# AQRP Monthly Technical Report

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| **PROJECT TITLE** | Sources and Properties of Atmospheric Aerosol in Texas: DISCOVER-AQ Measurements and Validation | **PROJECT #** | 14-005 |
| **PROJECT PARTICIPANTS** | Sarah Brooks and Ping Yang | **DATE SUBMITTED** | 6/9/2014 |
| **REPORTING PERIOD** | **From:** February 5, 2015<br>**To:** February 28, 2015 | **REPORT #** | 1 |

A Financial Status Report (FSR) and Invoice will be submitted separately from each of the Project Participants reflecting charges for this Reporting Period. I understand that the FSR and Invoice are due to the AQRP by the 15th of the month following the reporting period shown above.

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## Detailed Accomplishments by Task

### *Task 1. CASPOL Data Collection and Quality Control.*

From August 28 through October 4, 2013, the CASPOL was located on top of the Moody Tower. The Moody Tower is located at 29.7176° N, -95.3414° W, approximately four kilometers south of downtown Houston, Texas. The inlet was located on top of the building which is ~70 meters tall. The height of the tower is low enough that the aerosols being sampled are representative of the aerosols at the surface, but tall enough so that any intermittent point sources will not interfere with the measurements. This tower has been the location of many previous and current field campaigns (Brooks et al., 2010; Lefer et al., 2010; Rappenglück et al, 2010). The CASPOL inlet was specially designed to rotate so that it always points into the wind. The inlet was connected heated stainless-steel pipe (1.5 m in length), to maintain constant relative humidity and avoid condensation (Quinn et al., 1998), by a 3/4 inch outer diameter piece of non-conductive tubing that was 2.5 meters long. Beyond the heated pipe, the sample flow was split between the CASPOL (1.2 L $min^{-1}$) and a dump line (10 L $Min^{-1}$), and behind the CASPOL was a thermocouple, relative humidity meter (ROTRONIC H290D), HEPA filter, another thermocouple and then another relative humidity meter (ROTRONIC H290D), as seen in Figure 1. The inlet line was changed, and the other tubing was changed or dried at least twice a week. Data was removed if rainfall amounts exceeded three fourths of an inch in the six hours before and during any time period due to the likelihood of the majority of particles being removed via the wet deposition process. At the time of this report all CASPOL data collected during DISCOVER-AQ has been quality controlled. Data collected during and after precipitation events has been eliminated, as will any periods during which the CASPOL was operating offline for maintenance, drying, or flow testing.

