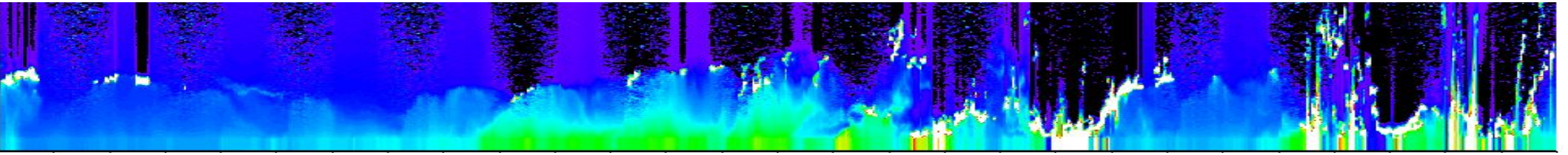
Public Domain Lidar: entry-level network system to enable boundary layer studies for the lower troposphere

T. Berkoff[1], R. Delgado[1], J. Compton[1], P. Sawamura[1], E. Welton[2], and R. Hoff[1]

1. University of Maryland Baltimore County, Baltimore, Maryland, USA
2. NASA Goddard Space Flight Center, Greenbelt, MD, USA

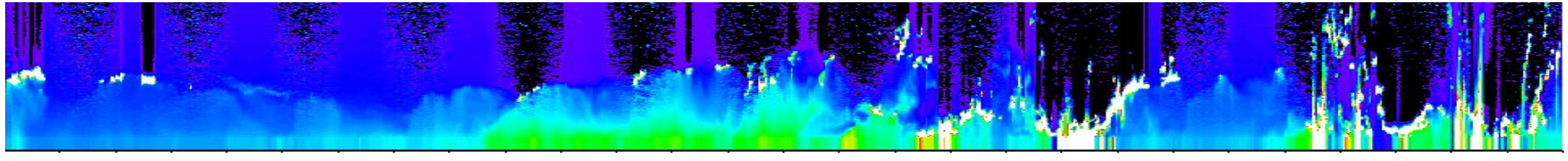
Acknowledgments: Larry Belcher, Seb Stewart, Sonia Cyrus for MPLNET operations. This work would not have been possible without help from UMBC's Monitoring of Atmospheric Pollution (UMAP – NASA NNX08A093G) project, NASA's Micro-Pulse Lidar Network, and UMBC's GEST operating budget.

Data source credits: EPA AIRNow, NASA MODIS-Giovanni, UMBC's Air Quality Web Log, NOAA NESDIS GOES Aerosol Smoke Product (GASP), and NOAA HYSPLIT-READY trajectory model.

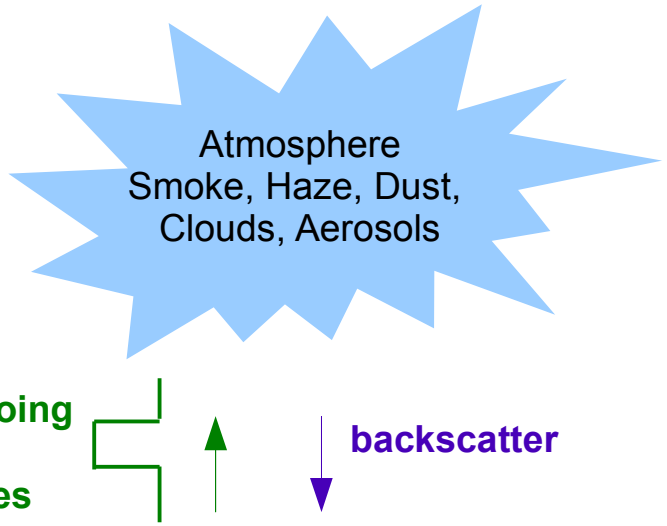


OUTLINE

- Lidar Background
- Tropospheric profiling needs
- Micro-Pulse Lidar Network – Description & Data examples
- Public Domain Lidar (PDL) concept
- Example data from “mini” receiver
- Future Plans & Summary



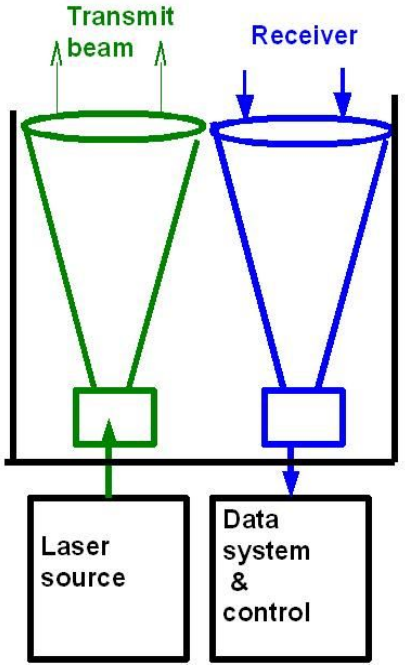
Lidar (Light Detection and Ranging)



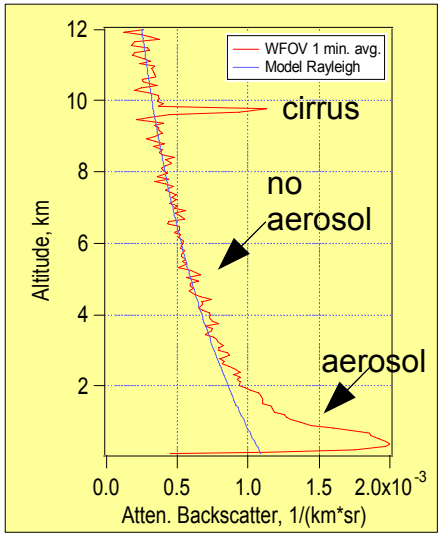
As each outbound pulse travels through the atmosphere, the resultant scatter is captured by the receiver/detector

The time delay between pulse emission to scatter signal is converted to distance

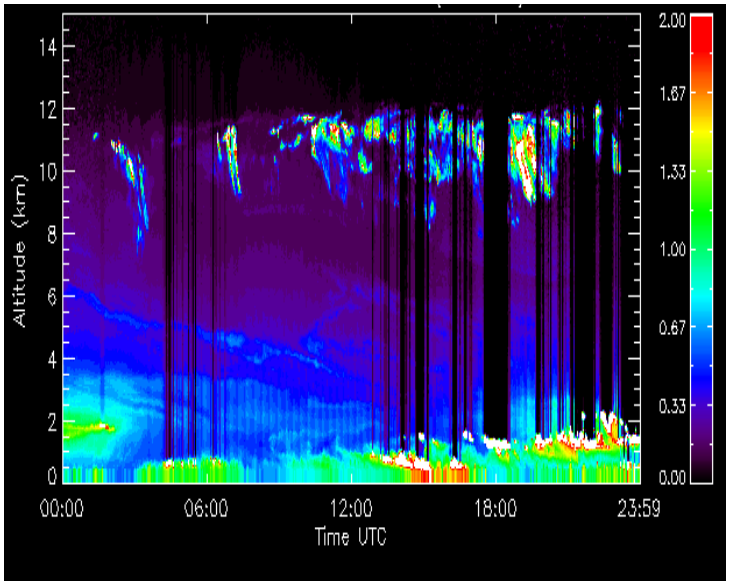
This allows for a range profile of backscatter to be obtained



Example vertical profile



Lidar backscatter image is formed by a series of profiles over time



NASA aerosol lidars big and small ...

