EPAMS Profiler and Ceilometer Network

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[8]U.S. Environmental Protection Agency

2019 MARAMA Air Quality Monitoring Training Workshop
Swarthmore, PA

Research Areas

- **Boundary Layer Dynamics (Air Quality and Wind Energy)**

- Inversion algorithms, optical, chemical and physical properties of atmospheric aerosols, gases, and clouds.

- Continental and intercontinental plume transport to Eastern US.

- AOD-$PM_{2.5}$ Estimator from Ground, Satellite Observations, and Global Models

- New remote sensing technologies for atmospheric observations.

https://alg.umbc.edu

Observations Lead The Way

NRC

R. Hoff

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

NSF

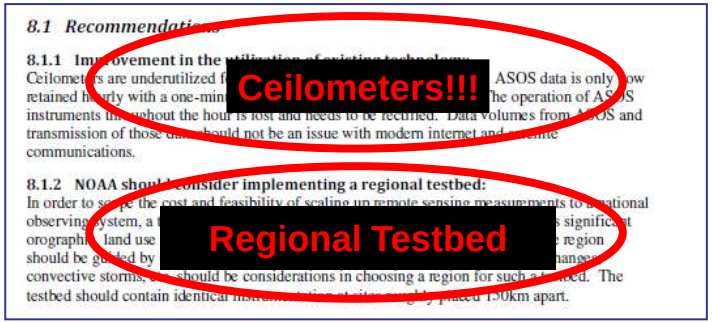
B. Demoz

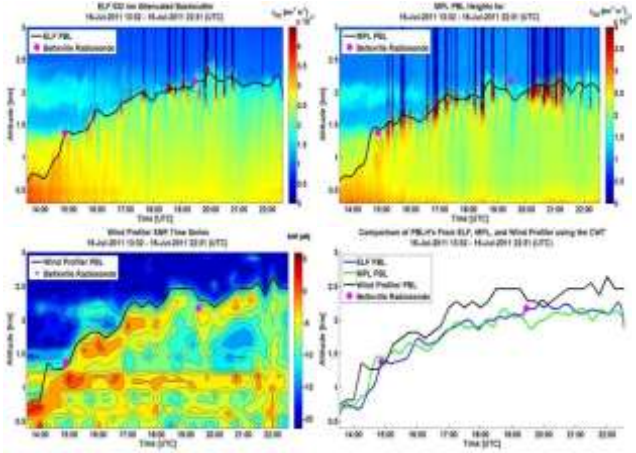
Thermodynamic Profiling Technology Workshop (2011)

NASEM

R. Delgado

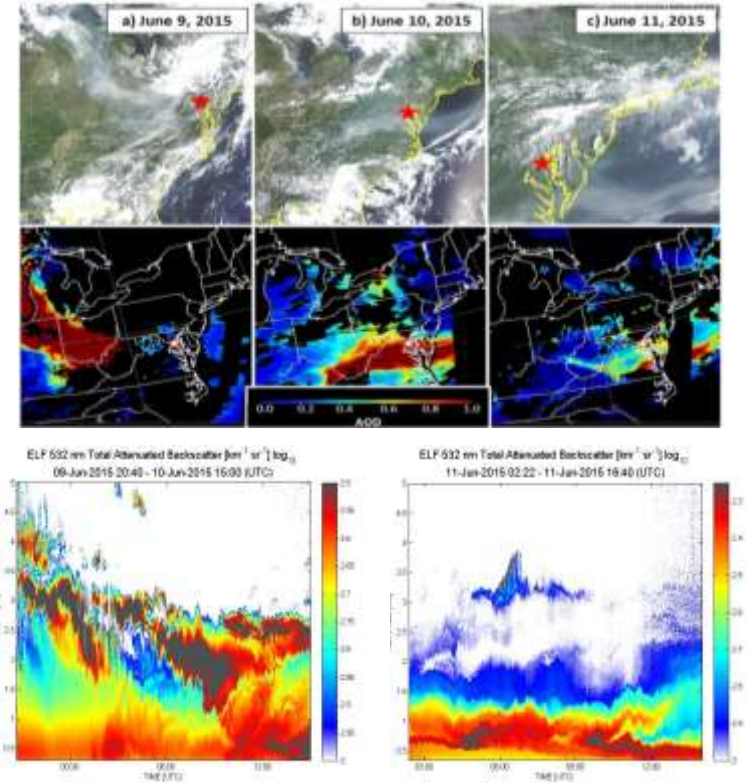
The Future of Atmospheric Boundary Layer Observing, Understanding, and Modeling (2018)





