AQRP Monthly Technical Report

PROJECT TITLE	**Sources and Properties of Atmospheric Aerosol in Texas: DISCOVER-AQ Measurements and Validation**	**PROJECT #** Project 14-005	Choose an item.
PROJECT PARTICIPANTS	Sarah Brooks and Ping Yang	**DATE SUBMITTED**	6/9/2014
REPORTING PERIOD	**From:** July 1, 2015 **To:** July 30, 2015	**REPORT #**	7

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.

Detailed Accomplishments by Task

-- Surveyed the previous studies on satellite retrievals of fine mode fraction (FMF).
-- Compared the Terra and Aqua MODIS FMF with CASPOL sub-micrometer fraction (SMF)
-- Completed laboratory recalibration of CASPOL aerosol particle sizing.

Preliminary Analysis

-- FMF retrievals from Aqua MODIS are very different than those from MODIS on Terra.
-- It appears that proportion of coarse particles at the noon is greater than that in the early afternoon, according to both the in-situ CASPOL data and the combined Aqua/Terra MODIS data.

Data Collected

-- No more data were collected.

Identify Problems or Issues Encountered and Proposed Solutions or Adjustments

--Further analysis regarding the differences between Aqua and Terra is needed.

Goals and Anticipated Issues for the Succeeding Reporting Period

-- Obtain AERONET aerosol size distribution retrievals and compare to the size distributions discussed here.
-- Begin writing summary of final results.

Detailed Analysis of the Progress of the Task Order to Date

Updated Analysis Strategy for MODIS Aerosol Retrievals

Two parameters available from MODIS aerosol retrievals, the size parameter (α), and the fine mode fraction, have been used to characterize urban aerosol concentration populations. In general, anthropogenic aerosols are mostly dominated by fine particles whereas natural aerosols are dominated by coarse particles [e.g. *Deuzé et al.*, 2001; *Kaufman et al.*, 2001; *Tanré et al.*, 2001], and consequently FMF retrievals have been widely used to characterize the anthropogenic component [e.g. *Bellouin et al.*, 2005; *Christopher et al.*, 2006; *Kaufman et al.*, 2005; *Ramachandran*, 2007; *Yu et al.*, 2009].

A number of studies have focused on the validations of MODIS aerosol retrievals since the first-generation MODIS aerosol algorithm [*Chu et al.*, 2002; *Remer et al.*, 2005]. The uncertainties of MODIS aerosol property retrievals stem from the applicability of retrieval assumptions in different environments, including assumed spectral dependence of surface reflectivity and aerosol models. Previous quality assessments of MODIS α and FMF retrievals have been made through comparisons with ground-based or airborne sun-photometer retrievals [e.g. *Anderson et al.*, 2005a; *Chu et al.*, 2005; *Kleidman et al.*, 2005; *Remer et al.*, 2005]. Historically, literature results report a poor correlation between MODIS Collection 5 aerosol size retrievals and sun-photometer FMF retrievals over land. Over oceans, MODIS appears to overestimate low values of FMF and underestimate high values of FMF. Based on these comparison studies, *Levy et al.* [2010] concluded that the MODIS Collection 5 aerosol size retrievals show noteworthy uncertainties and hence have little physical validity in a quantitative sense. However, an updated MODIS data set, Collection 6, has become available more recently. [*Levy et al.*, 2013]. Also, the spatial resolution of aerosol retrievals in MODIS Collection 6 is km, a major improvement over the previously 10 km resolution [*Igel et al.*, 2013]. To the best of our knowledge, no study has compared MODIS Collection 6 MODIS FMF retrievals with aerosol size distribution measurements collected in-situ. Here we compare the MODIS FMF retrievals with CASPOL aerosol size distribution measurements in the Houston urban area during DISCOVER-AQ campaign in 2013.