CALIPSO satellite: $223 million

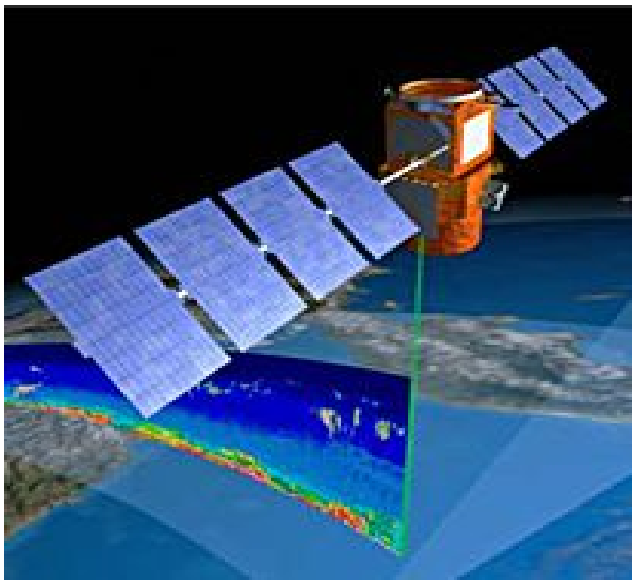


Image credit:NASA LARC

Ground-based MPL: $0.1 million

Photo credit: Michael Ives

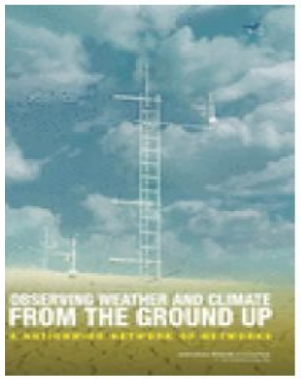
Both provide atmospheric profiles of particulate bacskcatter continuously 24-7 providing multi-year records

CALIPSO: global coverage, 16-day repeat cycle can make local studies of short-term dynamics a challenge

MPL: provides profile evolution over time, but at only at specific location

Profiles from both systems enable examination of vertical structure of particulate matter

Need for lower troposphere profiling is widely recognized .....



The National Research Council

Committee on Developing Mesoscale Meteorological Observational Capabilities to Meet Multiple Needs, National Research Council

ISBN: 978-0-309-12986-2, 250 pages, , paperback (2008)

NRC report: "As a high infrastructure priority, federal agencies and their partners should deploy lidars and radio frequency profilers nationwide at approximately 400 sites to continually monitor lower tropospheric conditions."

In the U.S.!

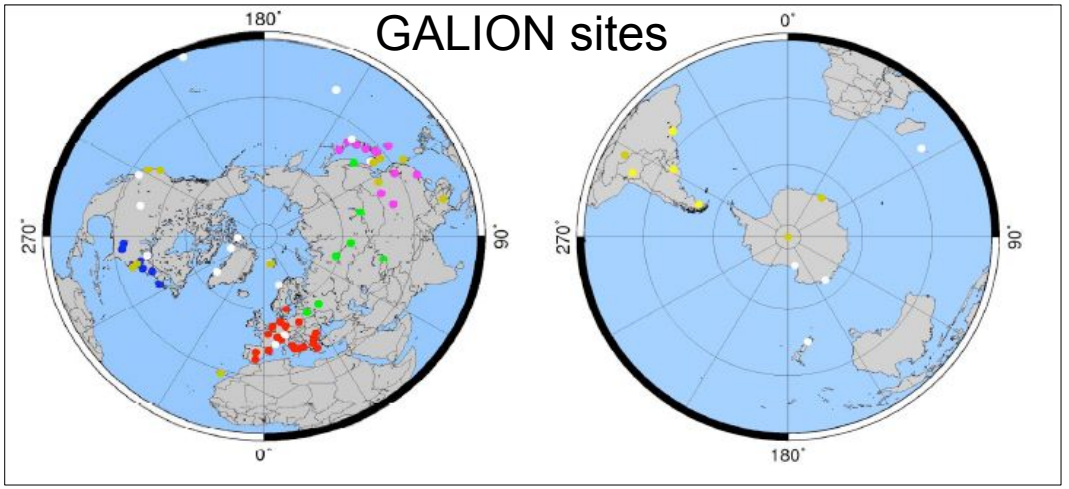
GALION

"Network of networks"

The Global Atmosphere Watch Aerosol Lidar Observation Network

2010 workshop participants
http://alg.umbc.edu/galion/

Bosenberg & Hoff WMO report # 178



The Micro Pulse Lidar Network

MPLNET

Micro-Pulse Lidar Network (see: mplnet.gsfc.nasa.gov)

Micro Pulse Lidar

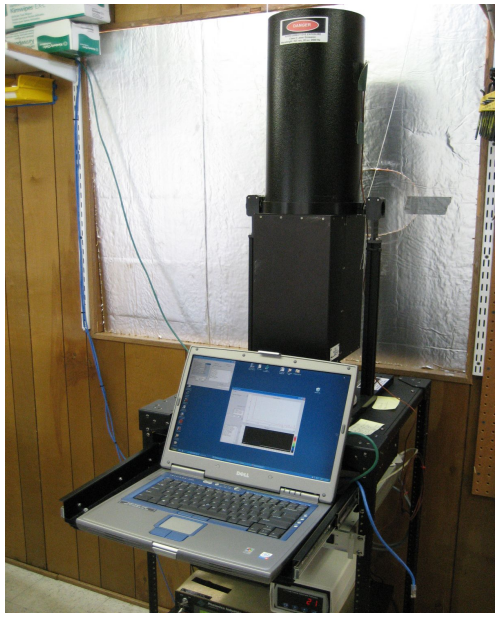
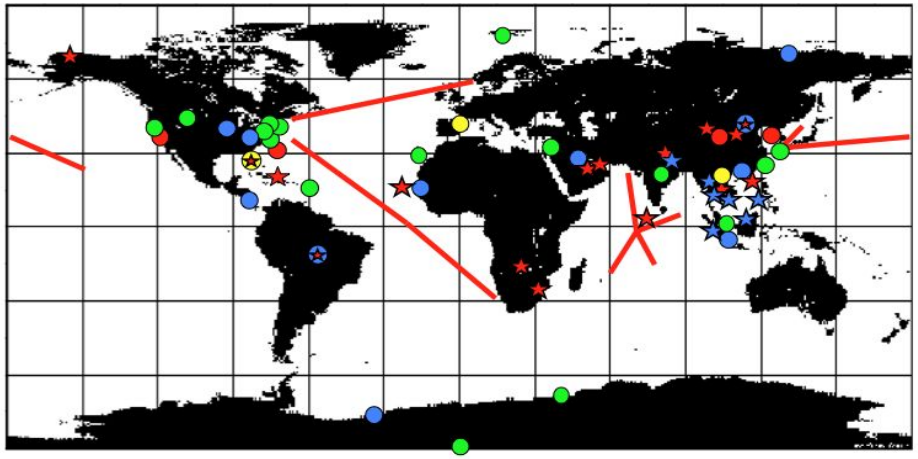


Photo credit: Michael Ives

MPLNET Sites: 2000 - current



* most sites co-located with AERONET

* Global network run by NASA-GSFC with site partners around the world
* Portable eye-safe lidars operating at 532 nm
* Currently 18 active sites, standardized instrument & data processing
* Provides continuous (24-7) multi-year records of vertical profiles
* Satellite & model validation, direct and indirect climate effects
* Aerosol climate and air quality model validation

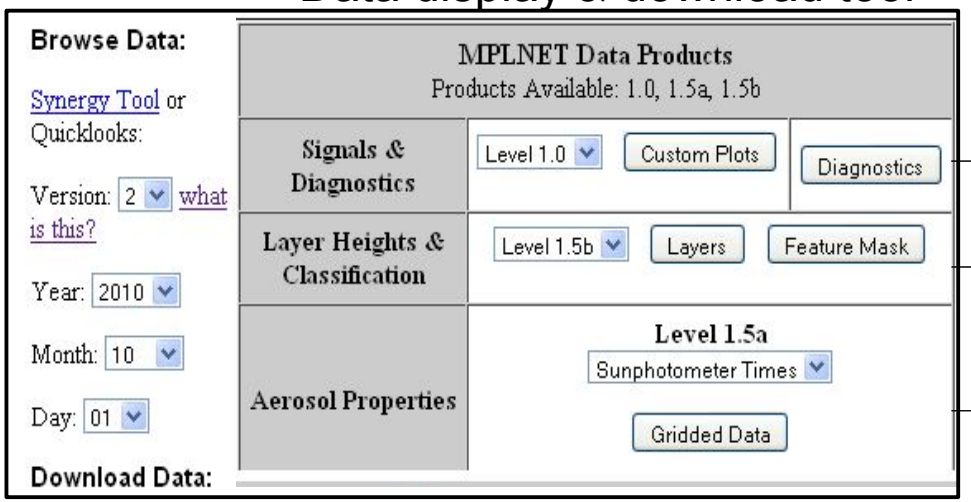
Five sites In the U.S.:
2 in MD
1 in NH
1 in MT
1 in CA