*Compton et al. (2013), J. Atmos. Ocean. Tech., doi:10.1175/JTECHD-12-00116.1

Measuring Our Changing World



Dressen et al., "Observations and impacts of transported Canadian wildfire smoke on ozone and aerosol air quality in the Maryland region on June 9–12, 2015", JAWMA, 2016

Ceilometer/Lidar Remote Sensing

- Observational platform for pursuing societal benefits.
- Engagement between the scientific community and wide range of stakeholders.
- Provide information for managing land, water, air quality, agriculture, energy, disaster response and ecosystems functions.
  - Field Campaigns: DISCOVER-AQ, OWLETS, LISTOS

US EPA PAMS Mixing Layer Height

- 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.

Ad-hoc Ceilometer Evaluation Study

- Joint Effort:
  - MDE/EPA/UMBC
  - Federal: NASA/NOAA
  - Academia: CCNY/Hampton and Howard University

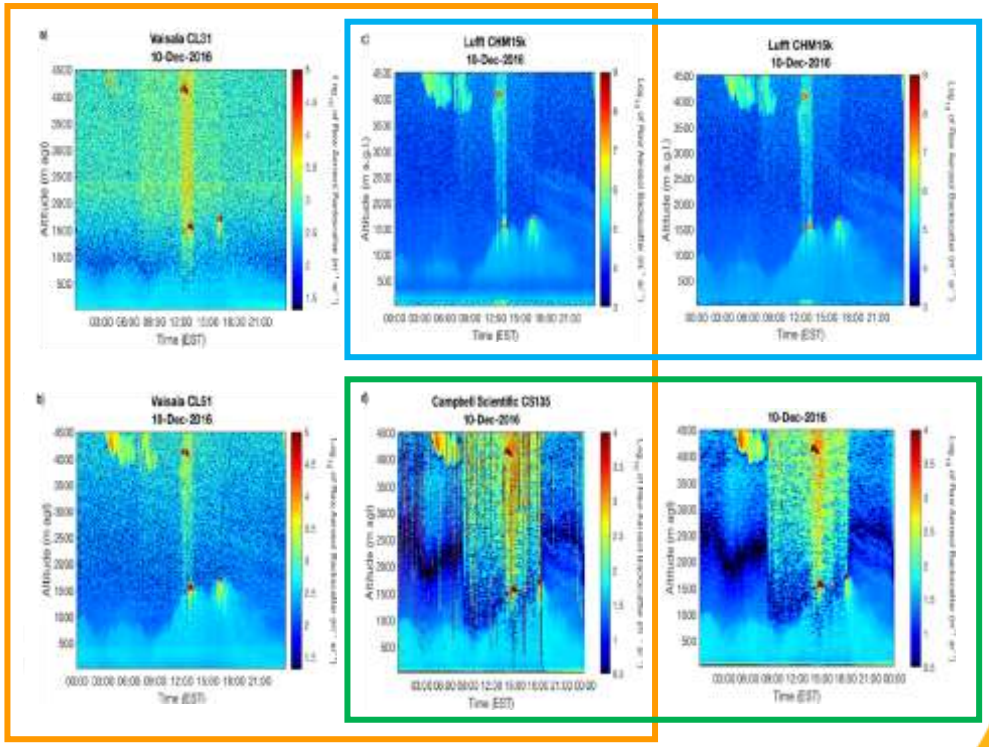
- Measurements to help guide EPA PAMS program implementation for new hourly MLH requirement.

