#### 1.12 AEROSOL PROFILING IN THE WASHINGTON-BALTIMORE URBAN CORRIDOR: A REALM APPLICATION

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#### 1. INTRODUCTION

There are now approximately twenty atmospheric lidars in operation in North America, many of which are routinely gathering data on tropospheric aerosols. Unlike a recent European concentrated effort at networking such lidars (EARLINET; Bösenberg et al., 2002), the United States and Canada have, to date, only provided small support and encouragement to undertaking a similar network of such systems on this continent. Encouraged by a recent NOAA Center for Remote Sensing Science and Technology (CREST) grant, a number of eastern U.S. and Canadian researchers have agreed to begin collaboration on a Regional East Atmospheric Lidar Mesonet (REALM). At this point, many of the collaborators are unfunded and are seeking individual support for the effort.

This paper will describe some of the systems available for REALM and show an example of two events over the summer of 2003 where the placement of such a network would provide benefit for satellite validation, for monitoring large-scale urban and regional hazes and for model verification. With the focus of this AMS meeting directed to forecasting, it is apparent that such a network would have significant value to verification of aerosol predictions in the future.

#### 2. THE REALM SYSTEMS

REALM is an opportunistic collaboration of lidar researchers at a number of eastern U.S. and government Canadian universities and laboratories. The placement of the systems within REALM has few design features other than the spatial discreteness of the researchers themselves. The fact that there is a significant coverage of the eastern half of the continent may be indicative that the researchers keep their distance from each other. Figure 1 shows the laboratories that have offered to provide data to

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REALM when available. Table 1 gives the location of the lidar, its PI and the type of system.

The lidar systems in the network are not uniform in frequencies, target species or products and, therefore, often will require some interpretation to intercompare. As a preliminary step, lidars that derive aerosol backscatter coefficient at one of the three wavelengths of Nd-YAG (1064 nm, 532 nm, or 355 nm) will be verified in the network. We are in the midst of a first round algorithm verification for REALM, similar to the European round robins performed for EARLINET (Böckmann et al., 2004; Matthias et al., 2004)



Figure 1: Location of the REALM lidars.

TABLE 1

REALM LIDAR SYSTEMS		
Location	PI	Type(s)
Egbert, ON	K.I. Strawbridge	Scanning elastic
Durham, NH	I. Dors	Winds
Halifax, NS	T. Duck	Elastic, Raman
New York, NY	S. Ahmed	Elastic, DIAL
State College,	C.R. Philbrick	Raman, DIAL
PA		
Baltimore, MD	R.M. Hoff	Elastic, Raman
Greenbelt, MD	D.N. Whiteman	Raman
Greenbelt, MD	D. Venables	Raman
Hampton, VA	M.P. McCormick	Elastic
Huntsville, AL	M. Newchurch	DIAL
Atlanta, GA	G. Gimmestad	DIAL

#### 3. REALM ACTIVITIES

#### 3.1 Algorithm Evaluation

The ability to combine data from disparate systems in the network will involve convergence on common hardware and software tools to process lidar data. This conclusion is based on the experience in EARLINET where certain lidar systems (elastic systems in particular) had serious limitations in the quantitative nature of the results obtained.

In order to determine the degree of reliability of the retrieval algorithms used by groups in REALM, we have begun an algorithm intercomparison based on synthetic data of varying complexity. This is a similar test to one conducted in EARLINET (Böckmann et al., 2004). This test began in November 2003 and is expected to be completed in February 2004.

#### 3.2 System Intercomparison

One of the most useful tests conducted in EARLINET was the use of mobile lidar systems to conduct pair-wise profiling between two of the systems in their network, one of which was mobile and effectively became a transfer standard. In early 2003, the GSFC Scanning Raman Lidar was co-located at UMBC for such an intercomparison study. Initial results from the measurements were very instructive showing the highly different noise levels seen by the more mature GSFC Raman system and the relatively novel UMBC Raman lidar. At the same time, the UMBC elastic lidar svstem (ELF: Comer, 2003) was used to determine the relative merits of a 532/1064 nm lidar and one operating at the more opaque wavelength of 355 nm.

An intention of the REALM network is to expand this pairwise intercomparison using mobile systems such as the MSC, GSFC SRL or CCNY mobile systems to profile coincidently with fixed systems. These comparisons are likely to occur during major field intensive campaigns where the lidars are at other locations in the region.

#### 3.3 REALM WebLog

A REALM weblog (blog) has been created at UMBC at the site (<u>http://alg.umbc.edu/usaq</u>). This log is designed to track daily changes in the air quality in the Mid-Atlantic States. The imagery from the MODIS instruments on the TERRA and AQUA satellites is obtained in near real time from a link to the University of Wisconsin MODIS direct

downlink facility and the data granules are transferred to UMBC as part of a collaboration sponsored by NOAA. The daily forecast by UMBC students is used to plan lidar profiling sessions for either the elastic aerosol system or the water vapor profiling Raman lidar. UMBC crosssectional lidar data are posted to the log daily.