MPLNET Data Products

For detailed information of data products: mplnet.gsfc.nasa.gov

Publicly accessible data-base with calendar based selection, custom display, and file downloads

Data display & download tool

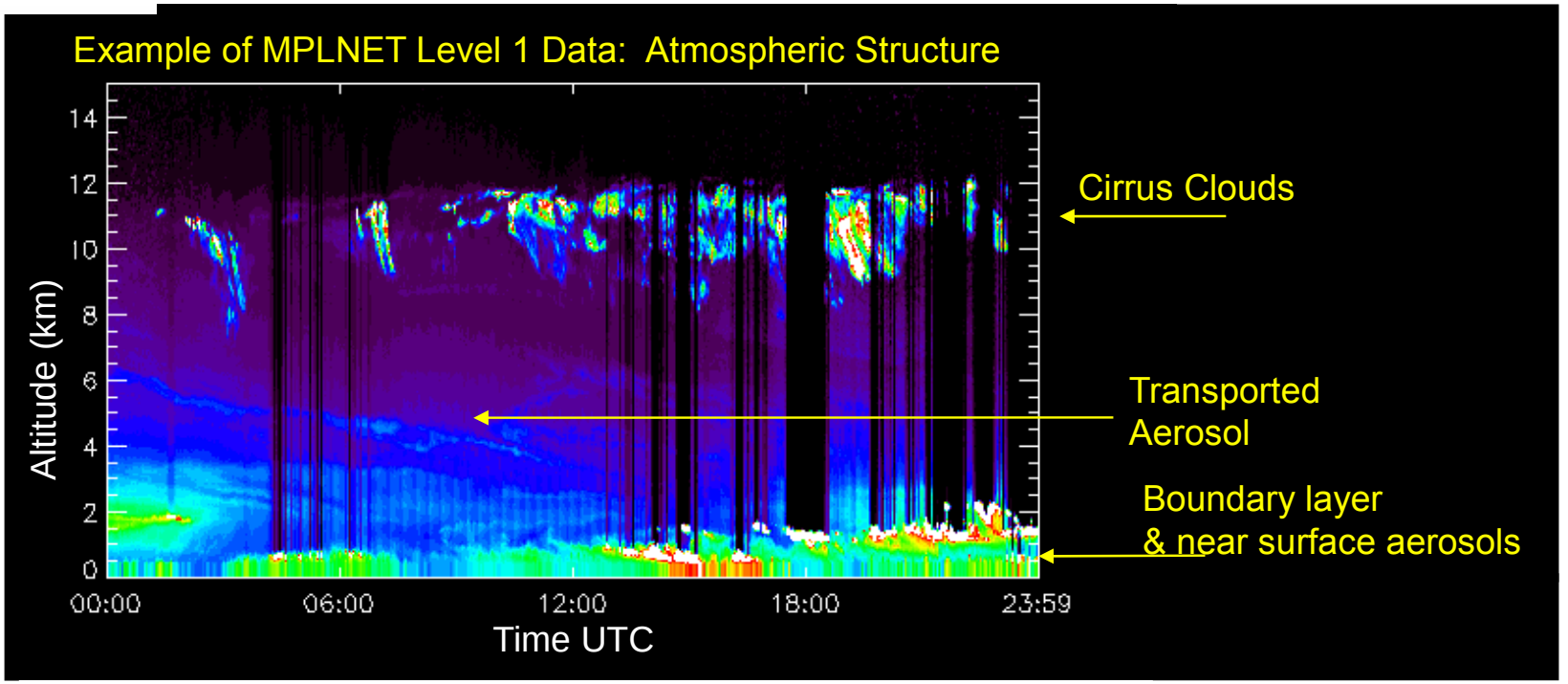


All data are publicly available in netcdf format. Errors included for all data products.

→ Daily lidar profiles & images

→ Layer heights & feature mask

→ Higher-level aerosol optical properties

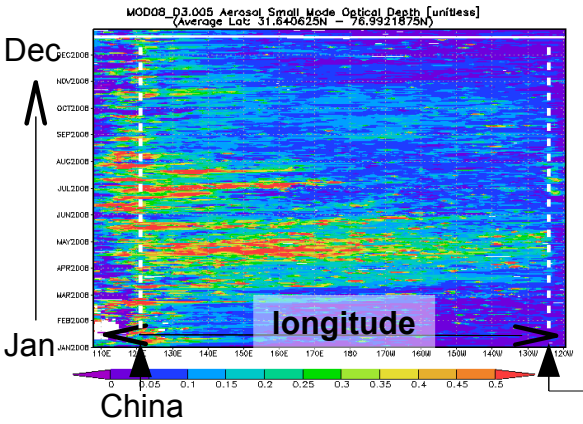


Example data from NOAA's Trinidad Head site (Northern CA coast)

NOAA CMDL site (MPLNET partner site)

Aerial view of Trinidad Head

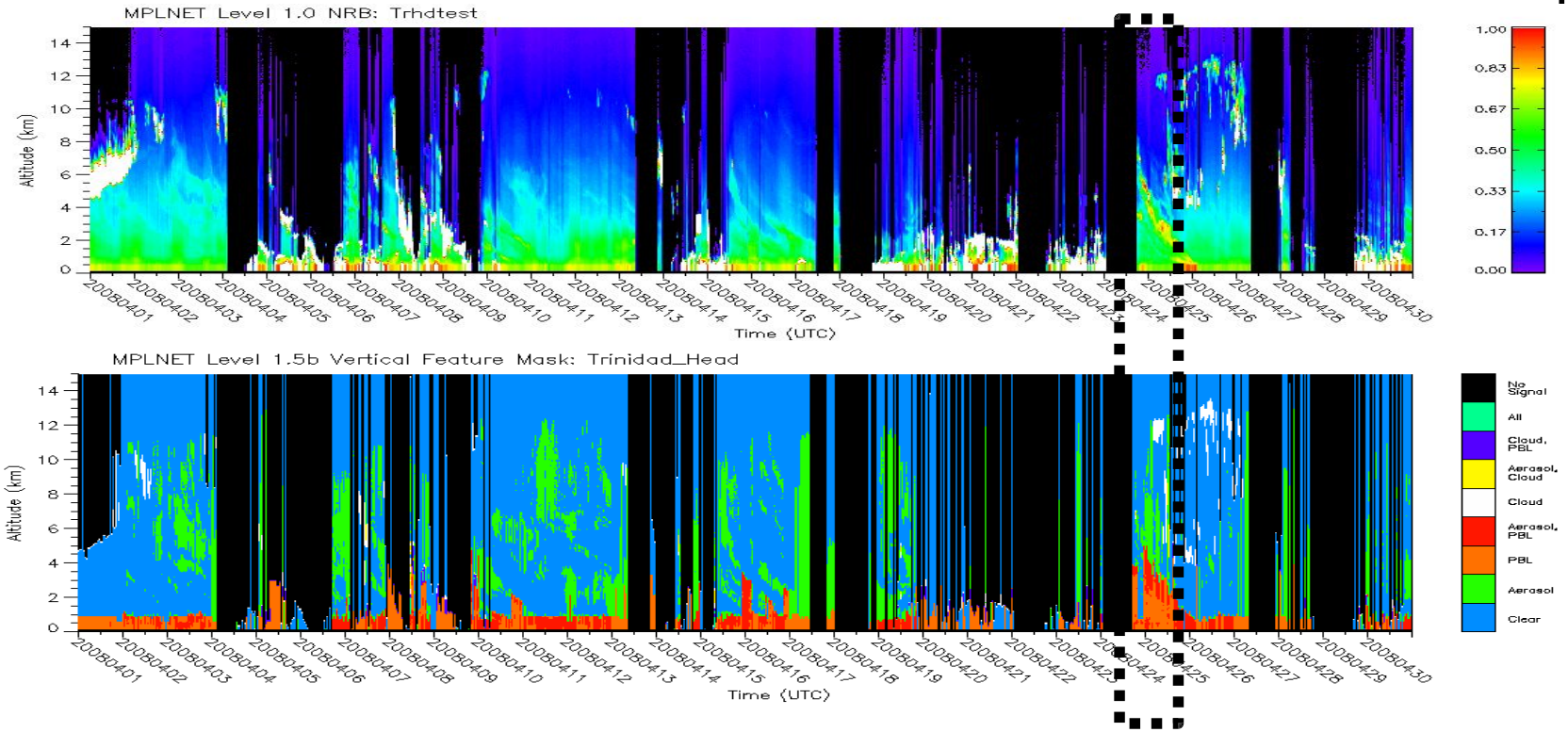
Satellite Aerosol Optical Depth
MODIS Jan-Dec 2008



