5.3 REALM LIDAR OBSERVATIONS DURING THE INTEX/NE-NEAQS STUDY PERIOD

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1. INTRODUCTION

During the summer of 2004, two major field programs were carried out on the US east coast, the Northeast Air Quality Study (NEAQS) under NOAA sponsorship and the Intercontinental Transport Experiment (INTEX-NE), under NASA sponsorship. We describe here a series of lidar observations which were coincident with these study periods and which were taken as part of measuring program of the Regional East Atmospheric Lidar Mesonet (REALM).

In June 2004, lightning strikes ignited severe fires in the areas around Kitimat, British Columbia, further north in the Yukon and through eastern Alaska. The fires near Fairbanks, Alaska, endangered wide areas of populated areas, burned 50 homes and covered much of Fairbanks in deep ash (K. Sassen, private communication). As a matter of scale, Alaska had 25,000 km^2 in fire this year and the Taylor Complex fire alone was 5,260 km^2 in area, twice the area of all the 2003 Southern California fires combined. The Alaska fires comprised 86% the fire area of the US up to September 1.

We followed the fire plumes from these fires for most of the months of June-August on the USAirQuality weblog (http://alg.umbc.edu/usaq). Guidance was given to the flight planners of the INTEX-NE and NEAQS experiments to help daily mission plans and aircraft altitudes.

2. THE REALM SYSTEMS

REALM is an opportunistic collaboration of lidar researchers at a number of U.S. and Canadian universities and government laboratories. Figure 1 shows the laboratories who have offered to provide data to 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) are being accepted in the network.

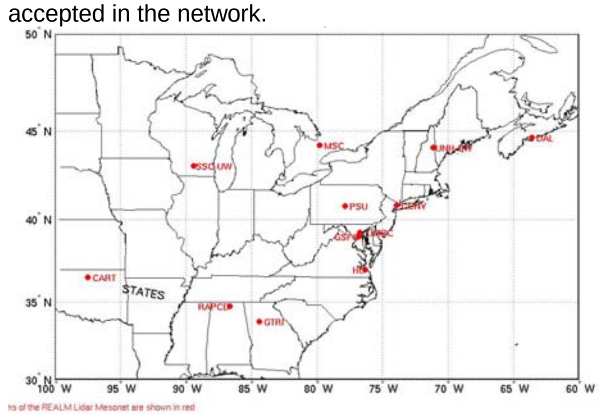

Figure 1: Location of the REALM lidars.

TABLE 1
REALM LIDAR SYSTEMS

Location	PI	Type(s)
Egbert, ON	K.I. Strawbridge	Scanning elastic
Durham, NH	I. Dors	Winds
Halifax, NS	T. J. Duck	Elastic, Raman
New York, NY	F. Moshary	Elastic, DIAL
State College, PA	C.R. Philbrick	Raman, DIAL
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
Madison, WI	E.W. Eloranta	HSRL
Lamont, OK	T. Ackerman	Raman

REALM lidar quicklook data are available for the public on the REALM Data Center website. (http://alg.umbc.edu/REALM/RDC/). The intent of the site is to provide the ability to access images which show aerosol features of interest and then to have the public contact the Principal Investigator of that site for further information and permission to use those data publicly.

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3. JULY 21, 2004 OBSERVATIONS

The plume from the Alaskan fires impacted the east coast for much of the summer. On the 21st of July, however, a significant plume of material covered much of the mid-Atlantic and northeastern US. Figure 1 shows the MODIS TERRA RGB (visual) images of the northeast and Figure 2 shows the MODIS aerosol optical depth.

