Creating and Sustaining a Cloud in a Chamber

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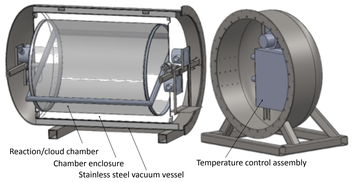
Aerosols Absent from Current Atmospheric Models

In current atmospheric models, in-cloud production of aqueous secondary organic aerosols (cloud aqSOA) is not accounted for or well represented (Volkamer et al., 2015, and Chen et al., 2015). The production of cloud aqSOA is an alternate SOA pathway from gasSOA, as the gas phase reaction products that form aqSOA are generally unimportant for gasSOA production (Blando and Turpin, 2000).
In order to better our understanding of cloud aqSOA production rates and properties, we developed the Multiphase Aging and Production of Particles (MAPP) chamber. The final emphasis of this on-going project is aqSOA production and properties (e.g. mass yield, hygroscopicity, and volatility) in a cloud, rather than reaction rates or composition, which can be studied with pre-existing chambers.

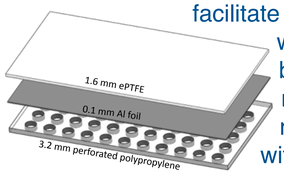
Designing a Cloud Chamber

The MAPP chamber consists of two main sections: a 0.05mm thick, cylindrical fluorinated ethylene propylene (FEP) Teflon bag, and a vacuum-sealable stainless-steel capsule.

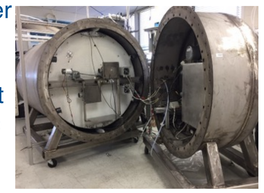


The bag is designed to be light, transparent, un-reactive, and have a low heat capacity, so that the chamber itself affects the cloud as little as possible.

Furthermore, the FEP cylinder is housed in a plastic enclosure, which is made from layering ePTFE, aluminum foil, and perforated polypropylene.The purpose of this enclosure is to facilitate temperature regulation without disturbing the FEP bag and to provide a reflective surface to maximize the light intensity within the chamber.



After the enclosure and chamber are secured in the capsule, the capsule is vacuum-sealed shut so that air from the room cannot get inside and all aspects of the chamber can be controlled.

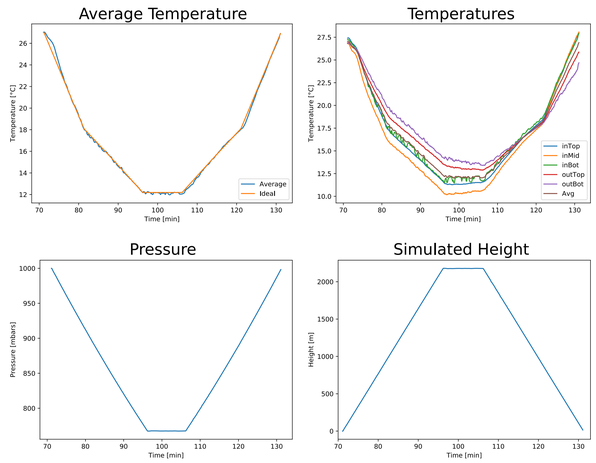


Other Chamber Considerations

- There is an external cooler and a heater inside the steel capsule which are used to regulate temperature.
- A motor spins the FEP chamber so that cloud particles are given some velocity and limit how many can settle.
- Temperature probes are located in the front and back of the chamber.
- Lasers and cameras are set up to see clouds form.
- An Aerodynamic Particle Sizer (APS) is used to sample the particle size distribution of cloud droplets in the chamber.
- During experiments, there is always small pressure so that the chamber walls are taut, lessening their contribution to particle loss.
- Aerosols are injected using an external DMA, which selects the size of the aerosols.

Creating a Cloud in a Chamber

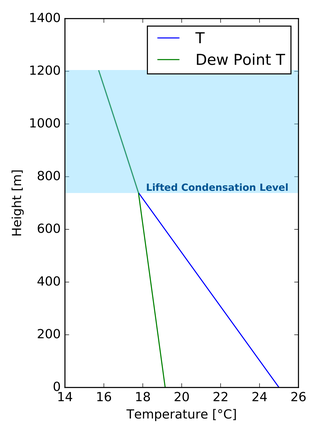
A typical experiment goes as follows:
1. "Zero air" with a high relative humidity fills chamber.
2. Seed aerosols are injected, followed by organic precursors and oxidants.
3. Initial gas concentrations and aerosols are measured. Concentrations are again measured before a cloud cycle to test pre-cloud changes.
4. Cloud cycle proceeds. Cloud droplet size measurements are taken throughout.
5. Cloud is dissipated, and post-cloud gas/aerosol measurements are taken.