The MODIS AOD Hovmoller diagram illustrates the aerosol intensification over the Pacific for springtime 2008

Spring time transport from Asia

MPLNET Trinidad Head Lidar Record for the month of April 2008



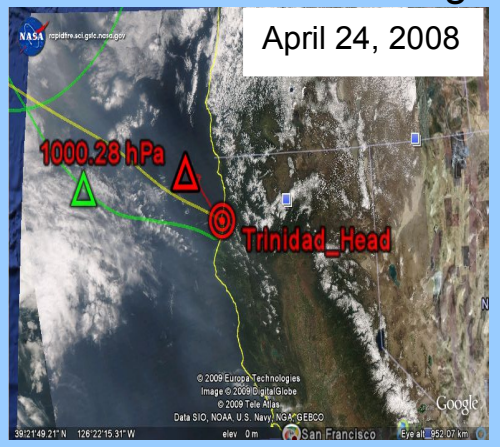
Level 1.0 Normalized Relative Backscatter Intensity

Level 1.5b Feature Mask categorization
cloud=white
aerosol= green
PBL=red

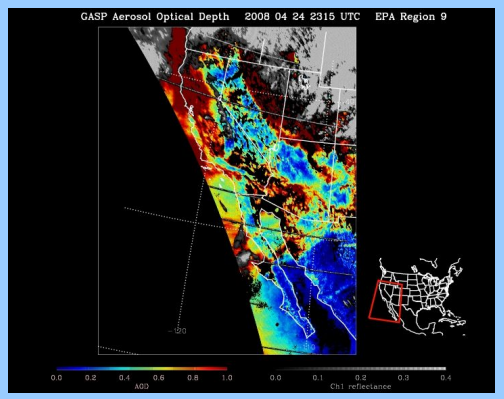
Lidar can provide the link between satellite and surface observations
Intercontinental transport case: April 25, 2008 Trinidad Head data