- 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

Ceilometer Signal Evaluation

- Varying signal quality
  - QC/QA protocols per make/model
- Ceilometer signal evaluation and corrections
  - **Signal-to noise ratios**
  - **Overlap corrections**
  - **Artifacts**
  - Resolution



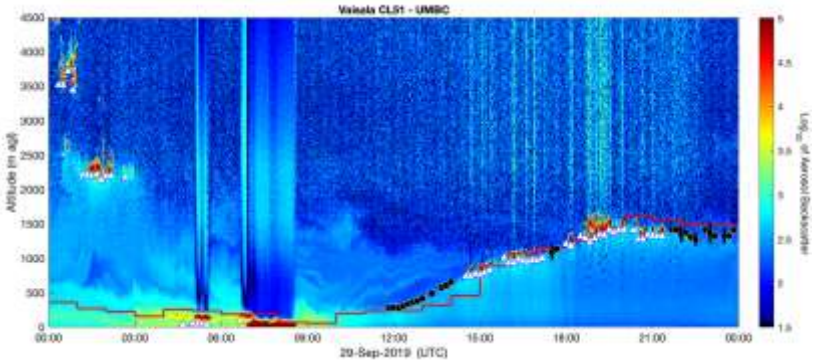
Commercial Software Evaluation

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?



Commercial Software Evaluation

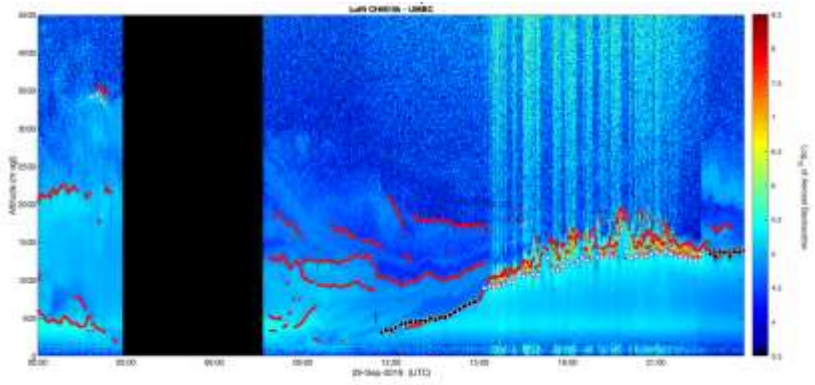
Software Evaluations: Lufft Interface Options

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

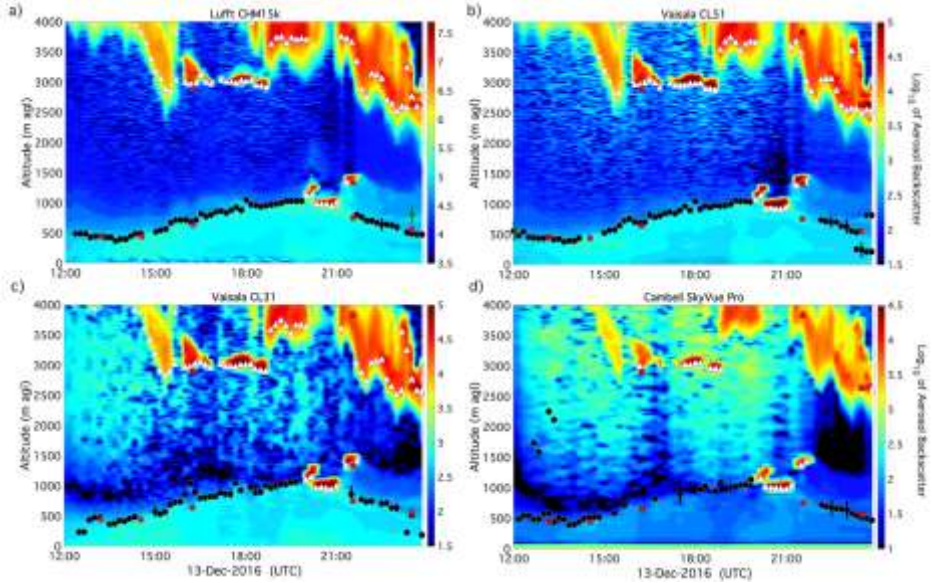
- Requires additional hardware
- Lufft PC software available for CHM15k only
- Allows for https transfers
- Internal SD card and PC data storage