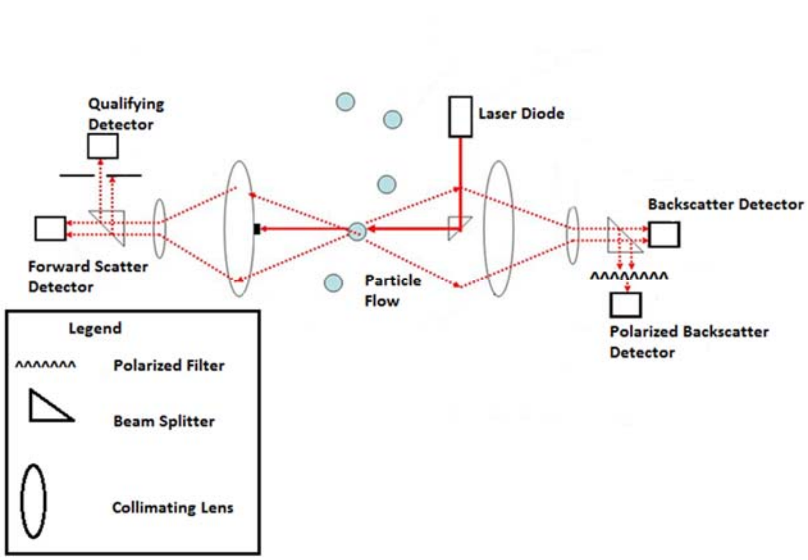


**Figure 1A.** A schematic of the CASPOL instrument adapted from DMT Manual (2011).

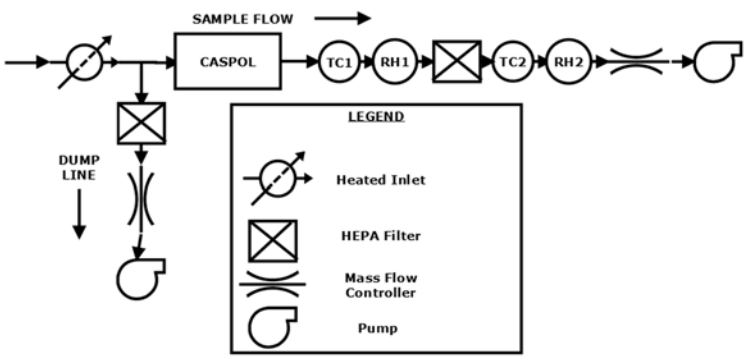


**Figure 1B.** A schematic of the experimental setup of the CASPOL on top of the Moody Tower during DISCOVER-AQ.

***2. Separation of All Data-Controlled CASPOL Data According to Source Location.***

Air masses over the Moody Tower are likely to have been influenced by one of four major aerosol sources. The Ship Channel source, which is a heavily industrialized area on the east side of Houston. An Urban source, which consists of the densely populated, urban center of Houston. A marine source, which consists of transported aerosols from the Gulf of Mexico and potentially further (Goudie and Middleton, 2001). Lastly the Semi-Urban/Rural source, which consists of transported aerosols from the west and passes over the less densely populated zones of the greater Houston area. Conveniently, these sources come from four different wind directions relative to the Moody Tower. Time periods of when these sources potentially occurred were determined using the NOAA, Atmospheric Resources Laboratories Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model (Draxler and Hess, 1997, 1998; Draxler et al., 1999) to create five day back trajectories with one hour intervals using Global Data Assimilation (GDAS) model data with 0.5 degree resolution. Ten cases were found in the data when HYSPLIT back trajectories were consistent, indicating the wind direction was from one of the four sources. These cases range from six to thirty hours in length. The Ship Channel case was sampled when the HYSPLIT showed the wind was from 45° to 135°, the Ocean case from 135° - 225°, the Semi-Urban/Rural case from 225° - 315°, and the Urban case from 315° to 45°. In total, five Ship Channel cases, three Urban cases, and two Ocean cases were identified for further analysis of the scattering properties. No Semi-Urban/Rural cases were identified during the time period of the campaign.

**Preliminary Analysis**

A technique for identifying particle type by the patterns in plotted optical properties for ensembles of sampled particle was developed by Glen and Brooks (2013). To create the patterns, or scattering signatures, the backscatter intensity and depolarization ratio are first discretized. Then the depolarization ratio is plotted on the x axis, and the backscatter intensity on the y axis. Next, the frequency of particles that have intersecting values of depolarization ratio and backscatter intensity are placed at each intersection. In Figure 2, the composite scattering signatures of all of the data from each of the three sources are shown. The color of each intersecting value indicates the percentage of particles at that intersecting value. The Ocean case has the strongest backscatter intensity, approaching 400, and is the most depolarizing. The data collected under the Ship Channel conditions (Figure 3) is slightly depolarizing but the backscatter intensity is around half of the Ocean data at around 210. The Urban data has an even lower backscattering intensity of 200 and is the least depolarizing at approximately 0.1 (Figure 3).