Satellite

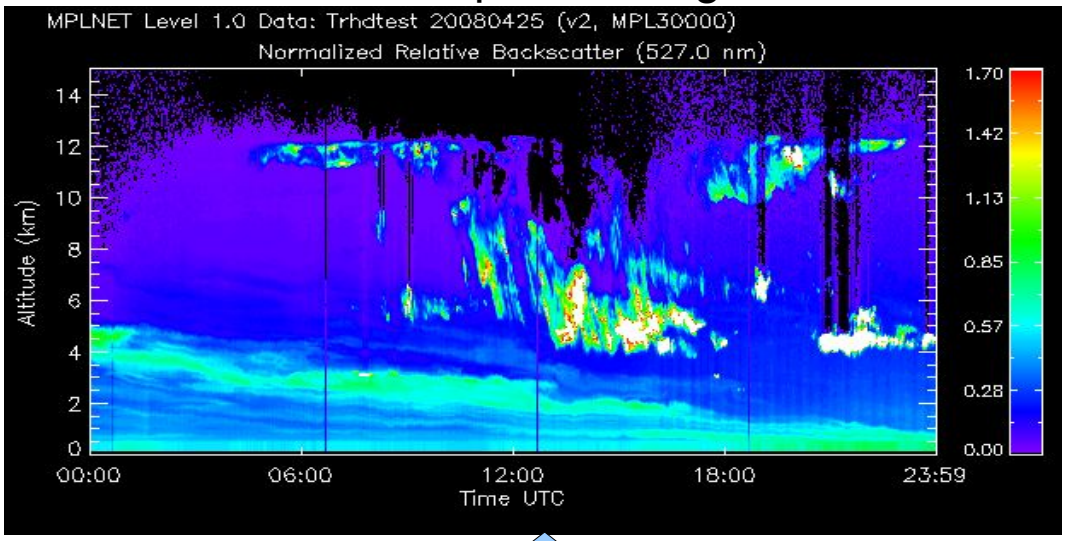
MODIS True Color Image



NOAA GASP image
High column AOD levels April 24



MPLNET profile image



NOAA CMDL Surface measurements
April 26-27

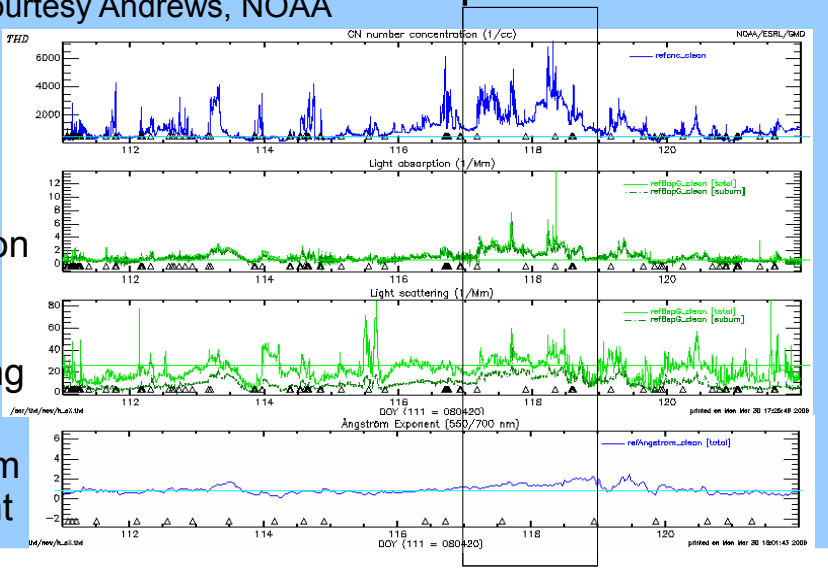
Data courtesy Andrews, NOAA

CN
conc

Light
absorption

Light
scattering

Angstrom
exponent



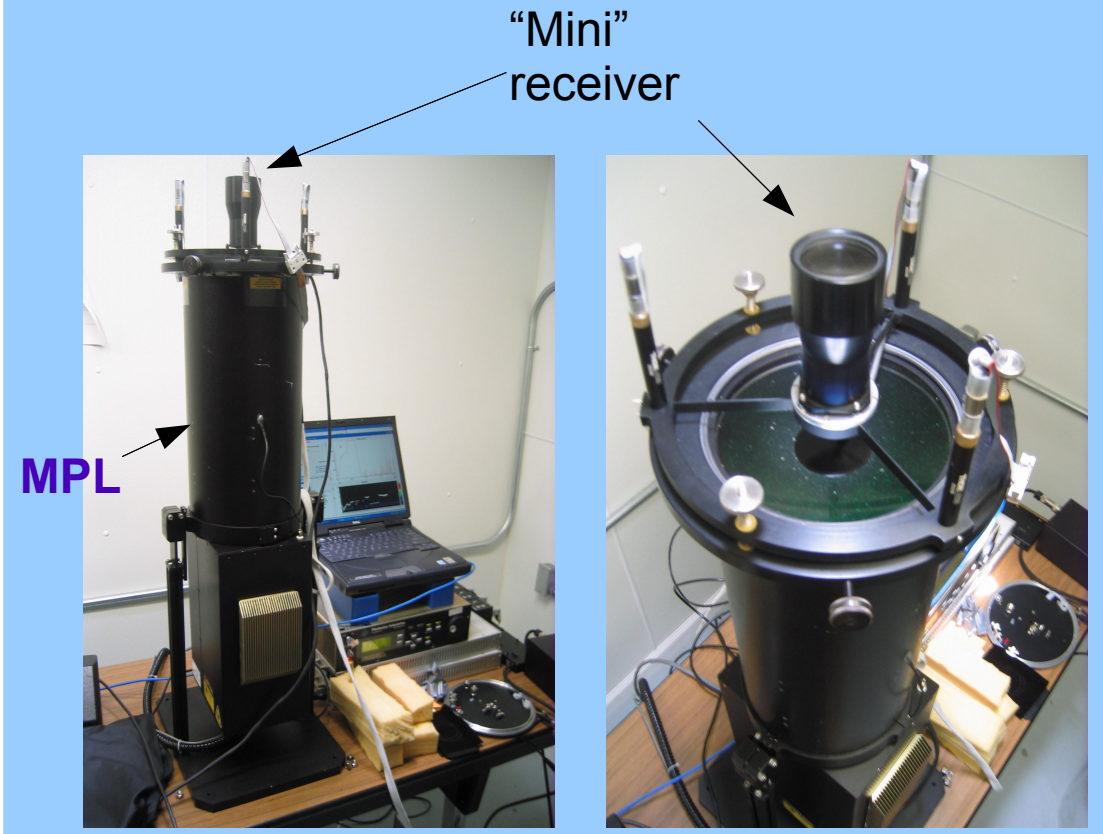
The MPL is useful however ....

MPL + site equipment = ~$150,000 per site

400 sites x 0.15 = $60 million of equipment

Micro-Pulse Lidar not originally designed specifically for lower troposphere and near surface measurements

Near-surface calibrations are problematic, generating quality-assured data is labor intensive



MPLNET has been using a "wide-field" small diameter receiver to recover near-range signals

Significantly reduces near-range complexities by using wide-field optics, but at the expense of increased noise during daytime

If only lower troposphere is needed, mini-receiver type approach is suitable for use as a stand-alone lidar system, much simpler and lower cost than MPL

“Public Domain” Lidar

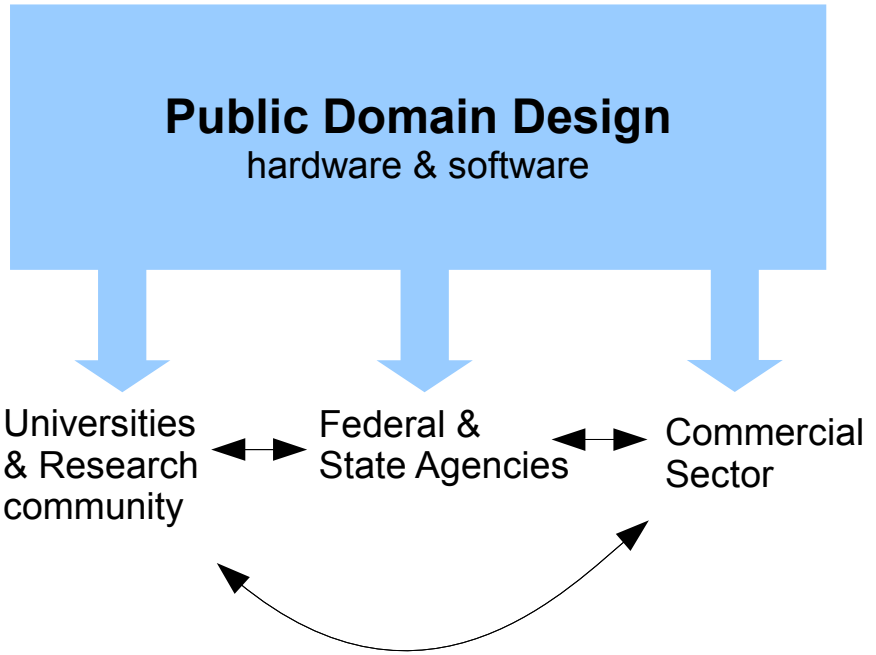
Open-source software benefits broad-based community, open-source hardware can too ...

Approach:

- A new, simple lidar system
- Can be replicated by groups new to lidar
- Ease of construction, alignment & calibration
  (i.e. “Heathkit” approach)
- Low cost (less than $35K parts cost)
- Suitable for autonomous operations (i.e. eye-safe output)
-

Broad-base benefits:

- A public-domain design benefits everyone
- Increases # sites for air quality and atmospheric studies
- Compliments commercial systems (near-IR ceilometers, MPLs)
- Additional source for validation of forecasting models
- Provides more direct technology education for future scientists in the field



UMBC's Monitoring of Atmospheric Pollution (UMAP)
Air quality analysis and testbed facility

(See Delgado et al.,
Thursday Remote Sensing Session)

http://alg.umbc.edu/umap/

- Recently augmented by a major NASA grant
- Five lidar systems
- MPLNET & AERONET site
- Radiosonde
- Surface measurements:
  - Nephelometer
  - BAMS
  - TEOM
  - Partisol

The "Mini-receiver" has been in operation at UMBC for calibration and automated day/night data collection for past 6 months

Pollution events captured at UMBC, Mini-receiver data on subsequent slides used to illustrate what can be done (30 min. temporal, 30 meter vertical resolutions)

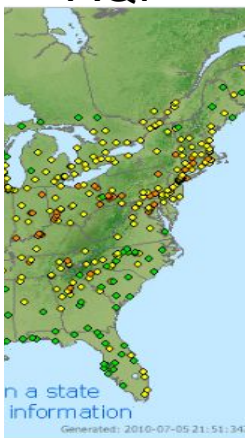
However, signal was attenuated by a factor of ~ 10 to avoid daytime detector saturation

A "Pubic Domain" lidar would be designed to avoid this extra attenuation and significantly improve performance over examples shown

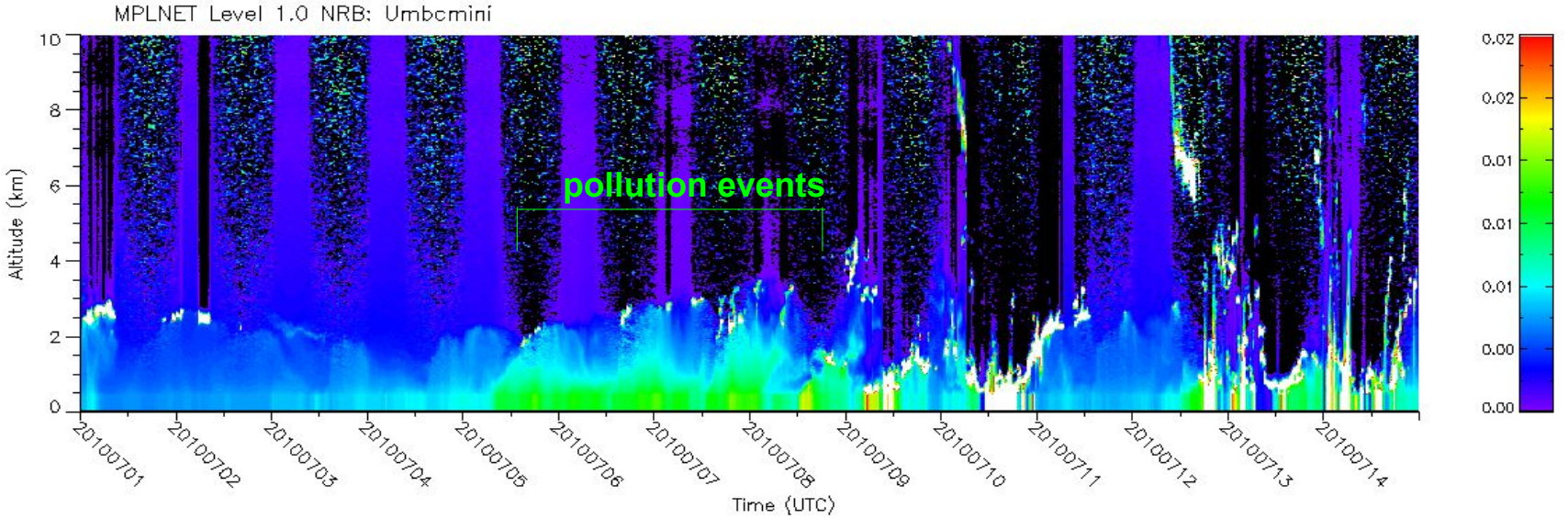
“Mini” receiver measurement during July 2010 air quality event @ Baltimore

