a turbulent environment (temperature and water vapor are fluctuating quantities), size and chemical composition are no longer one-to-one predictors of aerosol activation



Developing capabilities

Can we hold mean saturation ratio constant and vary the level of turbulence? - Yes!
If we fix the saturation ratio at the bottom plate using salt water, we can achieve the same mean saturation ratio, but with a different variance

Acknowledgments

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