Planetary Boundary Layer Height Algorithm

Covariance Wavelet Transform Algorithm

- **<u>Automated</u>** algorithm corrects for **instrument signal** quality and automatically **screens for precipitation and cloud layers**
- **Layer attribution** for the planetary boundary layer height with **<u>continuation and time-tracking parameters and uncertainty calculations</u>**



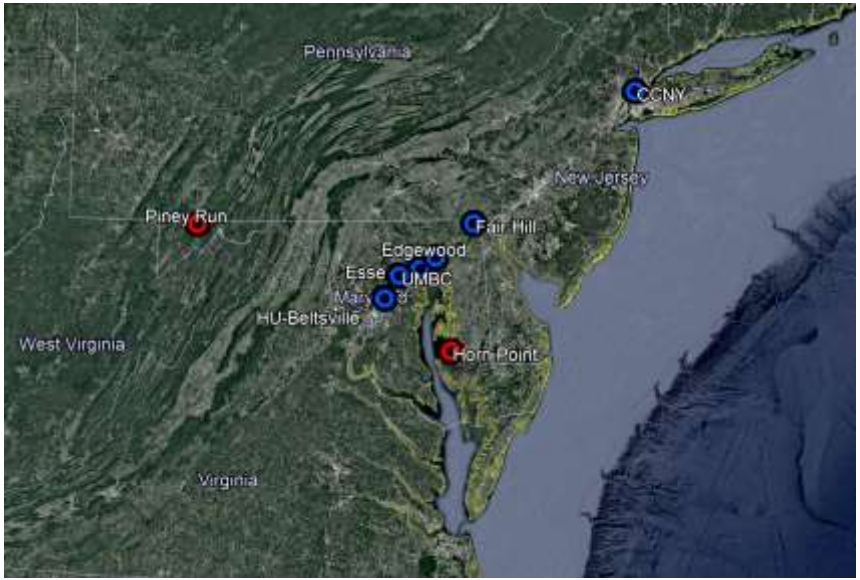
December 13, 2016 $(\overline{CWTC})$ profiles from CHM15k (a), CL51 (b), CL31(c), and SkyVue Pro (d) ceilometers. PBLH retrievals from the automated algorithm are displayed in black circles, while CBH retrievals are displayed as white triangles. Radiosonde heights for both PBLHs and CBH are displayed 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. (2019)

"An automated common algorithm for planetary boundary layer retrievals using aerosol lidars"