Multiple “Code Orange” AQI events

July 5
PM2.5
AQI



July 1 to July 14, 2010 ”mini” NRB lidar image (30 m vert., 30 min. temporal resolution)



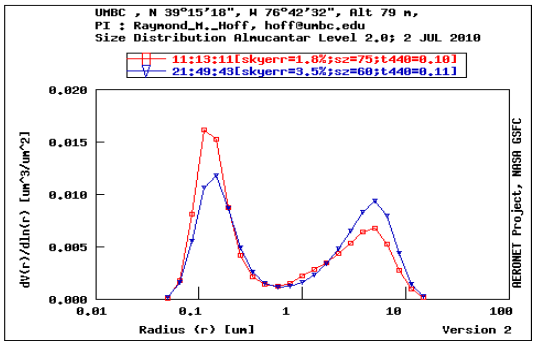
Airnow map

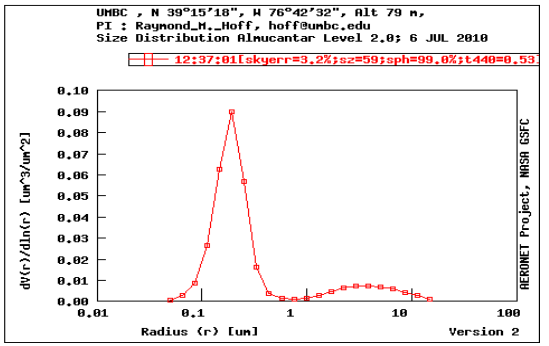
July 2, 00:00 UTC

July 7, 00:00 UTC

View of Baltimore
From UMBC

AERONET
Size distribution

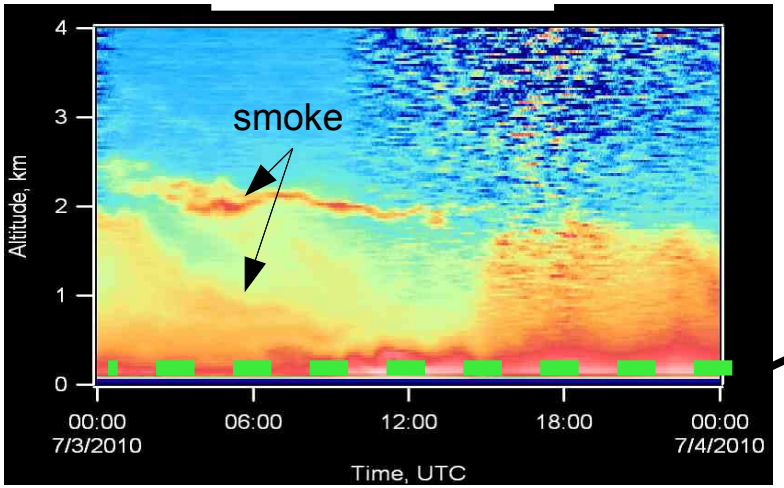




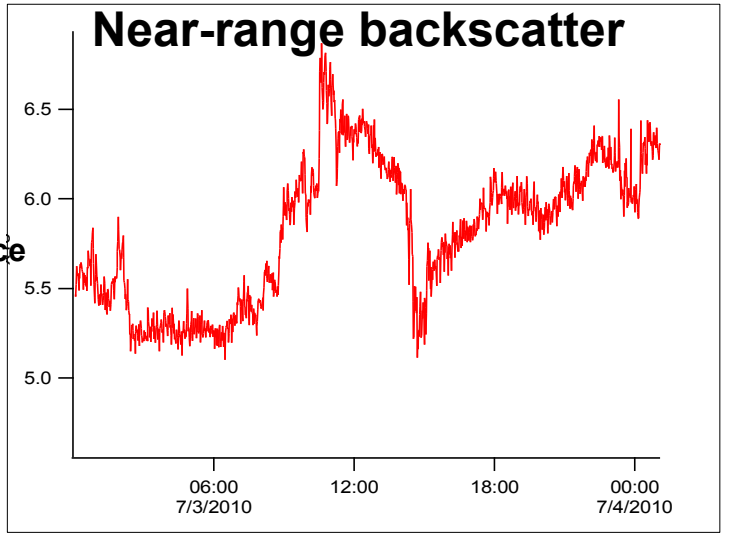
The “mini” receiver measurement on July 3, 2010

- Intrusion of Canadian forest fire smoke contributing to pollution event
- Near-range “mini” receiver signals can more easily be related to surface measurements

