Regional East Atmospheric Lidar Mesonet: REALM

Raymond M. Hoff, Kevin J. McCann, Belay Demoz, Jens Reichardt
Joint Center for Earth Systems Technology (JCET)
and the NOAA Center for Remote Sensing Science and Technology (CREST), UMBC
1000 Hilltop Circle, Baltimore, MD, USA
Tel :410-455-1610 Fax : 410-455-1291
Email : hoff@umbc.edu

David N. Whiteman and Tom McGee
NASA Goddard Space Flight Center
Greenbelt, MD

M. Patrick McCormick
NOAA Center for Remote Sensing Science and Technology (CREST), Hampton University
Hampton, VA

C. Russell Philbrick
Department of Electrical Engineering, Penn State University
University Park, PA

Kevin Strawbridge
Meteorological Service of Canada, Center for Atmospheric Research Experiments (CARE)
Egbert, Ontario, Canada

Fred Moshary, Barry Gross and Sam Ahmed
NOAA Center for Remote Sensing Science and Technology (CREST),City College of New York
New York, NY

Demetrius Venable and Everette Joseph
NOAA Center for Atmospheric Science, Physics Department., Howard University
Washington, D.C.

ABSTRACT

A proposed Regional East Atmospheric Lidar Mesonet (REALM) is described. Building from the research capabilities already established at a number of Eastern North America lidar facilities, a coordinated mesonet is now possible. This paper will outline the facilities available through the mesonet, the routine observing schedule currently in use, and potential applications of the mesonet for upcoming studies.

1. INTRODUCTION

Unlike recent European successes in networking lidar systems (TOR, EARLINET), little coordination of North America lidar capabilities has evolved. This is believed to be largely due to the multi-agency funding and varied research goals for U.S. and Canadian lidar facilities, which includes climate change research, ozone attainment goals, PM2.5/PM10 attainment goals, investigations of the physics of optical scattering, etc. The funding agencies are diverse for these applications and campaign style use of the systems has been the norm over the last twenty years. There has been no significant funding for long term continuous measurements from surface based lidars other than those for the stratosphere (NDSC).

This paper describes a proposal by a number of lidar researchers to form a loose confederation of lidar facilities

under the aegis of a program called the Regional East Atmospheric Lidar Mesonet (REALM). Funding for parts of the program has been made available from a pair of NOAA sponsored centers, the Center for Atmospheric Sciences (CAS) based at Howard University, and the Center for Remote Sensing Science and Technology (CREST) based at City College of New York. CCNY, Hampton University, and UMBC are partners in CREST.

The future of the REALM is based on contributions from the user community who see its potential in campaign or long-term research studies on aerosols, climate, water vapor, and ozone. Proposals from REALM partners will be submitted to agencies such as NASA and EPA as research opportunities arise. There is no core funding for the effort and it is truly a collaboratory of lidar researchers interested in making something larger occur than they could individually bring to a project. Other lidar researchers are invited to become members of REALM.

2. CAPABILITIES

Lidar systems in REALM are expected to deliver (at minimum) lidar backscatter ratio at the fundamental or on of the harmonics of the Nd-YAG laser. Systematization of processing for extinction retrievals will be a task for the Raman systems. Water vapor retrievals and ozone retrievals are level two products and are not expected to be available at all sites. All systems are zenith pointing unless otherwise noted. Currently, 13 active lidar systems and 6 planned systems are available to the REALM. Sites for the REALM lidars are shown on Figure 1.

a. UMBC

The lidar groups associated with JCET and CREST at UMBC work in the Physics Department and in collaboration with Goddard Space Flight Center scientists. Systems include:

1. ALEX – the atmospheric lidar experiment, a Raman H_2O and aerosol extinction Raman lidar with a Continuum 9030 source and 14" Celestron telescope detection system (Wooten et al., 2002)
2. ELF – the elastic lidar facility, a Continuum Surelight 532/1064 elastic system with detection system similar to one previously run in Canada (Hoff et al., 1996)
3. UAWL – UMBC Atmospheric Water vapor Lidar, a 32" astronomical telescope facility with a Surelite laser mounted on the optical mount (scanning system, currently under construction).

