

# Aerosol optical and chemical properties within and without clouds during an airborne field campaign in central Oklahoma

E. Andrews<sup>1,2</sup>, Y.-N. Lee<sup>3</sup>, L. Alexander<sup>4</sup>, J. Ogren<sup>2</sup>, J. Hubbe<sup>4</sup>

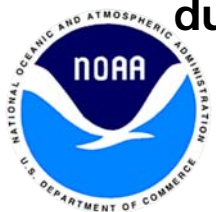
<sup>1</sup>Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO

<sup>2</sup>NOAA/Earth Systems Research Laboratory/Global Monitoring Division, Boulder, CO

<sup>3</sup>Brookhaven National Laboratory, Department of Energy (DOE), Brookhaven, NY

<sup>4</sup>Pacific Northwest National Laboratory, Department of Energy (DOE), Richland, WA

**Aerosol particles are ubiquitous, clouds cover much of the earth. Clouds and aerosol particles are going to interact in the atmosphere in many ways. The results of this interaction can be important for both indirect aerosol forcing, (i.e., how aerosol affects the radiative properties of the cloud) and for direct aerosol forcing (how the aerosol optical properties are affected by cloud processing).**



## SCIENTIFIC QUESTIONS

- What are differences in aerosol optical properties within and outside the plume of a mid-sized city?
- How do clouds change the optical properties of the aerosol?
- What does aerosol chemistry tell us about these changes in aerosol optical properties?



- G1 based in Ponca City (PNC)
- Flew in vicinity of Oklahoma City to sample plume
- Flew within and outside of cloud

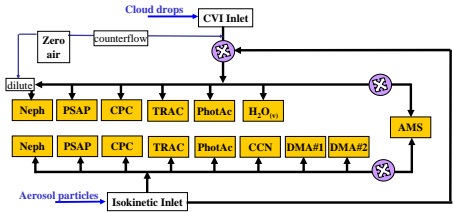
## Tandem Inlet System



Isokinetic inlet samples particles with  $D < 5 \mu m$ . → clear air - sampling the ambient aerosol  
 → in-cloud - samples interstitial aerosol, but... subject to contamination by droplet shattering

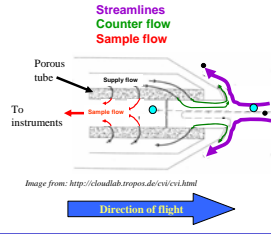
CVI inlet designed to only sample large particles ( $D > 11 \mu m$ )  
 → clear air - doesn't see any particles  
 → in-cloud - samples fog droplets

## Aerosol Instrumentation on ASP G1



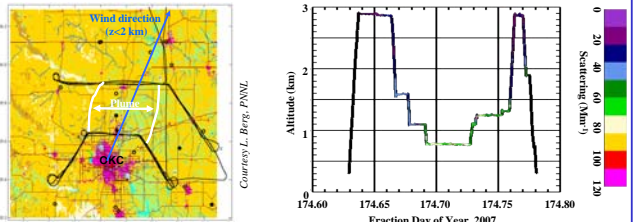
- AMS switched between CVI and isokinetic inlet depending on flight plan and cloud conditions.
- CVI inlet instruments could sample from CVI or isokinetic inlet (e.g., for instrument comparison).

## Counterflow Virtual Impactor (CVI) Inlet



1. The speed of the aircraft creates **streamlines** around the CVI tip
2. Smaller particles (•) either follow the **streamlines** or enter the CVI tip but are then repelled by the counterflow. Either way, they are not sampled.
3. The large particles (•) have enough momentum that they are unable to follow the stream lines and instead enter the CVI tip
4. If particle momentum is high enough the particle is able get past the **counter flow** at the CVI tip and end up in the **sample flow**.

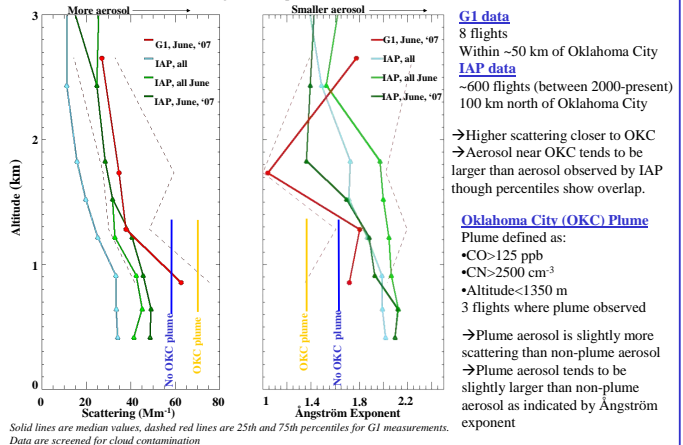
## Example G1 Flight Track (June 23, 2007 (DOY 174))



- Horizontal flight plan designed to sample within and outside of Oklahoma City (OKC) urban plume.
- Vertical flight plan designed to profile aerosol with altitude and sample within and outside clouds.
- Plume indicated by increased scattering along flight track; wind direction from NOAA/HYSPLIT model

## Vertical Profile of Aerosol Optical Properties

Comparison of aerosol optical property profiles measured near Oklahoma City by G1 with those measured over Southern Great Plains (SGP) site with DOE's Atmospheric Radiation Measurement (ARM) In-situ Aerosol Profiling (IAP) airplane.