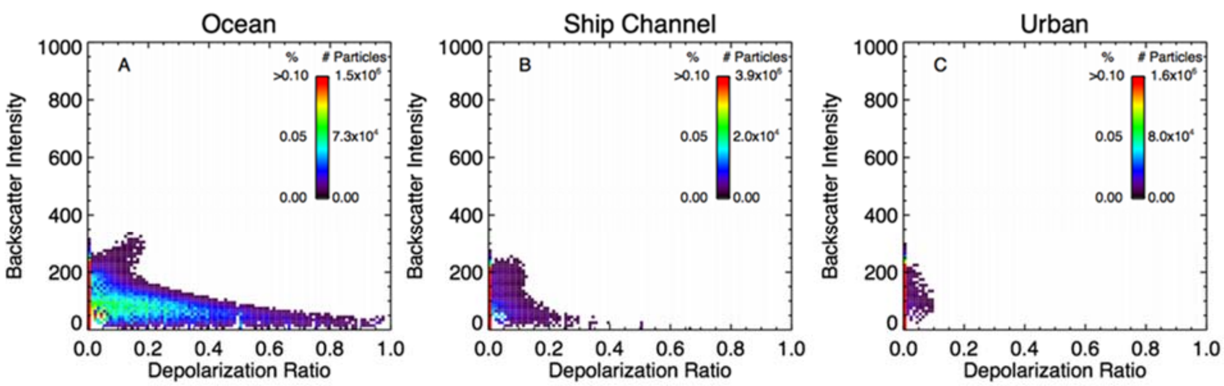


**Figure 2.** The scattering signatures for all of the data in the Ocean, Ship Channel, and Urban sources.

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## Data Collected

### Scattering Signatures from Estimated One and Eight Hours of Data

To determine the feasibility of using the CASPOL as an air quality monitoring and diagnostic tool, scattering signatures were generated using one and eight hours of data collected under each type of conditions. Being able to determine aerosol source in a short amount of time is important in providing useful air quality information. Based on the average number concentration of 94.8 $L^{-1}$ and the standard CASPOL flow rate of 1.2 L $Min^{-1}$, the number of particles that the CASPOL sampled in one hour is approximately 7,000 ± 5,500, and the number of particles that might be sampled in eight hours is approximately 55,000 ± 44,000. Scattering signatures were then created for each case using only 7,000 particles for one hour of data and 55,000 particles for eight hours of data. The estimated one hour of data was not enough to recreate the scattering signatures from the extended time period. With eight hours of data, the recreated scattering signatures are distinguishable from the extended time period data. There are some differences between the scattering signatures using the full data sets (Figure 2) and the scattering signatures generated using eight hours of data (Figure 3). Even though the estimated one hour of data is not enough data for the CASPOL to recreate scattering signatures of aerosol source, the CASPOL can still be used as an air quality monitoring tool because the estimated eight hours of data is enough to reliably determine aerosol source. Eight hours is a useful amount of time for air quality monitoring because the United States Environmental Protection Agency (EPA) uses eight hour average limits for many critical gaseous pollutants and up to 24 hour averages for particulate matter. However, the EPA monitors particulate matter by mass only. A measurement of particulate mass does not give us any information into a particles source or composition. A component based or source based monitoring of particulate matter would give better insight into the actual health effects, and the CASPOL could be used as a

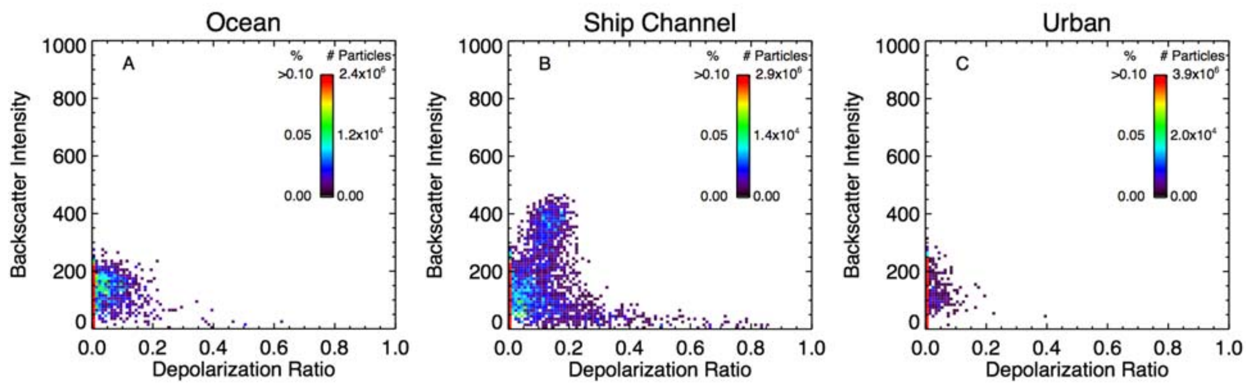


**Figure 3.** The scattering signatures for the estimated eight hours of data for the Ocean, Ship Channel, and Urban sources.