EPAMS Profiler and Ceilometer Network

Mixing Layer Height Network Testbed



Ceilometer/Lidars

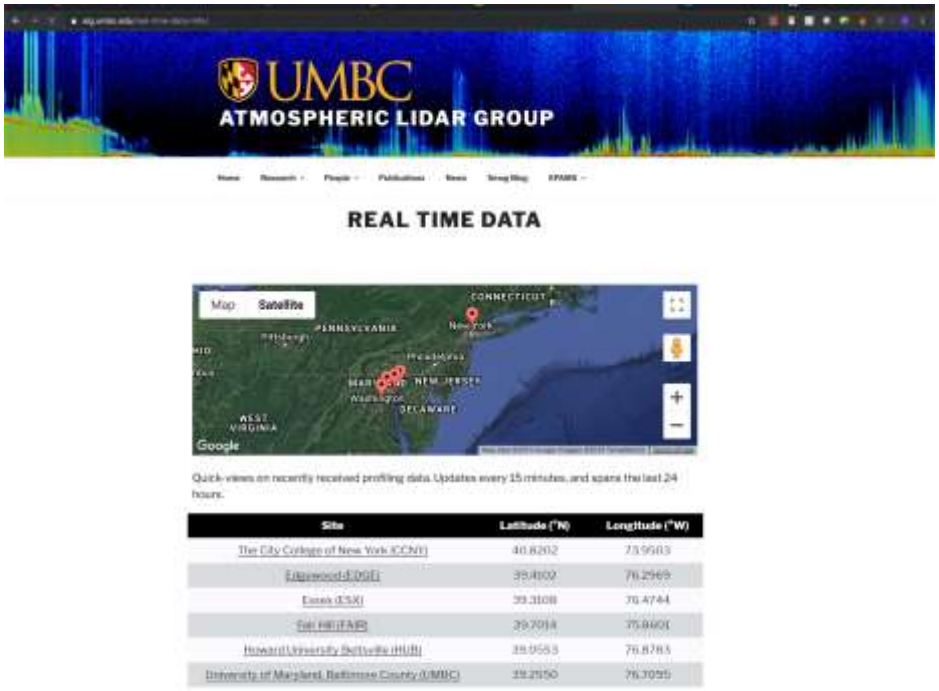
- **Fair Hill: Vaisala CL31**
- **Edgewood: Vaisala CL51**
- **Essex: Lufft CHM8k**
- **UMBC: Lufft CHM15k and MPL Sigma Space**
- **Beltsville (Howard Univ.): Lufft CHM15k**
- **CCNY: Lufft CHM15k**

Radar Wind Profiler

- **HU-Beltsville**
- **Horn Point Laboratory**
- **Piney Run**

EPAMS Profiler and Ceilometer Network

Real-time Monitoring – Sites and Data Transfer



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

Current Sites

Data Transfer: ftp

Next Steps

- https data transfers
- MD radar wind profilers (3)
- UMBC Doppler wind lidar
- Microwave Radiometer