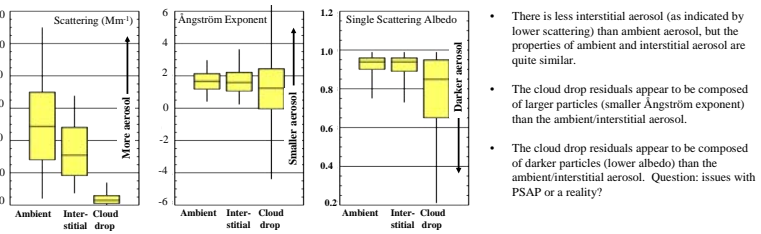
**G1 data**  
 8 flights  
 Within ~50 km of Oklahoma City  
**IAP data**  
 ~600 flights (between 2000-present)  
 100 km north of Oklahoma City

→ Higher scattering closer to OKC  
 → Aerosol near OKC tends to be larger than aerosol observed by IAP though percentiles show overlap.

**Oklahoma City (OKC) Plume**  
 Plume defined as:  
 • CO > 125 ppb  
 • CN > 2500 cm<sup>-3</sup>  
 • Altitude < 1350 m  
 3 flights where plume observed

→ Plume aerosol is slightly more scattering than non-plume aerosol  
 → Plume aerosol tends to be slightly larger than non-plume aerosol as indicated by Angstrom exponent

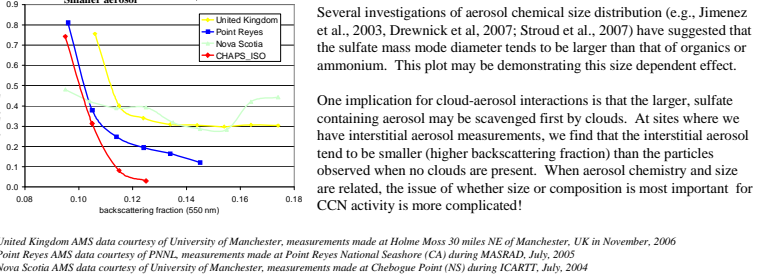
## Aerosol Optical Properties Within and Outside Clouds



- There is less interstitial aerosol (as indicated by lower scattering) than ambient aerosol, but the properties of ambient and interstitial aerosol are quite similar.
- The cloud drop residuals appear to be composed of larger particles (smaller Angstrom exponent) than the ambient/interstitial aerosol.
- The cloud drop residuals appear to be composed of darker particles (lower albedo) than the ambient/interstitial aerosol. Question: issues with PSAP or a reality?

Plots show 5<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup> and 95<sup>th</sup> percentiles of aerosol optical properties measured on G1 between 1000-2000 m (most common altitude for clouds). Ambient and interstitial aerosol were sampled through the isokinetic inlet for cloud-free and cloudy conditions, respectively; cloud drop residuals are those sampled via the CVI inlet during clouds.

## Chemistry and Size



Several investigations of aerosol chemical size distribution (e.g., Jimenez et al., 2003; Drewnick et al., 2007; Stroud et al., 2007) have suggested that the sulfate mass mode diameter tends to be larger than that of organics or ammonium. This plot may be demonstrating this size dependent effect.

One implication for cloud-aerosol interactions is that the larger, sulfate containing aerosol may be scavenged first by clouds. At sites where we have interstitial aerosol measurements, we find that the interstitial aerosol tend to be smaller (higher backscattering fraction) than the particles observed when no clouds are present. When aerosol chemistry and size are related, the issue of whether size or composition is most important for CCN activity is more complicated!

United Kingdom AMS data courtesy of University of Manchester, measurements made at Holme Mass 30 miles NE of Manchester, UK in November, 2006  
 Point Reyes AMS data courtesy of PNNL, measurements made at Point Reyes National Seashore, (CA) during MASRAD, July, 2005  
 Nova Scotia AMS data courtesy of University of Manchester, measurements made at Chequoque Point (NS) during ICART, July, 2004

## Conclusions

- The presence of an urban center changes the aerosol optical properties compared to those measured in a rural area  
 → The aerosol scattering (indicator of amount) increases and the Angstrom exponent (indicator of size) decreases → more large aerosol!  
 → The OKC plume highlights these effects.
- Interaction with fog changes the optical properties of aerosol.  
 → Cloud scavenging decreases the amount and size of the interstitial aerosol.  
 → Cloud drop residuals suggest the scavenged particles are larger and may be more absorbing, as indicated by a decrease in single scattering albedo. This is different than what has been observed at other sites where observations suggest that the absorbing aerosol is not scavenged and remains in the interstitial air.
- The chemical composition appears to be related to the size of the aerosol  
 → Smaller aerosol tend to contain less sulfate.  
 → Suggests that role of chemistry and size in CCN activity is intertwined
- FUTURE WORK:  
 → Explore the relationship between aerosol optical properties and chemistry in more detail. Are there systematic relationships?  
 → Look in more detail at differences in ambient, interstitial and cloud aerosol properties.

## Acknowledgements:

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