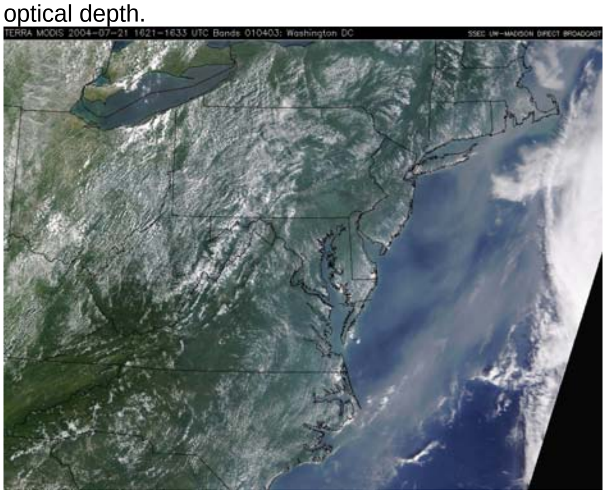

Figure 1: MODIS RGB image of the smoke pall over the northeast on July 21, 2004.

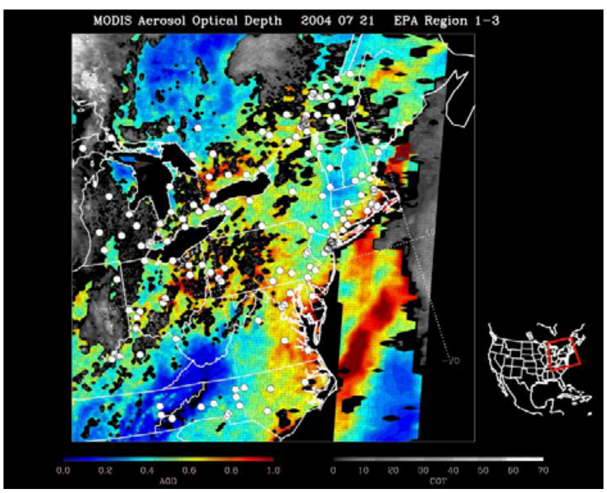

Figure 2: MODIS aerosol optical depth (red indicates τ_a >1.0) for the morning of July 21, 2004. Courtesy IDEA, University of Wisconsin.

Figure 3 shows the lidar results in Baltimore for the morning and afternoon of July 21. The downward movement of smoke into the boundary layer caused us to look at the surface levels of $PM_{2.5}$ in Baltimore. Figure 4 is the time series of $PM_{2.5}$ at the Maryland Department of the Environment monitoring station at Old Town, MD.

On July 21, the fires caused an increase of $PM_{2.5}$ in Baltimore which nearly put the city out of exceedance for $PM_{2.5}$. In a more detailed analysis that will be presented in the oral version of this paper, we will show that the optical depth seen by MODIS is in excellent agreement with lidar derived optical depth when the aerosol below the boundary layer is treated as well mixed to the surface.

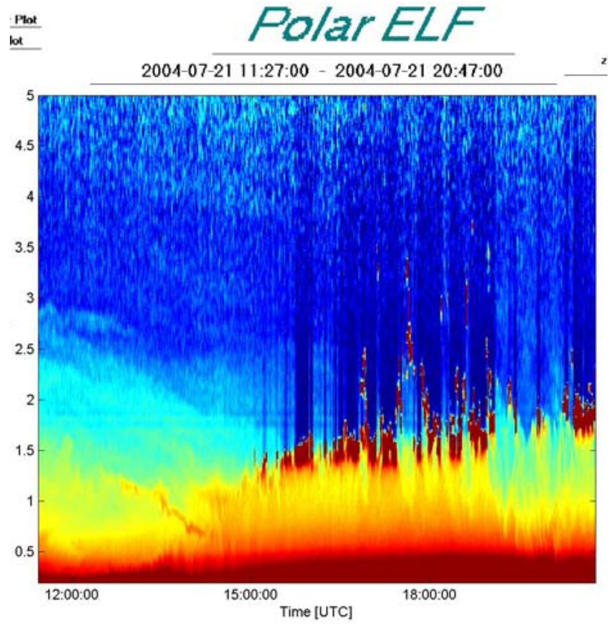

Figure 3: UMBC lidar profile of aerosol backscatter (left axis: km). The figure shows descent of aerosol from above the nighttime boundary layer interacting with the daytime boundary layer at 14:00 UTC (10:00 AM local time)

Figure 4: 96-hour back trajectories from UMBC and CCNY from July 21, 2004 and 96-hour back trajectory from Madison, WI, from July 19. All trajectories start at 3km altitude. The direction of the trajectories are consistent with smoke derived from the Alaska-Canadian fires. Trajectory endpoints courtesy NOAA HYSPLIT.