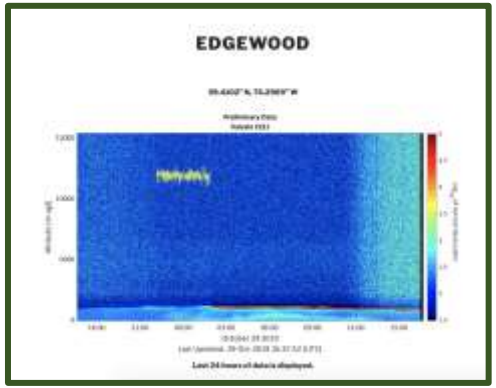
EPAMS Profiler and Ceilometer Network

Real-time Monitoring - Displays

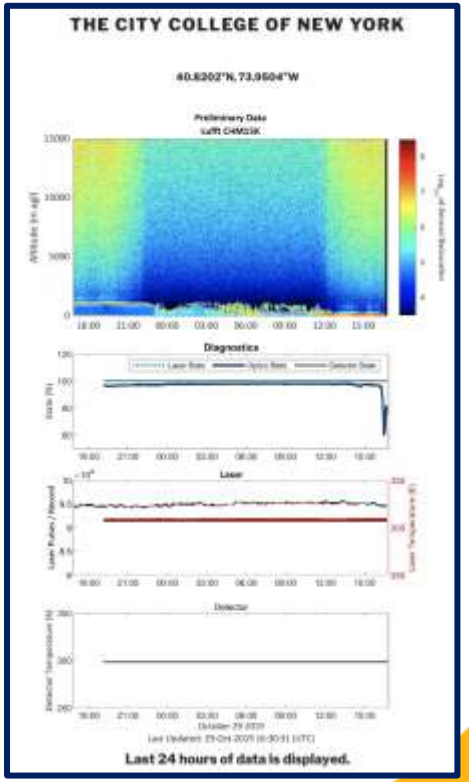
Current Status

- Display of 15-minute data for all MD sites + CCNY
  - Essex is displaying hourly data due to data limitations at site
- Real-time diagnostic parameters displayed for Lufft ceilometers
  - state of laser, detector, and optics; laser pulses; laser temperature; detector temperature

Vaisala Real-Time Display



Lufft Real-Time Display



Next Steps

- Real-time retrievals for all sites (second server setup)
  - PBL and cloud heights
- Notification/Monitoring for diagnostic parameters
- Dynamic display

EPAMS Profiler and Ceilometer Network

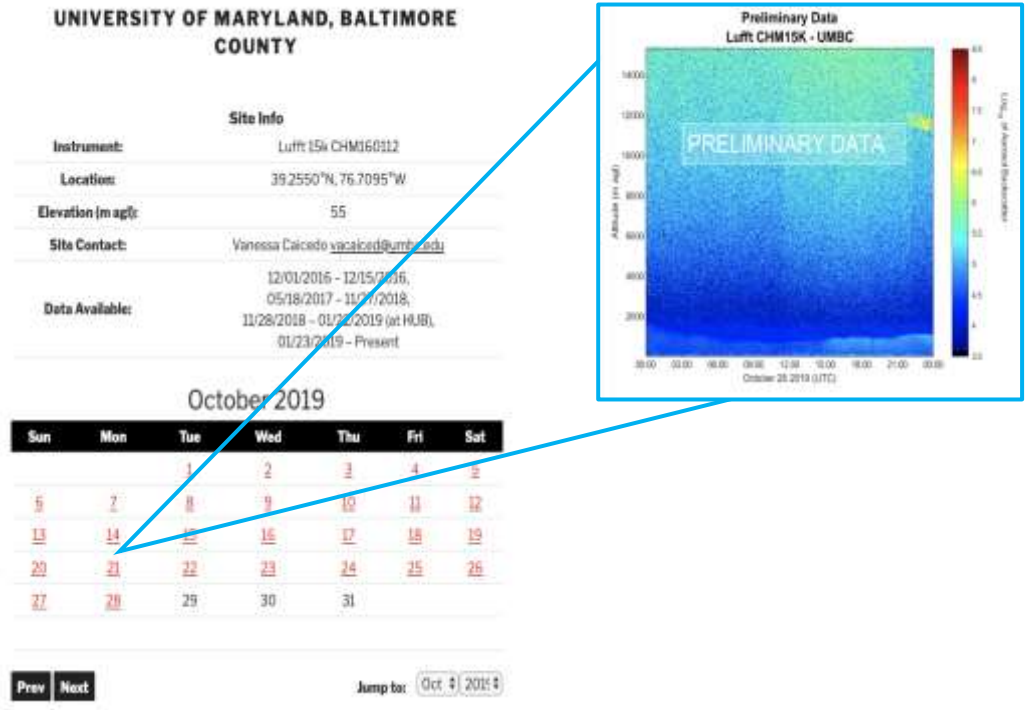
Data Archive

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)



EPAMS Profiler and Ceilometer Network

How to join?

Consideration will be given to include non-MDE sites depending on the complexity of the effort required to obtain data feed.

To join email data@umbc.edu, guidance will be provided to bring site on board.

QC/QA Mixing layer height will be provided to those joining network

User Feedback

Besides MLH requirement, what you are considering using data for?