monitor of aerosol source improving the monitoring of particulate matter (Lippmann, 2008). It is also important to note that the number concentration used in these calculations seems low because it is the average of all the cases, which span many hours and conditions. Under more concentrated aerosol conditions, the CASPOL would need less time to recreate the aerosol source scattering signature accurately.

**Estimating Mass Concentrations using the CASPOL**

Particulate matter is monitored throughout the United States by the EPA in terms of a mass concentration in micro-grams per cubic meter (μg $m^{-3}$). Using the CASPOL, a mass concentration of aerosols can be estimated. To calculate $PM_{2.5}$ we summed up the CASPOL size bins from 0.5 to 2.5 μm, and for $PM_{10}$ we summed up the size bins from 0.5 to 10.2 μm because the CASPOL does not have a 10 μm size bin. Then we created volume distributions for both $PM_{2.5}$ and $PM_{10}$. To convert volume to mass, we used an assumed density of dust, 1.71 g $cm^{-3}$, and of water, 1.0 g $cm^{-3}$ to represent the upper and lower boundaries of the density of particles potentially sampled (Smettem, 2006; Hiranuma et al., 2011). Daily averaged $PM_{2.5}$ mass concentration for the month of September 2013 as estimated by the CASPOL, and organic carbon and elemental carbon $PM_{2.5}$ mass concentrations are seen in the top panel of Figure 4, and in the bottom panel of Figure 8 the daily averaged $PM_{10}$ mass concentration as measured by the CASPOL, for the month of September 2013, is shown. The red bar at 35 μg $m^{-3}$ is the US EPA maximum 24 hour average limit of $PM_{2.5}$. It is only violated three times according to the CASPOL's estimations. The EPA PM10 daily limit of 150 μg $m^{-3}$ is not violated during the time period. There is only a slight difference between the $PM_{2.5}$ and $PM_{10}$ mass concentrations which implies that the majority of the particles sampled are 2.5 μm and smaller.