b. GSFC

Four ground-based systems are available for REALM:

1. EXCITES – a multi-wavelength polarization Raman lidar for measurements of, cloud optical properties, water vapor and temperature (Reichardt et al., 2002)
2. SRL: the Scanning Raman lidar (Whiteman et al., 1999) measurements can be acquired at low angles with respect to the horizon to enable retrievals of aerosol extinction near the surface.
3. 9-Channel 355, 532, 1064 - backscatter, 387, 607 extinction, 402 liquid water, 407 water vapor, 355 parallel and perpendicular polarization currently under development.
4. STROZ-LITE – The STROZ-LITE system has been actively acquiring data since 1988 (Gross, 1997). It is a mobile lidar instrument housed in a forty-five foot trailer. This system is capable of making vertical profile measurements of ozone, atmospheric temperature, and aerosols. This instrument is a primary instrument within the International Network for the Detection of Stratospheric Change, and is part of the UARS Correlative Measurements Program.

c. CAS/Howard University

Howard University's Beltsville, MD Research Campus currently has available a non-coaxial ground based lidar system. This system is designed primarily to measure lower tropospheric ozone and is based on Raman scattering from atmospheric oxygen, nitrogen and water vapor. The single channel system utilizes a KrF excimer laser, a Beckman prism spectrometer, and a scanning 30" astronomical telescope. A new system is also being constructed at the site. This will be a multichannel system and will be based on a multi-harmonic Nd:YAG laser, traditional photon counting electronics, and a zenith pointing telescope.

d. Penn State

Four lidar systems have been developed at Penn State University and are used by graduate students for their investigations. They have been the focus for the research projects in 37 graduate degrees and about 100 papers and reports during the past 10 years. The lidar instruments are:

1. LAPS (Lidar Atmospheric Profile Sensor) measures the water vapor, temperature, optical extinction at 3 wavelengths and ozone profiles using rotational and vibrational Raman techniques. Use of the "solar blind" ultraviolet wavelengths provides measurements during both night and day conditions.
2. LAMP(Laser Atmospheric Measurements Profiler) was developed in 1990 with two sets of detectors to emphasize the higher (stratosphere and mesosphere) and lower (troposphere) regions and it has been used for several

investigations; both Raman techniques at lower altitudes and high altitude temperature techniques (to 85 km) have been used.
3. LARS (Lidar and Radar Sounder) was developed in 1995 and is a fully steerable lidar instrument with Rayleigh and Raman detection channels for investigations of contrails, clouds and plumes.
4. BALS (Bistatic Atmospheric Lidar System) has been developed to investigate and profile the optical scattering properties of airborne particulate matter.

e. Hampton University
As part of the CREST affiliation, Hampton University is investigating the contribution of an elastic lidar to the REALM network.

f. CREST/CCNY
The Optical Remote Sensing Laboratory associated with NOAA CREST center is in the Electrical Engineering Department at the City College of New York (CCNY). It operates two lidar systems:
1. Mobile Lidar: Elastic Lidar system operating in a van with a Continuum Surelite II laser transmitter at 355/532/(and soon to be added 1064) nm and a Celestron 14" Cassagrain receiver.
2. CCNY Lidar Observation Facility: The system became operational in May 2002. It has two transmitters a) Coherent Infinity YAG laser (355/532/1054) with repetition rate to 100 Hz, and b) Continuum 20 Hz PowerLite-Sunlite-FX system (250-1800 nm tunable narrow-band). It has a 20" Dobsonian receiver.