Cloud Cycle Creates a Cloud Through Adiabatic Expansion
During a cloud cycle, the chamber's temperature and pressure are lowered, which simulates an air parcel rising in the sky. Once relative humidity reaches super-saturation, a cloud will form. The cloud is then maintained to allow cloud aqueous chemistry to take place. The clouds are then dissipated by adding in less-humid air and raising the temperature and pressure. A typical cycle lasts for an hour, but the time is adjustable for different experiments.

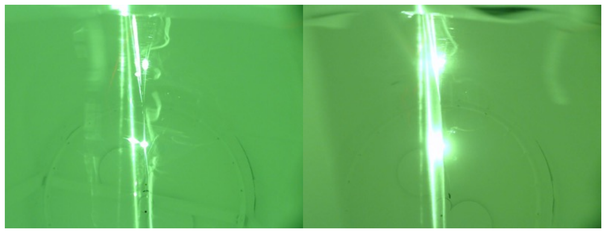
Current Cloud Creation

The majority of our recent experiments focused on testing cloud production and sustainability, without SOA chemistry. The aerosol seed used was ammonium sulfate ($(NH_4)_2SO_4$), with particles sized around 0.1 μm.



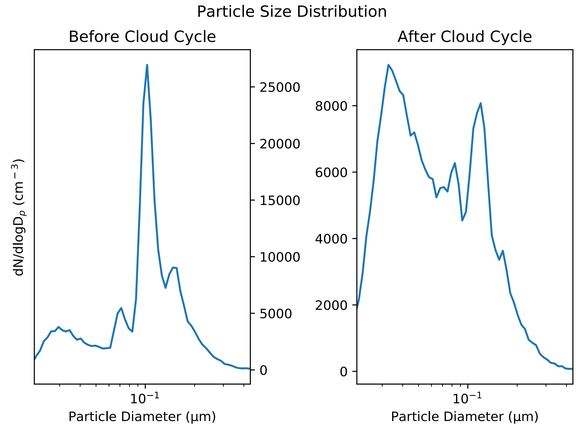
The Lifted Condensation Level (LCL) Determines When a Cloud Will Form
Given relative humidity and temperature, we can use calculated dew point lapse rates and dry adiabatic lapse rates to find the LCL, which determines at what simulated height water droplets will condense on aerosols, creating a cloud (blue area on graph).
The chamber's temperature and pressure were adjusted accordingly to form a cloud.

Aerosol Particles Survived Cloud Cycle
In initial tests, high humidity, high temperature, thick cloud cover, and low cloud condensation nuclei caused cloud droplets to become too large and settle in the chamber. After adjustments were made, the ammonium sulfate particles were able to survive full cloud cycles. Smaller residual particles resulted from an unknown contaminant.



Laser Light Illuminates Cloud Formation
Left: With no cloud particles, the laser light is seen clearly.
Right: Cloud particles scatter the laser light.

Testing Particle Growth



Trials Show Particle Growth During Cloud Cycle
SO_2 and O_3 were injected into the chamber with the $(NH_4)_2SO_4$. When the cloud formed, SO_2(aq) reacted with H_2O to form sulfite, which then reacted with the O_3 to create sulfuric acid, which condensed on the aerosol particles as the cloud dissipated. The resulting aerosol particles were slightly larger than the initial 0.1 μm. The smaller particles are still believed to be residuals from contamination.

Future Work

- Repairs to the chamber will be made in order to remove/limit contaminants, better control heating/cooling, and obtain size distributions from the APS.
- Precursor gasses will be varied to determine their affects on SOA yields.
- Different seed aerosols will be used to test the effect of cloud droplet acidity, impact of Fenton chemistry, and how producing oxidants affects cloud aqSOA production.
- The initial conditions of clouds (liquid water content, base temperature, evaporation rate, etc.) will be varied to assess the effect on cloud aqSOA.
- Once all experiments are completed, we will be able to determine a set of parameters describing cloud aqSOA that should be included in future atmospheric models.

Acknowledgements

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