Acknowledgements

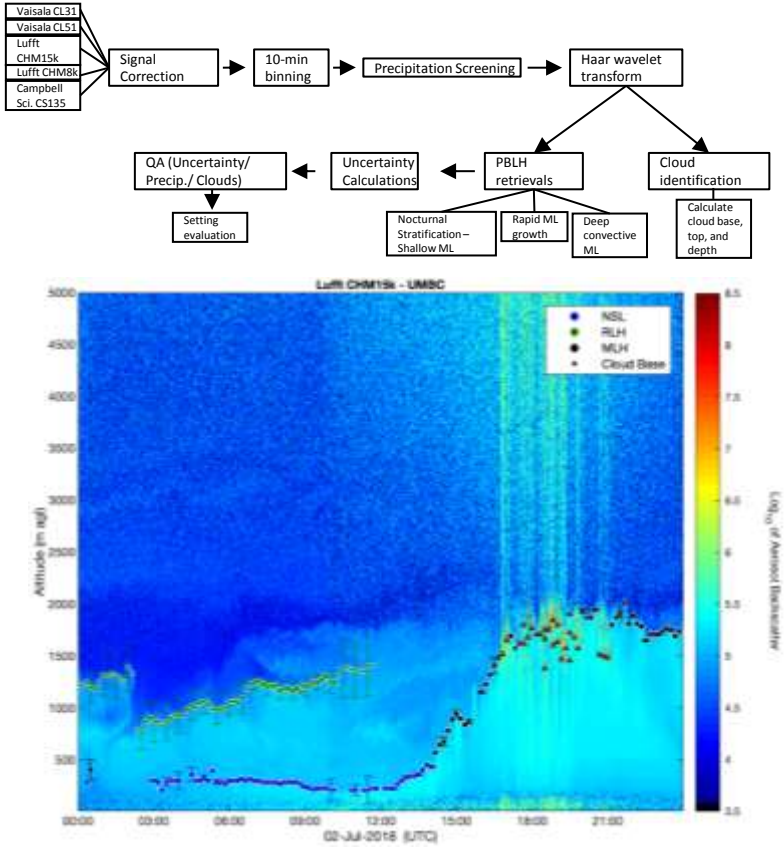
Maryland Department of the Environment
Environmental Protection Agency
NOAA Office of Education
NASA
Campbell Scientific
Lufft
Vaisala
Leosphere
NRG Systems

Backup Slides

Ad-hoc Ceilometer Evaluation Study

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, 2019)

Planetary Boundary Layer Height Algorithm

Covariance Wavelet Transform Algorithm

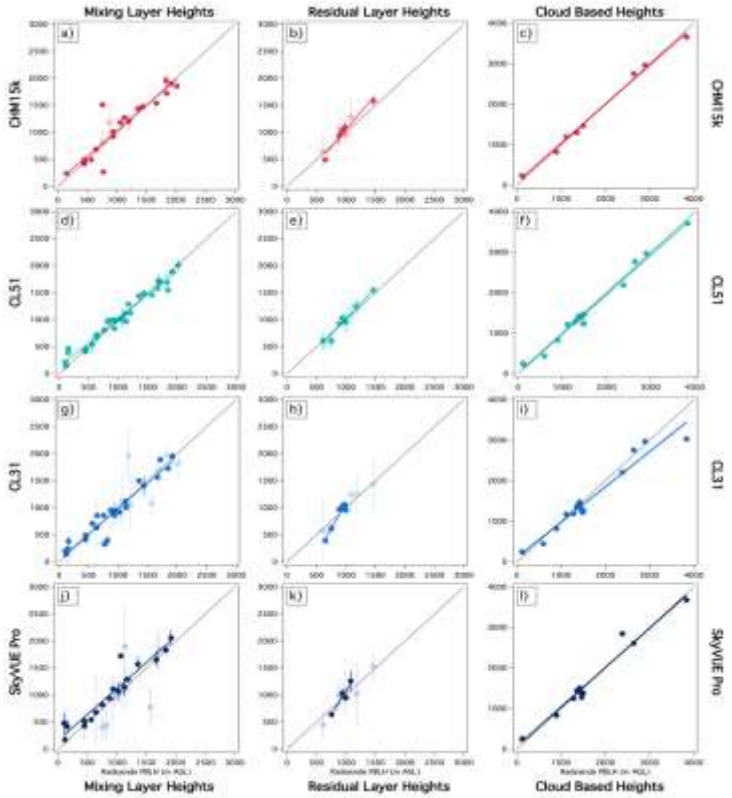
- **Automated** algorithm corrects for **instrument signal** quality and automatically **screens for precipitation and cloud layers**
- **Layer attribution** for the planetary boundary layer height with **continuation and time-tracking parameters**
- **Calculated uncertainties** in the **individual**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