The log also allows hot links to the websites of other REALM contributors and will pull changing data from daily postings at those sites. It is expected that this weblog will be useful to state and local air quality managers who want to understand the regional air quality context in which they find themselves. One of the critical decisions for such air quality managers is whether high levels of pollution are locally generated or as a result of a transport event. The ability to combine the spatial discrimination of a spaceborne imager, such as MODIS, and vertical profiling of lidar systems in a wide region, provides such contextualization.

# 3.4 Example of a Haze Event from a Remote Source

In June, 2003, the UMBC elastic lidar system was being operated in support of a validation experiment for the Advanced Infrared Radiometric Sounder (AIRS) at Chesapeake Lighthouse (36°54.6' N, 75°42.6' W). Figures 2 and 3 show the morning and afternoon ELF Lidar profiles for the two MODIS overpasses (TERRA and AQUA). AIRS is carried on the AQUA satellite. The color scale is proportional to the aerosol backscatter coefficient at 532 nm and the vertical extent of the sounding is 15 km.



Figure 2: 0700-0900 UTC June 2, 2003 Lidar backscatter coefficient



Figure 3: 13:34-19:29 UTC June 2, 2003 Lidar Backscatter Coefficient at Chesapeake Light

The layer of aerosol at 3 km persisted for most of the day on June 2 and was moderately hazy. Optical depths reported by the AERONET sunphotometer at the site were 0.34. Both MODIS and the Total Ozone Mapping Spectrometer (TOMS; Torres et al, 2002) saw a widespread haze layer over the Mid-Atlantic States. The MODIS aerosol optical depth is shown in Figure 4.

It appears that the MODIS optical depth retrievals may have underestimated the optical depth over the water or, vice-versa, overestimated them over the land surface since the visual image of the event doesn't show as strong a land/sea contrast as does the optical depth product.



Figure 4: MODIS Aerosol Optical depth product (MOD04) showing optical depths of >0.6 inland and  $\sim 0.3$  over the water off Virginia.

It would be tempting at ascribe this event to another hazy day in Maryland but back trajectory information (Peter Colarco, GSFC, private communication) indicates that the source of the aerosols was distant. The haze plume seen in the Mid-Atlantic States can be tracked back to a position west of Hudson's Bay on May 29, 2003. There is conjecture that this plume originated from a very large group of forest fires in Siberia in mid-May. There are other pieces of information from TOMS and from the lidar depolarization that support this conclusion.

#### 4. A HAZY DAY IN MARYLAND

On October 13, 2003, the UMBC ELF lidar had been back in operation at the UMBC campus in Baltimore for over a month when a significant urban haze event occurred. Figure 5 shows the three-hour time series of aerosol in the lower boundary layer near sunset.



Figure 5: A well-structured boundary layer haze with optical depth greater than 1 at UMBC.

The HYSPLIT trajectory (Figure 6; courtesy NOAA ARL) for this evening showed that the flow was down the eastern seaboard from the megacity to the northeast.

## 5. POTENTIAL FOR MONITORING THE URBAN MEGACITY

The use of the name "mesonet" in REALM was inspired by the concept of monitoring mesoscale features in the aerosol from a number of lidars operating on that scale. Within REALM, we have lidars at Greenbelt, MD, (both GSFC and Howard University lidars have expressed interest in cooperating in REALM), Baltimore, MD, Philadelphia and New York City. This corridor is one of the most intensively populated areas in the US. Since the flow is often southwesterly over these sites, the potential exists for examining the evolution of the urban megaplume over a 12-36 hour Lagrangian transport timescale.





Figure 6: HYSPLIT 500m, 750m and 1000m trajectories arriving at UMBC at 00UTC on 12 October 2003. The trajectories were northeasterly and passed over the urban megalopolis to our northeast.

NOAA has expressed initial interest in REALM and is providing some funding for three of the REALM partners via the Center for Remote Sensing Science and Technology (CREST; http://icerd.engr.ccny.cuny.edu/noaa/fact.html).

Howard University is additionally funded via the NOAA Center for Atmospheric Sciences (http://epp.noaa.gov/programs/?ID=2).

The USEPA and NOAA recently signed a memorandum of understanding to commit to forecasting ozone and  $PM_{2.5}$  by 2008 and 2013, respectively. Validation of the models that will be part of this forecast system will require knowledge of the vertical extent of these predicted contaminants. REALM provides an effective tool for such validation at a cost that is minimal compared to aircraft sorties that are the only other effective means of obtaining such profiles.

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