g. MSC
The Meteorological Service of Canada has three systems that it can contribute to REALM:
1. AERIAL (AERosol Imaging Airborne Lidar): The airborne lidar system allows for simultaneous upward/downward operation with depolarization capability. The lasers used are modified Continuum Surelite II lasers operating at the fundamental wavelength of 1064 nm at a repetition rate of 20 Hz. The detector package consists of a 14" Celestron telescope and logarithmic amplified APD. Data is displayed in real time with a typical vertical resolution of 3m and 10 shot average.
2. RASCAL (Rapid Acquisition SCanning Aerosol Lidar): The mobile scanning lidar system uses two large 24" mirrors to direct the scattered light onto the same detection package as AERIAL. The laser is a Continuum 8050 operating at 1064nm (50Hz). The system is capable of fast elevation scanning profiles of the lower troposphere with a resolution of 3m along the beam axis and scanning speeds up to a few degrees per second.
3. ALIAS (Aerosol Lidar Instrument for Atmospheric Studies): Dual wavelength lidar operating at 1064/532 nm. The laser is a Continuum NY81 (10Hz) with 14" Celestron telescope. Typical vertical resolution is 3.75 m and temporal resolution from 1s to 1 minute.

3. Applications for REALM

a. EPA Supersites
The Penn State multiwavelength lidar system is currently involved in the EPA supersite program and the North American Regional Strategy for Tropospheric Ozone Northeast Project (NARSTO-NE).

b. AIRMAP
Discussions have begun with the NOAA AIRMAP project to add future lidar capabilities to the project to look at New England state regional haze and outflow to the Atlantic. REALM should be well placed for the 2003 Sutton, Quebec study (MacDonald, private communication) and the 2004 AIRMAP intensive.

c. EOS and ESSP Validation Studies
SRL, ALEX and ELF are being used this year to support validation activities for the Atmospheric Infrared Radiometer which is now flying on the AQUA satellite. ELF will be deployed at the mouth of the Chesapeake Bay on the Chesapeake Lighthouse for three periods per year for the next two years to provide cirrus cloud clearing for the Atmospheric Emittance Radiometer (AERI) based at that site. At other times, the ALEX and SRL systems will be providing water vapor profiles for validating the AIRS retrievals. SRL will be based in 2002 at the Oklahoma IHOP site and at UMBC during the January 2003 intensive intercomparison.

ALEX and ELF have been committed to gather data for the ESSP CALIPSO extinction retrieval validation. A climatology of 355, 532 and 1064 nm aerosol backscatter and extinction retrievals are being obtained to better constrain the range of regional east lidar ratios used in the CALIPSO algorithms.