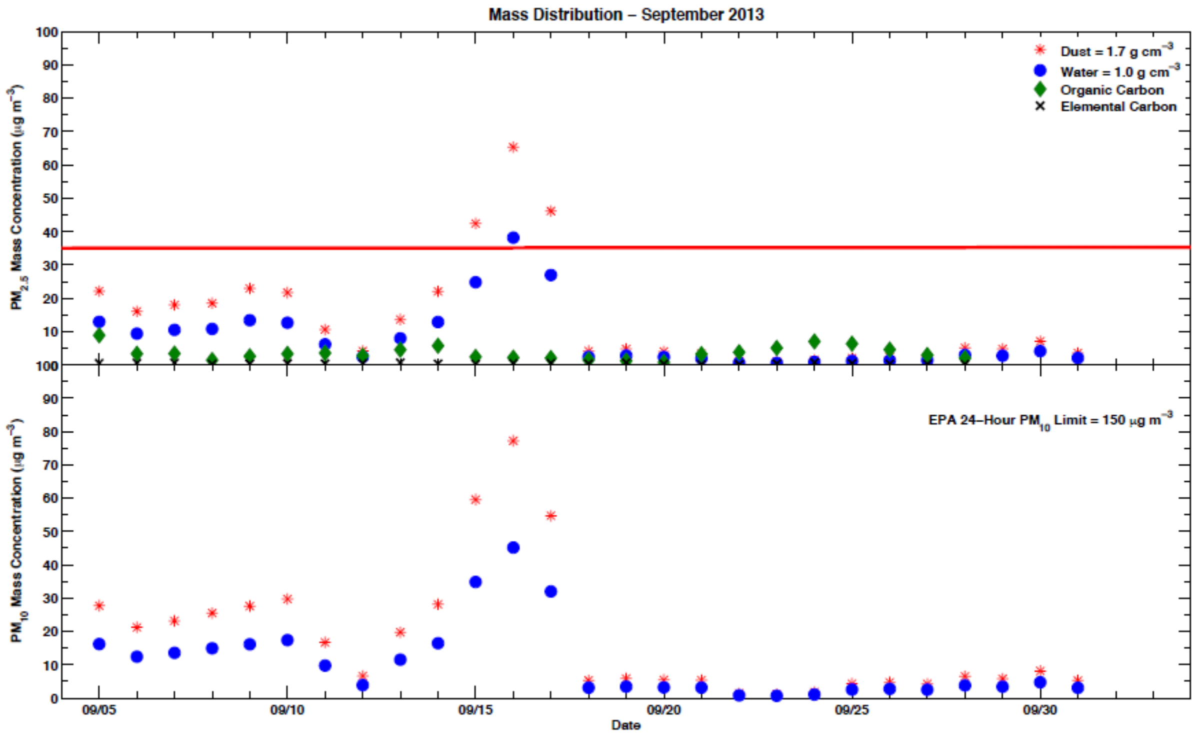


**Figure 4.** The CASPOL estimated daily averaged $PM_{2.5}$, organic carbon, and elemental carbon mass concentrations (top panel) and $PM_{10}$ mass concentrations (bottom panel) for the month of September, 2013. The density of dust and water were used as upper and lower bounds of mass respectively. The red bar represents the EPA's $PM_{2.5}$ 24-hour average limit.

The $PM_{2.5}$ mass concentration of organic and elemental carbon are similar in trend but lower in magnitude compared to the CASPOL's estimated mass concentrations throughout the first half of the month of September. On September 17, the mass concentration as measured by the CASPOL decreases drastically. After September 17, the mass concentration as measured by the CASPOL is close to the mass concentration of organic and elemental carbon for the rest of the month. Surface measurements and satellite measurements of aerosols are often in disagreement due to layers of aerosols at various heights. Layers containing high concentrations of smoke particles were detected by the High Spectral Resolution Lidar (HSRL—2) in the free troposphere which would mix in with the boundary layer as the day progressed from 09/11 — 09/14 (Burton et al., 2014; Ferrare et al., 2014). Thus the large peak and subsequent drop seen in the CASPOL mass concentration measurements could possibly be illustrating the importance layers of aerosols can have in an urban environment.

## Identify Problems or Issues Encountered and Proposed Solutions or Adjustments

None at this time.

## Goals and Anticipated Issues for the Succeeding Reporting Period

In the next reporting period, we will begin comparisons between the quality controlled CASPOL data and MODIS and CALIPSO data products. We anticipate that there will not be many periods in which CALIPSO and CASPOL are both available and CASPOL data is collected for at least 2 hours under constant source conditions.

**Detailed Analysis of the Progress of the Task Order to Date**

***Task 1 Deliverables:***
***A file has been produced for each day which contains for all quality controlled data collected that day CASPOL time, total particle number, size distribution.***

***Next, the data was classified according to source location. For each period in which the CASPOL continuously sampled under constant source conditions, a file was created containing single particle backscattering, and depolarization data, which was used to generate optical signature plots in Task 2 below.***

***Task 2 Deliverable: HYSPLIT back trajectories have been run for all quality controlled CASPOL DATA. Based on the back trajectories, all CASPOL data has been sorted into categories, i.e. urban pollution, industrial pollution from the Ship Channel, or transported aerosol. From these files, CASPOL data from has been used to generate optical signature plots (backscattering vs. depolarization) for each time period of data of 6 or more continuous hours of CASPOL data collected in a single category.***

Work on Task 3 will begin in the next reporting period.

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