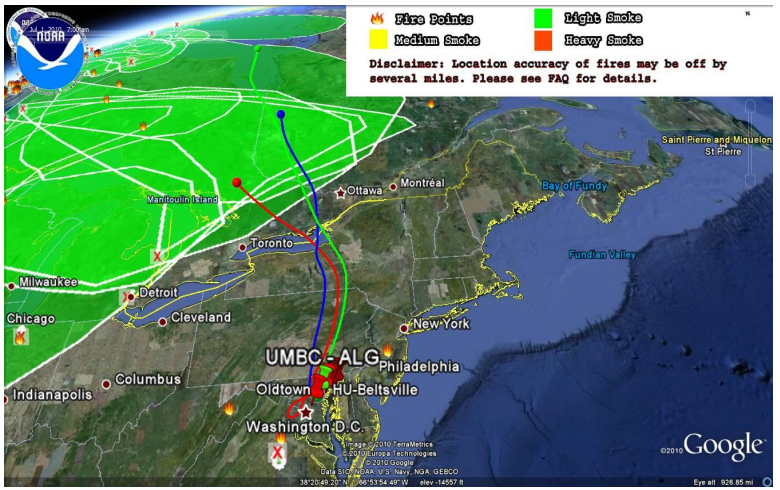
“mini” receiver

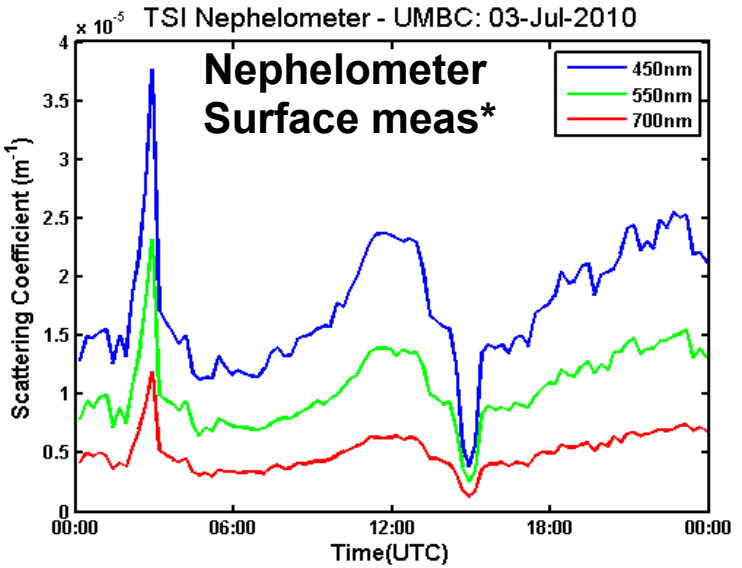


Surface signal



Back-trajectories*

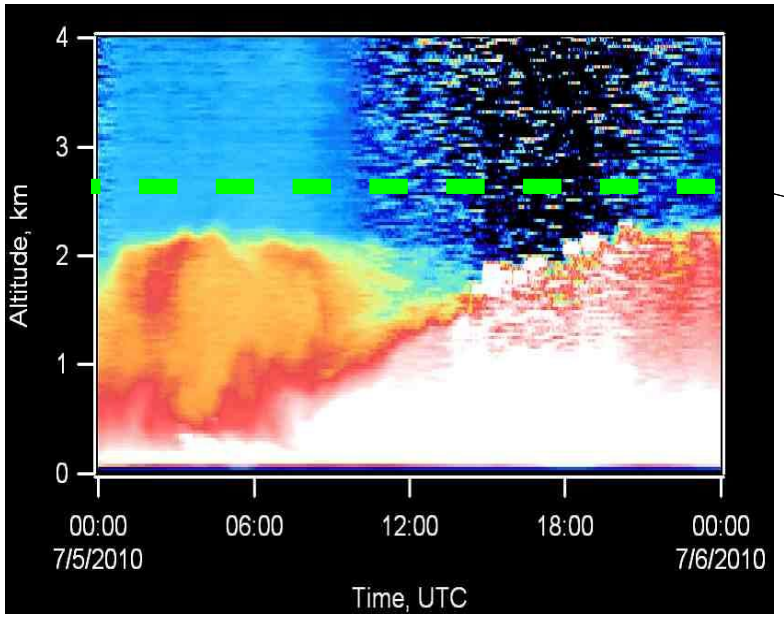




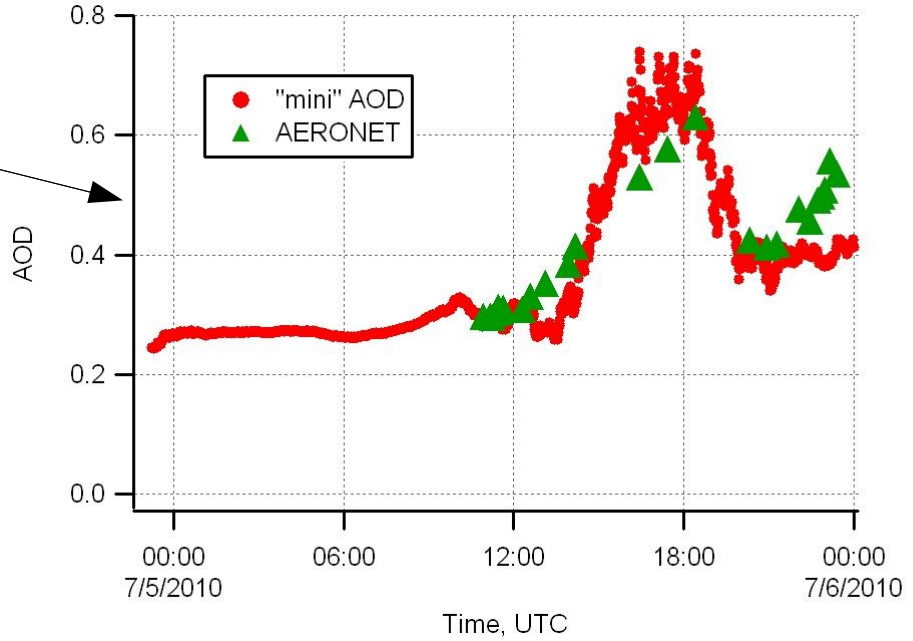
*From Sawamura et al., MDE report, 2011

Signal above PBL can be used as a proxy for PBL optical thickness
"Mini-receiver" measurement July 5, 2010

mini-receiver



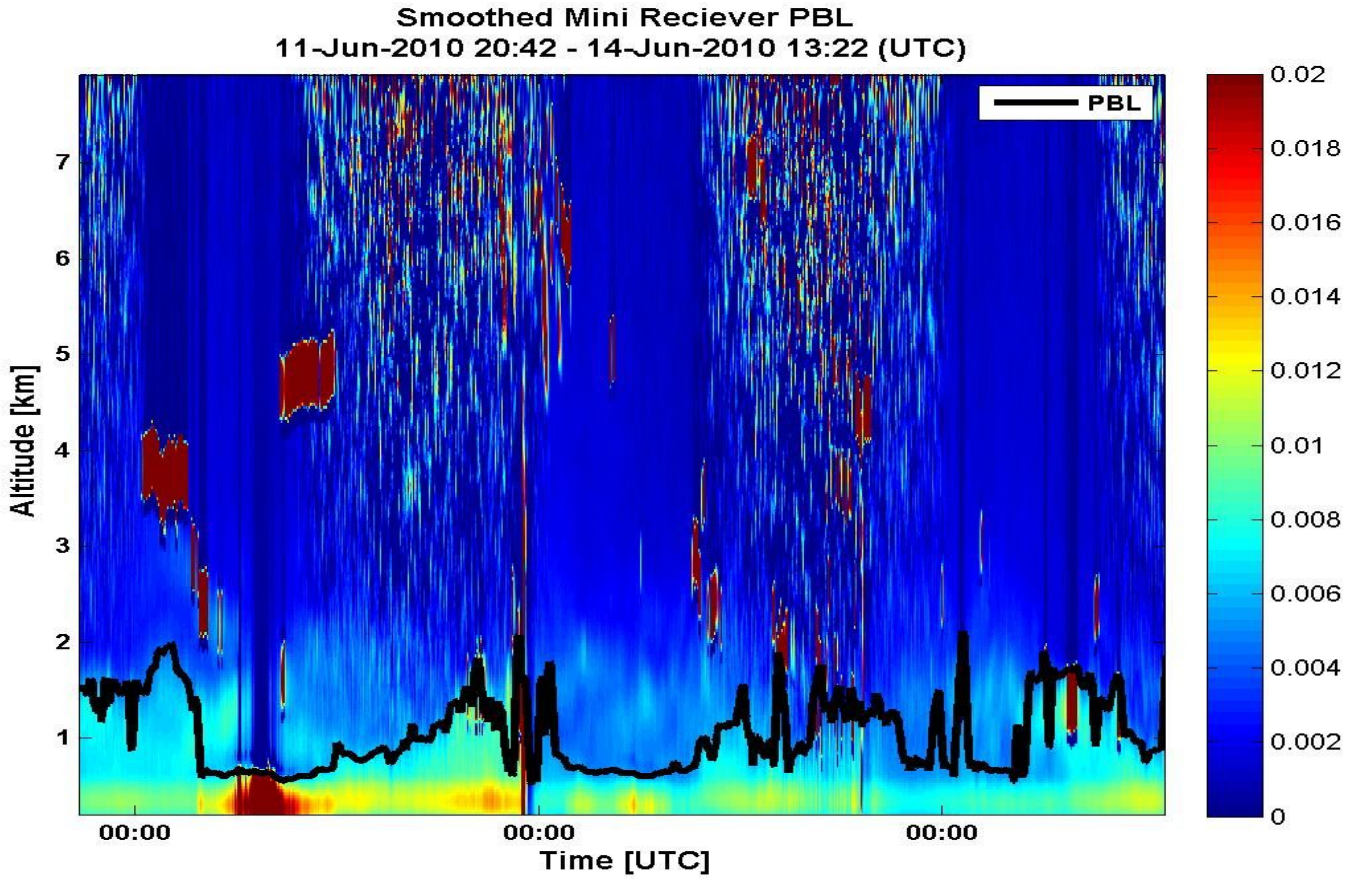
Derived AOD from free-troposphere (molecular) backscatter signal



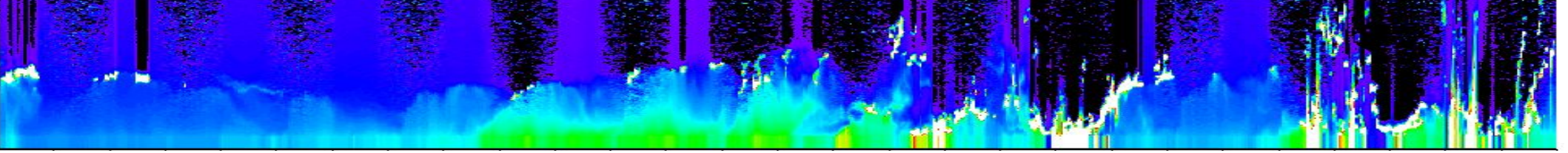
If free troposphere signal above aerosol can be obtained, aerosol optical depth determination and other inversion techniques can be applied to help determine aerosol type (Dust v. smoke, etc.)