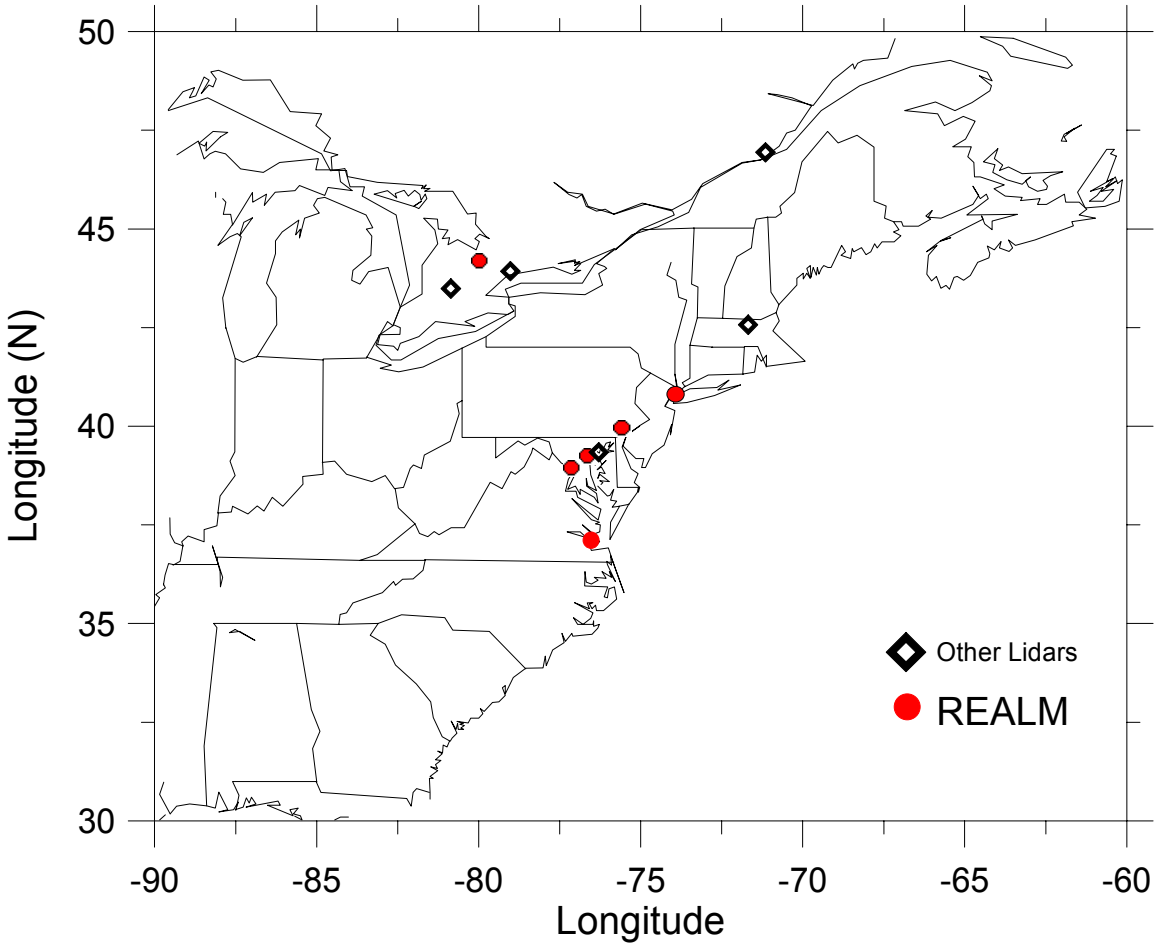

Figure 1 : Locations of the REALM lidars

REFERENCES

Gross, Michael R.; McGee, Thomas J.; Kimvilakani, Patrick, 1997:Temperature measurements made with a combined Rayleigh--Mie and Raman lidar. *Applied Optics,* 36, pp. 5987.

Hoff, R. M., L. Guise-Bagley, R. M. Staebler, H. A. Wiebe, J. Brook, B. Georgi, T. Dusterdiek, 1996: Lidar, Nephelometer and In-situ Aerosol Experiments in Southern Ontario, *J. Geophys. Res. D.* 101, 19,199-19,209.

Mulik, K.R. and C.R. Philbrick: "Raman Lidar Measurements of Ozone During Pollution Events," in Advances in Laser Remote Sensing, Selected papers from 20th ILRC, 10-14 July 2000 in Vichy France, pp 443-446, 2001.

Philbrick, C.R. and K.R. Mulik, "Application of Raman Lidar to Air Quality Measurements" in Laser Radar Technology and Applications, SPIE Vol 4035 pg 22-33, 2000.

Reichardt, J., L. Ramos, W. Welch, L. Twigg, G. Sumnicht, R. Farmer, D. Silbert, T. J. McGee, and R. Baumgart, 2002: Experiment for Cirrus, Humidity, and Temperature Studies (EXCITES) lidar, Abstract submitted to the *21th Int. Laser. Rad. Conf.*, Quebec, Canada.

Whiteman, D. N., S. H. Melfi, 1999: Cloud liquid water, mean droplet radius and number density measurements using a Raman lidar, *J. Geophys. Res.D.,* 104, 31411-31419.

Wooten A. Dan, R. M. Hoff, S. H. Melfi, 2000: An advanced fiber optic coupled Raman lidar for aerosol measurements, *20th International Laser Radar Conference*, Vichy, France.