Figures 5 and 6 show coincident data taken at CCNY in New York City and in Madison, W. Figure 5 shows the lidar backscatter and depolarization on July 19,2004, two days earlier when the smoke was passing over that site. Figure 6 shows the same smoke plume over New York City seen in the CCNY lidar system. We believe that this is the first observations which demonstrate multiple lidar observations across the North American continent from coordinated lidar systems. Such observations have occurred in Europe with the EARLINET systems (Bosenberg, 2002) but this capability is now being demonstrated in North America.

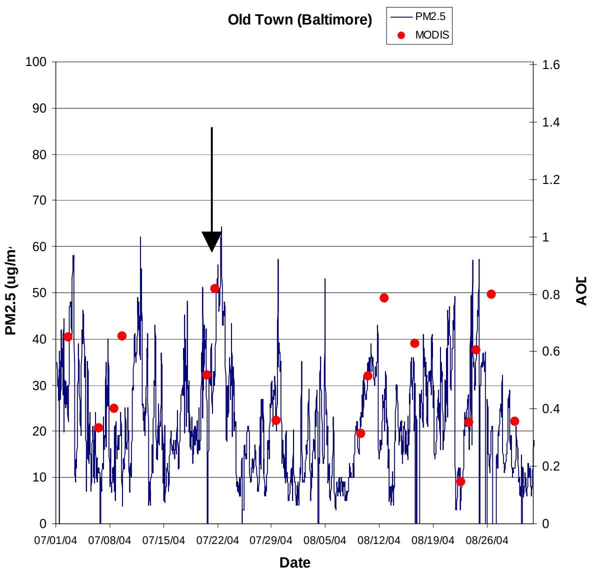

Fig. 4 - PM2.5 (line) and MODIS AOD (red dots) from IDEA product (Al-Saadi et al., 2004). The arrow points to the June 21 data discussed here.

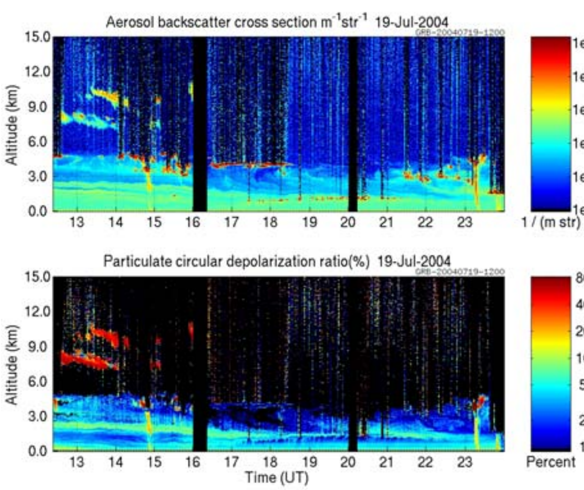

Figure 5a: Morning particulate backscatter crosssection (top) and particulate depolarization (bottom) at Madison WI on July 19, 2004 from the Arctic HSRL Lidar. Material above 2 km is smoke which advected eastward to reach NY and MD on 7/21.

