E-PAMS Profiler and Ceilometer Network

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Air & Waste Management Association
Baltimore-Washington Regional Air Quality Symposium
Observations Lead The Way

**NRC**
Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks (2009)

**NSF**
Thermodynamic Profiling Technology Workshop (2011)

**NASEM**

Ceilometers!!!
Regional Testbed

NWS Ceilometer Testbed
• State and local air quality agencies to measure hourly MLH at the national PAMS, as is set forth in 40 CFR Part 58.

• Purpose for the hourly MLH under PAMS driven by the state’s State Implementation Plan (SIP) modeling data needs.

• PAMS MLH requirement not limited to a particular technology and will likely be meet through the deployment of a combination of instrumentation (ceilometers, lidars, Doppler wind lidars and radar wind profilers).

• Need to develop a common MLH algorithm that can be implemented across a heterogeneous network. Hence, centralized standardization of data outputs and retrievals is needed.
Understanding the evolution of the **PBL** is crucial for air pollution as PBL dynamics control pollutant accumulation and dispersion, which in turn also influence aerosol-radiation PBL interactions.

Current observations are rarely available in the spatiotemporal scales needed to further our understanding of complex PBL dynamics. Ceilometers offer a low cost and reliable option for continuous measurements of the PBL.

Ceilometers (Aerosol Backscatter) can monitor:

- **Clouds and precipitation**
- **PBL stratification**: residual layers, nocturnal boundary layers (NBL), lofted aerosol layers, etc.
- **Synoptic changes influencing PBL dynamics**
- **Impact of local circulation** (bay/sea/lake/land breeze)
- **Strong shallow inversions**
Joint Effort:
- UMBC/MDE/EPA
- Federal: NASA/NOAA
- Academia: NOAA CESSRST and NCAS-M

Measurements to help guide EPA PAMS program implementation for new hourly MLH requirement.

Evaluation of Aerosol Backscatter and mixing layer height retrievals from commercial ceilometer/lidars (software):
- **Campbell Scientific** CS135 and SkyVue Pro (Viewpoint)
- **Leosphere** Windcube 200S (Windforge)
- **Lufft**: CHM8k and CHM15k (Lufft Viewer)
- **Vaisala**: CL31 and CL51 (CL-View And BL-View)

Development of Common Algorithm for MLH
- Varying signal quality
  - QC/QA protocols per make/model

- Ceilometer signal evaluation/correction*
  - Signal-to-noise ratios
  - Overlap corrections
  - Artifacts
  - Resolution

*(O’Connor et al., 2004; Wiegner and Geiss 2012; Hervo et al. 2016; Kotthaus et al. 2016, among others)
Development of standardized retrieval algorithms for heterogeneous network

Covariance Wavelet Transform Algorithm

- **Automated** algorithm corrects for instrument signal quality and automatically screens for precipitation and cloud layers.
- **Layer attribution** for the planetary boundary layer height with continuation and time-tracking parameters and uncertainty calculations through automatic filtering.

December 13, 2016 (GWTC) profiles from CHM15k (a), CL51 (b), CL31 (c), and SkyVue Pro (d) ceilometers. PBLH retrievals from the automated algorithm are displayed in black circles, while CBH retrievals are displayed as white triangles. Radiosonde heights for both PBLHs and CBH are displayed as red squares. Error bars display 10-minute retrieval uncertainties every 30 mins for display clarity purposes although uncertainties are calculated with every retrieval.

Caicedo et al. (2020)

“An automated common algorithm for planetary boundary layer retrievals using aerosol lidars”
EPAMS Profiler and Ceilometer Network

**Ceilometer/Lidars**
- CCNY
- Philadelphia, PA
- Fair Hill, MD
- Edgewood, MD
- Essex, MD
- UMBC
- Howard Univ./Beltsville
- Washington DC
- Richmond, VA
- Clark County, NV
- New Haven, CT
- Indianapolis, IN

**Radar Wind Profiler**
- Piney Run
- Howard Univ./Beltsville, MD
- Horn Point Laboratory

**Partners**
- NOAA CESSRST/NCAS-M
- MD Dept. of Environment
- U.S. EPA
- DC Dept. of Energy and Environ.
- Phil. Air Management Serv.
- VA Dept. of Environ. Quality
- NOAA (OAR/NWS)
- NASA
In addition to:

- Real-time data display of backscatter plots
- Real-time optics monitoring
- Real-time data processing (MLH, NBL, residual layer (RL), aerosol layers, Clouds, and precipitation screening)
- Data archive with display for retrospective analysis including exceptional events

Operational Procedures:

- Instrumental signal evaluation
- Standardized retrieval development
- Data Archiving and Processing

https://alg.umbc.edu/ceilometer-testbed/
**EPAMS Profiler and Ceilometer Network**

**Real-time Monitoring - Displays**

- **Vaisala Real-Time Display**

- **Lufft Real-Time Display**

**Current Features**
- Display of 15-minute data
- Notification of data transfer interruption
- Real-time diagnostic parameters

**Next Steps**
- Real-time retrievals for all sites
  - PBL and cloud heights
  - Dynamic display

https://alg.umbc.edu/ceilometer-testbed/
Data Archive

Current Status
• Archiving all ‘raw’ data from all sites
• Displaying archive images for all sites

Next Steps
• Download capabilities
  • Raw Data
  • Retrieval (MLH) Data
  • Data Export (NetCDF, h5, ASCII)
  • Quicklooks (jpeg, png)
Level 0: Data archiving of ‘raw’ signals directly from instrumentation
Level 1: Reformatted ‘raw signals’ into uniform Network Common Data Form (NetCDF) data files
Level 2: NetCDF data files of calibrated signals
Level 3: PBL and cloud products: 10-minute to hourly retrievals (NetCDF data files and ASCII files)
Want to join?