“Mini” receiver data: automated retrieval of aerosol layer top

Mini-receiver data 11-14 June 2010 with UMBC's “PBL” retrieval applied
Compton et al., 2011



PBL height is important for improved air quality assessment and forecasting.



“Public Domain” Lidar

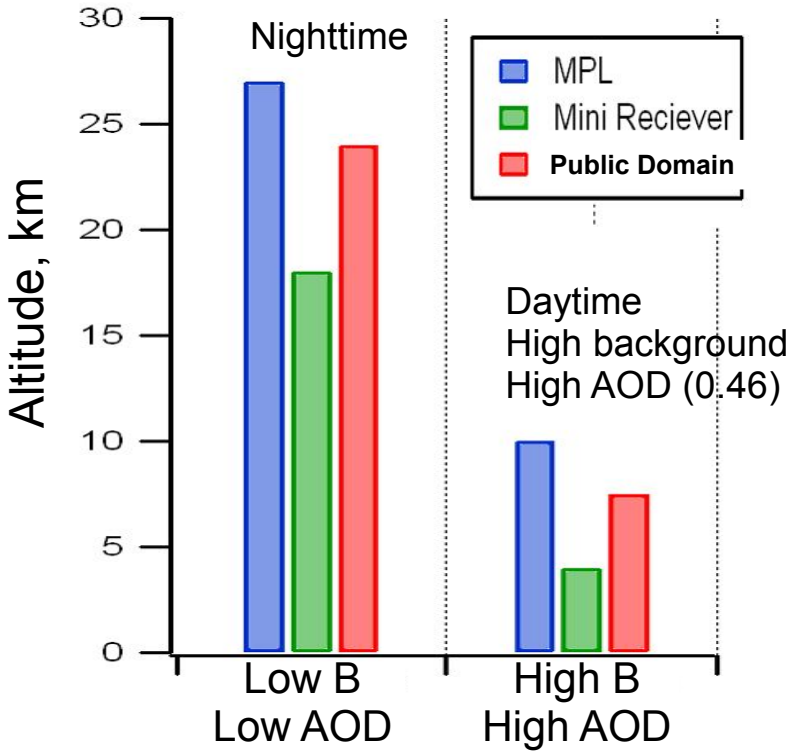
The “mini-receiver” data used here is a very conservative demonstration, the “public domain” system would yield even better daytime S/N performance

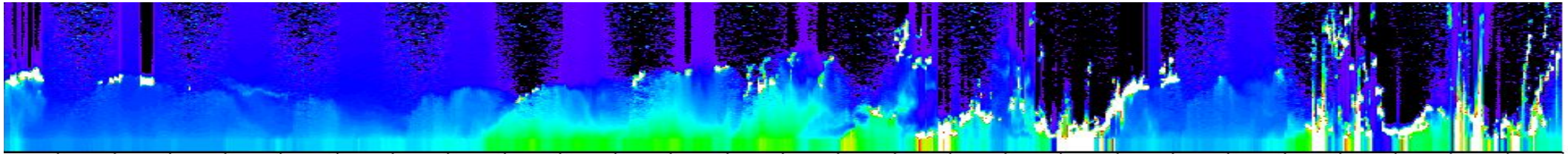
With modest design changes, 30 minute time average can approach same performance for an MPL at a 1 minute time average

Daytime measurements of high altitude weak aerosols & very thin cirrus will remain a challenge, but system is still well suited for lower troposphere studies

Performance study from Sept 22, 2010 data and model prediction, comparison between:

MPL at 1 min. average (Blue)
Mini Receiver 30 min. average (Green)
Public Domain 30 min. average (Red)





“Public Domain” Lidar

System capabilities

- Near surface & lower troposphere boundary layer dynamics
- Better relate surface measurements to satellite data
- Column aerosol optical depth if sufficient free-trop signal is present
- Daytime PBL mixing-height
- Assessment of aerosol in low-level jets (clean v. polluted)
- Transport interaction with boundary layer

Current status

• Proposal submitted to National Science Foundation for seed funding to develop a prototype system & test

•Concept presented at WMO's GALION lidar workshop (2010) & American Meteorological Society Meeting (2011)

•Seeking additional feedback & broad-based participation, particularly from air quality community

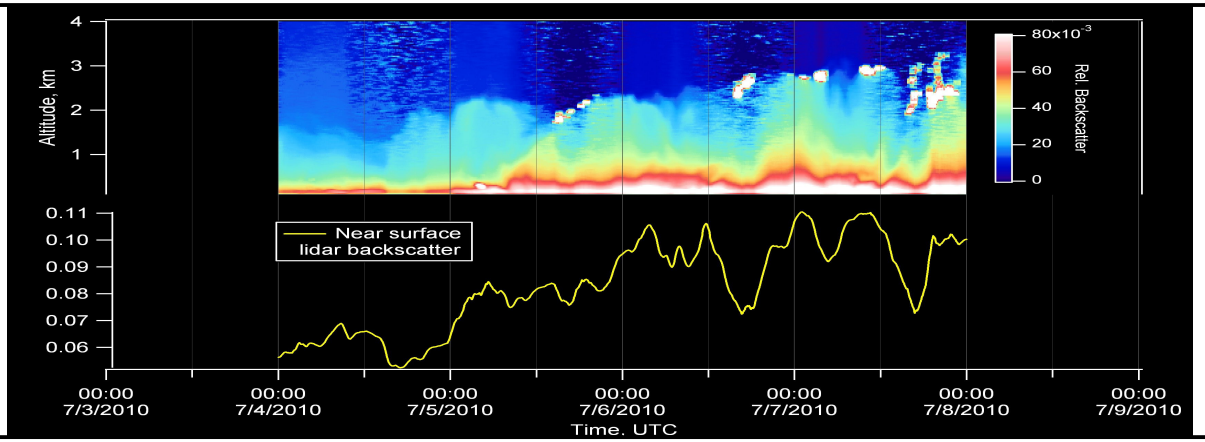
• In process of developing a contact list

Questions, or if you are interested in this activity please email contact info and interests to:

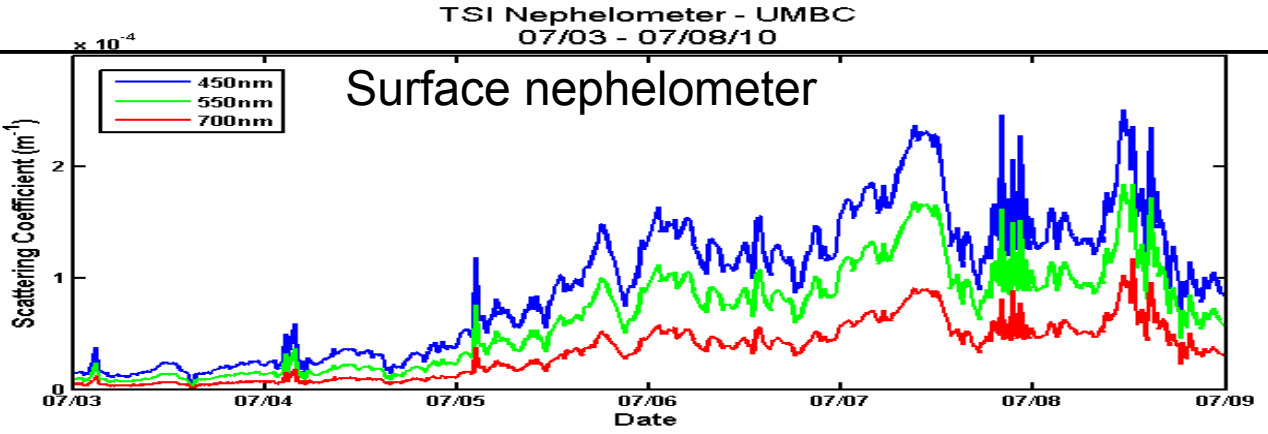
berkoff@umbc.edu

Expanded View: July 3-7, 2010

Mini-receiver data



Sawamura et al., MDE report, 2011



PM 2.5 via AIRNow-tech