IN-Situ CASPOL DISCOVER-AQ Aerosol Measurements

As discussed in our previous reports, the Cloud and Aerosol Spectrometer with Polarization (CASPOL) is a new optical particle counter developed by the Droplet Measurement Technology, Inc. (DMT) and calibrated in the laboratory [*Glen and Brooks*, 2013; 2014]. This instrument measures the particle-by-particle optical properties of aerosols. The forward scatter intensity, measured by the detector in the forward direction, is used to derive the size distribution of particles within 28 bins from 0.68 μm to 30 μm in diameter based on the Mie scattering theory. In addition, two detectors are used measure the parallel and perpendicularly polarized backscatter radiation. The size range covers the cut-off point of ~1 μm that is often adopted to discriminate fine and coarse aerosol particles [*Anderson et al.*, 2005b]. Thus, the ratio of the concentration of particles smaller than the cut-off to the total concentration can characterize the proportion of fine particles. For the purposes of this study, we define this as the CASPOL submicrometer fraction, SMF, following the similar naming by *Anderson et al.* [2005a]. (Specifically, the CASPOL bin boundaries closest to 1 μm are 0.96 μm and 1.03 μm, and we therefore average the two values as the cut-off to calculate SMF.)

The 2nd intensive DISCOVER-AQ campaign took place over the Houston area in the late summer and early fall of 2013. One of the missions of the campaign was improved interpretations of satellite observations with regard to air pollutants. During the field campaign, CASPOL was put on the Moody Tower (29.7176° N, 95.3414° W) for measurements from 15 August to 2 October in 2013, providing a chance to compare the CASPOL in-situ aerosol measurements with satellite aerosol retrievals. The Moody tower has been the location of a number of previous field campaigns [*Brooks et al.*, 2010; *Lefer et al.*, 2010; *Rappenglück et al.*, 2010; *Wong et al.*, 2011]. The height of the Moody tower is about 70 meter. It is low enough so 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.

DISCOVER-AQ was the first field deployment of CASPOL since it was designed and built by DMT. Following a period of successful data collection, the CASPOL experienced a serious drop in observed concentration on 17 September, 2013. A plausible cause was an (unspecified) instrumental issue in the CASPOL at that time. Hence, we removed the data later than September 17. Recent laboratory calibration indicates that the CASPOL is once again working well and accurately counting and sizing aerosols. Hence, we tentatively conclude that the problem experienced in the field was related to a blockage in the CASPOL inlet tubing, rather than an issue in the instrument itself. As a consequence, only the CASPOL measurements during 5-17 September are included in this study.

MODIS-CASPOL Intercomparison

Based on observations of bimodal aerosol size distributions, in the MODIS aerosol algorithm over dark continental surfaces, a combination of fine-dominated and coarse-dominated aerosol models are assumed. Aerosol populations are assumed to be bimodal with a coarse mode assumed to be dust and a fine mode with characteristics defined according to location and season. The fine-dominated model choices include three spherical aerosol models whose absorbance levels are different, representing weakly, moderately, and strongly absorptive aerosols. Consequently, the fine mode was identified as weakly absorptive aerosols for the duration of the DISCOVER-AQ project over the Houston area in September, 2013. Table 1 listed the size parameters of the weakly absorptive fine model and the coarse model in the MODIS aerosol algorithm, where r_v, σ, and V_0 are median radius, standard deviation, and volume concentration, respectively.

Table 1. Size parameters of the weakly absorptive fine model and the coarse model in the MODIS aerosol algorithm [*Levy et al.*, 2009].

	Fine model (weakly absorptive)		Coarse model	
	Accumulated	Coarse	Accumulated	Coarse
Mean Radius, r_V(μm)	$0.0434\tau+0.1604$	$0.1411\tau+3.3252$	$0.1416\ \tau^{-0.0519}$	2.2
Standard Deviation in radius σ(μm)	$0.1529\tau+0.3642$	$0.1638\tau+0.7595$	$0.7561\tau^{0.148}$	$0.554\ \tau^{-0.0519}$
Volume concentration (V_0)	$0.1718\ \tau^{0.8213}$	$0.0934\ \tau^{0.6394}$	$0.0871\ \tau^{1.026}$	$0.6786\ \tau^{1.0569}$

Fig. 1 shows the volume size distributions of the fine (weakly absorptive) and coarse models in the conditions of $\tau = 0.2$, 0.8, 1.4, and 2.0, The vertical dashed black line corresponds to a radius of 0.5 μm. The peaks of the coarse model are at a radius 2.2 μm. The peaks of the fine model vary between 0.1 μm and 0.5 μm. Note that ~ 0.5 μm in radius is also a division between the assumed fine and coarse particles in the MODIS aerosol algorithm, in agreement with the CASPOL submicron fraction cut-off chosen above.