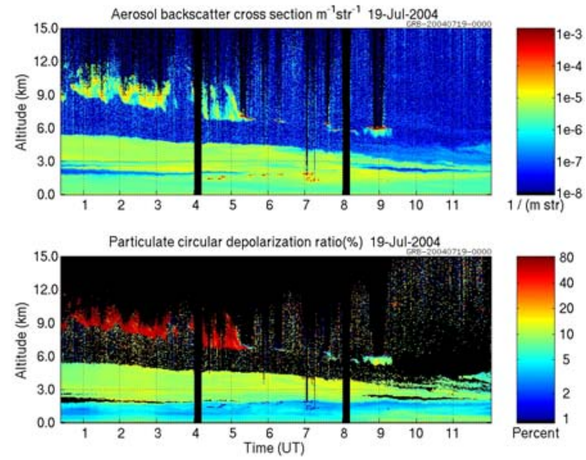

Figure 5b: Evening particulate backscatter crosssection (top) and particulate depolarization (bottom) at Madison WI on July 19, 2004 from the Arctic HSRL Lidar. Material above 2 km is smoke which advected eastward to reach NY and MD on 7/21.

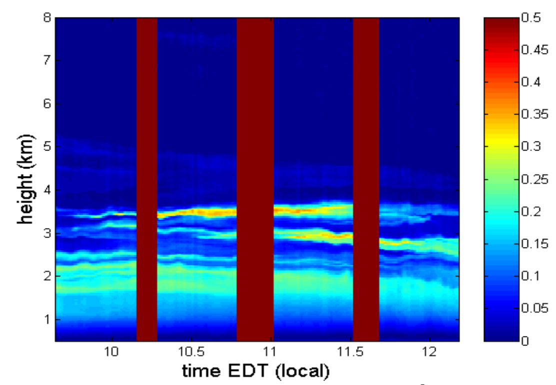

Figure 6: Particulate extinction data (km^{-1}) from the CCNY lidar in New York City on July 21, 2004, showing elevated smoke plumes at 2-4 km. A lidar ratio of S_a = 80 was assumed in deriving this data.

4. July 12, 2004

It is an unfortunate but common fact that one or more REALM sites are precluded from observations by clouds when other sites are making measurements. On the case shown in section 3, the Dalhousie University site at Chebogue Point, Nova Scotia, was obscured by clouds and low fog for much of the day. On July 12, 2004, however, smoke was observed to 4.5 kilometers altitude at the Dalhousie site, while much of the rest of the east was obscured by a large system to the south.

Figure 7 shows the Dalhousie University lidar scattering ratio profiles for July 12.

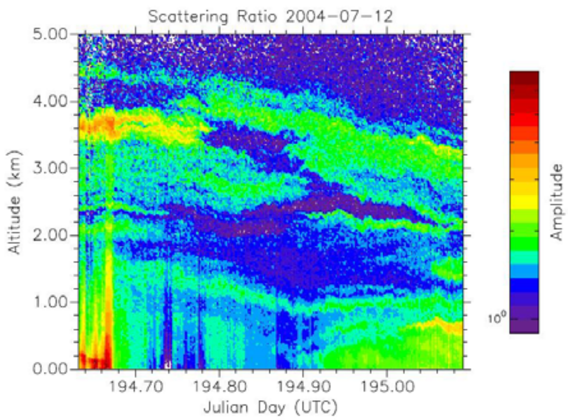

Figure 7: Lidar scattering ratio at Chebogue Point, Nova Scotia on July 12, 2004. The scattering ratio $R=\beta_a/\beta_r - 1$ where a,r refer to aerosol and Rayleigh components of the scattering.

5. CONCLUSION

There are now thirteen atmospheric lidars in operation in North America that have agreed to contribute to REALM. During the INTEX-NE and NEAQS period in 2004, four sites routinely gathered 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). This paper shows such synergy in the use of lidar and satellite assets to evaluate long-range transport of aerosols. The forest fire plumes from Alaska and the Yukon were a convenient and obvious aerosol target for study.

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.

5. REFERENCES

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Bösenberg, Jens et al., 2002: EARLINET: Establishing the European Aerosol Research Lidar Network, *Proceedings Lidar Remote Sensing in Atmospheric and Earth Science,* Eds. Luc R. Bissonnette, Gilles Roy, and Gilles Vallee, Defense Research Board Valcartier, publ., Quebec City, Quebec, Canada, pp. 293-296.

6. ACKNOWLEDGEMENTS:

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