• Consideration given to sites depending on the complexity of the effort required to obtain data feed.

• All products provided to those joining network.

How to join?

• Email data@umbc.edu, guidance will be provided to bring site on board.
Technical Guidance

• Definition and guidelines for data transfer to UMBC database
  • Assisted FTP/HTTPS transfers setup

• Recommended guidelines for regular maintenance
  • Real-time instrument diagnostic monitoring

• Definition and guidelines for data usage/download
  • Web portal documentation for data download and correct use of scientific data

• Guidance for the scientific use of data products
  • Detailed documentation for data products and methodologies

• Review and exchange of relevant technical and scientific information

EPAMS Profiler and Ceilometer Network
Moving Forward

Spring 2020
• Prototype implementation phase of dynamical web display and retrieval applications
• Prototype pre-operational phase (i.e. operational testing)

Summer-Fall 2020
• Prototype incorporation of early EPAMS instrumentation and academic partners

2021
• Fully Operational for 2021 EPA requirement

*Contribute of E-PAMS to North America WMO Global Atmospheric Lidar Observation Network (GALION).
Acknowledgements

Maryland Department of the Environment
US Environmental Protection Agency
NOAA Office of Education
(NA16SEC4810006 and NA16SEC4810008)
NASA
Campbell Scientific
Lufft/OttHydromet
Leosphere/Vaisala

Disclaimer: Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.
• Backup Slides
Retrieval Algorithm

1. Signal corrections (noise, artifacts, overlap, etc.)
2. Continuation parameters for layer attribution
3. Time-tracking height limitations to reduce misidentification of aerosol layers during transition times
4. Cloud identification independent of commercial cloud retrievals
5. Range of Haar wavelet transforms to calculate uncertainties in retrievals
6. Cloud classification in order to include convective cloud-topped boundary layers and cloud cover information
7. Define dilations and ranges based on uncertainties

Caicedo et al. (2017, 2020)
Planetary Boundary Layer Retrievals

Development of standardized retrieval algorithms for heterogeneous network

Caicedo et al. (2020): “An automated common algorithm for planetary boundary layer retrievals using aerosol lidars”

- Covariance Haar Wavelet Transform Algorithm
- **Automated algorithm corrects for instrument signal quality and automatically screens for precipitation and cloud layers**
- Layer attribution for the planetary boundary layer height with continuation and time-tracking parameters and **uncertainty calculations through automatic filtering**

December 13, 2016 (CWT/C) profiles and retrievals from CHM15k (a), CL51 (b), CL31(c), and SkyVue Pro (d) ceilometers.
Planetary Boundary Layer (PBL)

Understanding the evolution of PBL is crucial for meteorological mechanisms such as precipitation, convection, severe weather and for air pollution dispersion and distribution.

- Lack of observations in the spatiotemporal scales needed to further our understanding of complex PBL dynamics.
- Ceilometers offer vertical monitoring as a low cost and reliable option.

Aerosol layering can be related.attributed to PBL.
Table 3. Overall results of all comparison available for the study including linear regression correlation coefficient ($r^2$), slope of linear regression, offset of linear regression, Bias, and root-mean square error.

<table>
<thead>
<tr>
<th></th>
<th>CL51</th>
<th>CHM15k</th>
<th>CL31</th>
<th>CS135</th>
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<tr>
<td>(r^2)</td>
<td>0.96</td>
<td>0.86</td>
<td>0.90</td>
<td>0.90</td>
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<tr>
<td>Slope</td>
<td>0.90</td>
<td>0.96</td>
<td>0.96</td>
<td>0.97</td>
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<tr>
<td>Offset</td>
<td>116.75</td>
<td>75.16</td>
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<tr>
<td>Bias (m)</td>
<td>-12.66</td>
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<td>11.82</td>
<td>-108.31</td>
</tr>
<tr>
<td>RMSE (m)</td>
<td>94.33</td>
<td>208.31</td>
<td>156.83</td>
<td>168.88</td>
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</tbody>
</table>

**Covariance Wavelet Transform Algorithm**

- **Automated** algorithm corrects for instrument signal quality and automatically screens for precipitation and cloud layers.
- **Layer attribution** for the planetary boundary layer height with continuation and time-tracking parameters.
- **Calculated uncertainties** in the individual planetary boundary layer height retrievals.
  - Uncertainties >200m are automatically flagged as invalid.

**Next Steps**

- Automatic parameter selection
- Algorithm training
Software Evaluations: Vaisala BL-View 2.1.x

- CL-View (.dat) and BL-View (.his) files supported → no offline reprocessing/viewing
- Undescribed resolution (temporal and vertical) changes between L1, L2, L3 files in both .nc and .his formats
- Documentation insufficient:
  - Archive data imports
  - Variables in new .nc files are not described (quality index, extinction profiles, etc.)
- Licensing verification failure (licensing server unreachable) stops BL-View software
  - Data loss unless manually restarted
  - Serial splitter prevented data loss
  - Raspberry Pi data logging alternative is possible

Retrievals

- Hourly MLHs comparison to CWT retrievals
  - Treatment of cloud signals (cloud base/top interchangeable in retrievals)
  - ML growth delay
  - Determination of PBL during precipitation?
Software Evaluations: Lufft Interface Options

**Web-based interface**
- Requires static IP
- Possibility at PAMS sites?
- Consistently falls out-of-sync with time
- Built in ftp transfer only with 1,5,10,15 minute options
- Internal SD card data storage

**PC software**
- Requires additional hardware
- Lufft PC software available for CHM15k only
- Allows for https transfers
- Internal SD card and PC data storage