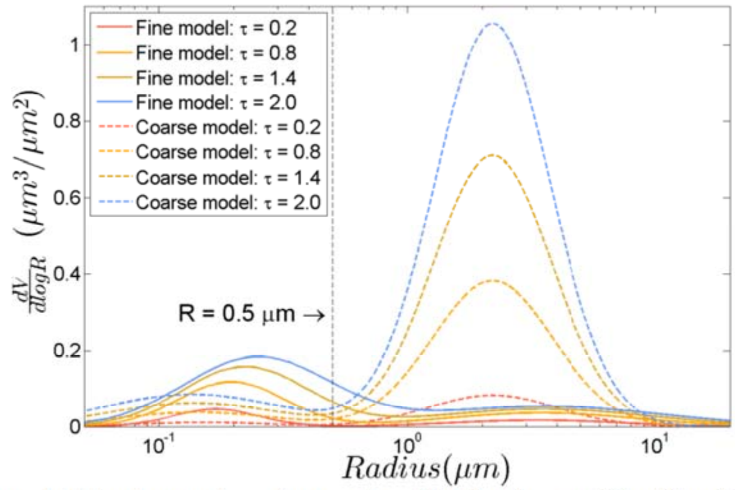

Figure 1. The dynamic volume size distributions of the fine (weakly absorptive) and coarse (dust) models in the conditions of different AODs in the MODIS aerosol algorithm.

MODIS FMF is defined as the proportion of the spectral reflectance contributed by the fine aerosol model [*Levy et al.*, 2010]. We compared MODIS FMF retrievals with CASPOL η measurements during the campaign. Specifically, The 3-km FMF retrievals from the Terra and Aqua MODIS Collection 6 were used in this study. Terra and Aqua, two polar-orbiting satellites, carry MODIS. In the daytime, Terra passes the Houston area around the noon and Aqua passes the same area in the early afternoon.

For example, Fig. 2 shows the monthly mean distributions of FMF retrievals from Terra and Aqua over southeast Texas in September, 2013. In each panel, the red circle is centered at the Moody Tower with a radius of 50 km. We averaged the available FMF retrievals within the circle for the comparisons with CASPOL η measurements. The monthly mean area-averaged FMF from Aqua MODIS outnumbers that from Terra MODIS. They are 0.63 and 0.19, respectively.

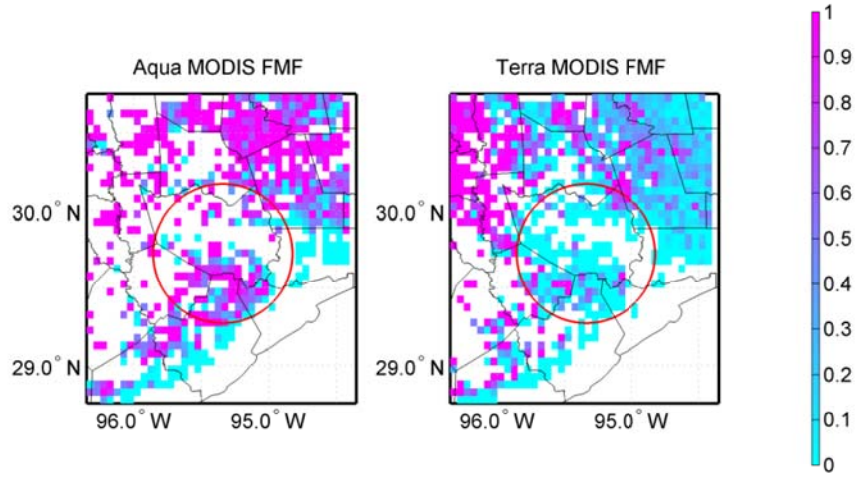

Figure 2. The monthly mean Aqua (left panel) and Terra (right panel) MODIS FMF distributions in September 2013 over an area from 28.75° N to 30.75° N and from 96.35° W to 94.35° W. The red circle in each panel is centered at the Moody Tower with a radius of 50 km. It is not known why the Aqua and Terra monthly average fine mode fractions are remarkably different in the same area.

During the period when CASPOL sampling, we found 7 Aqua and 6 Terra MODIS FMF retrieval cases. For each case, we counted the particles sampled by CASPOL as to their sizes 30 minutes before and after the satellite overpassing time. The aerosol number size distributions measured by CASPOL for all the 13 cases are plotted in Fig. 3. The vertical dashed black line marks R = 0.5 µm. As shown in Fig. 3, the proportions of coarse particles for the Terra cases are higher than those for the Aqua cases, suggesting that the concentration of aerosols increased between noon (when Aqua passes over the site) and 3 pm (when Terra overpasses the site). This is qualitatively consistent with the differences between the Aqua and Terra monthly averages in Fig. 2 above.

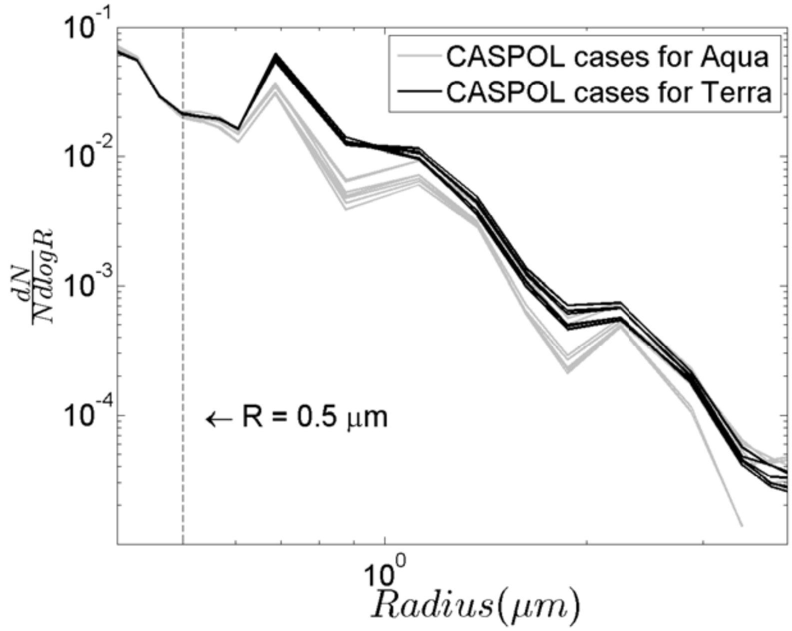

Figure 3. The normalized number size distributions from CASPOL measurements for the 7 Aqua and 6 Terra comparison cases.

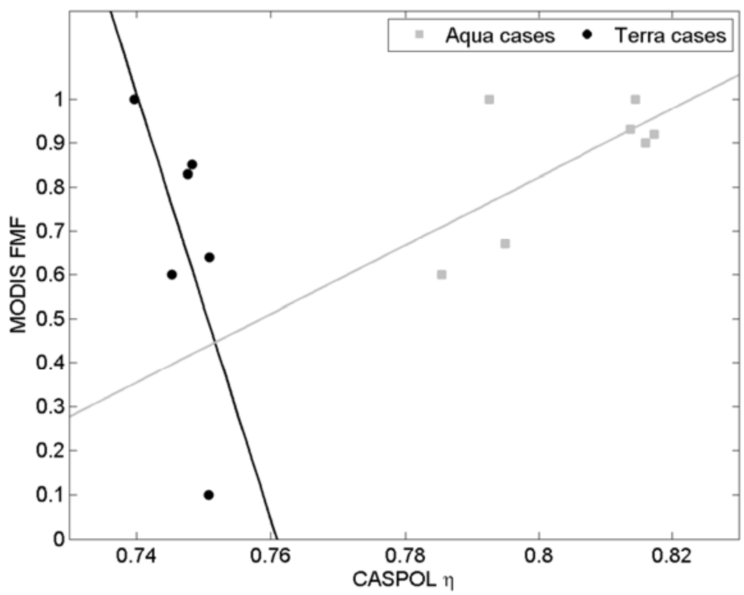

Figure 4. CASPOL Submicron Fraction SMF (η) vs. MODIS Fine Mode Fraction. The lines are the linear regressions.

A summary of the CASPOL submicron fractions and the coincident MODIS fine mode fraction for each point in time is shown in Figure 4. If the Aqua and Terra data sets are taken together, then one would report qualitative agreement between in-situ CASPOL submicron mode fraction and the fine mode fraction derived from satellite. However, the largest differences are those between Aqua and Terra observations. We are currently exploring future explanations for these very large differences. Additional information is needed before we can finalize conclusions regarding this Intercomparison.

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