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.

	CL51	CHM15k	CL31	CS135
r^2	0.96	0.86	0.90	0.90
Slope	0.90	0.96	0.96	0.97
Offset	116.75	75.16	27.39	134.52
Bias (m)	-12.66	-30.35	11.82	-108.31
RMSE (m)	94.33	208.31	156.83	168.88

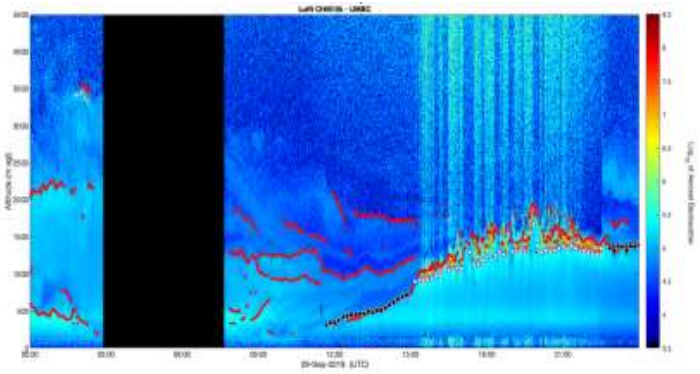
Next Steps

- Automatic parameter selection
- Algorithm training

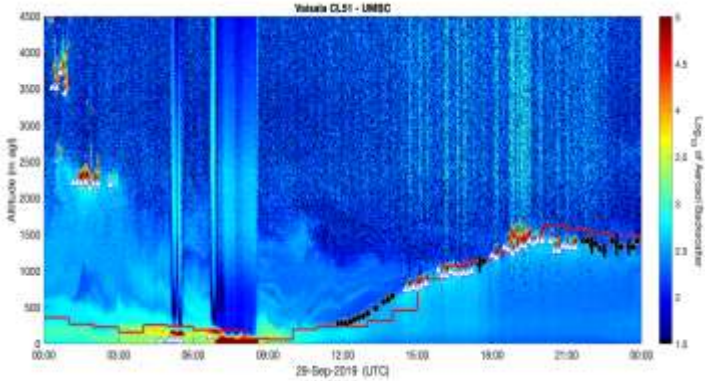


Commercial Software Evaluation

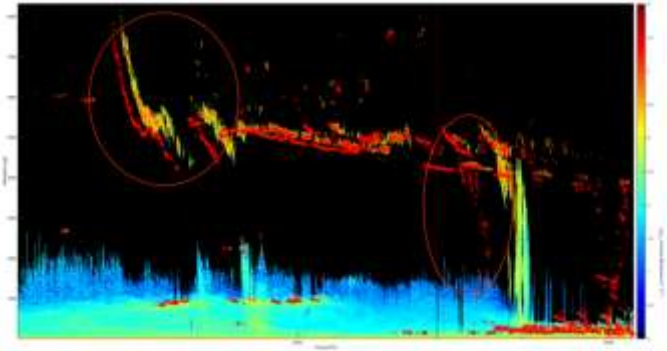
Lufft PBL heights



Vaisala Hourly PBL heights



Campbell Sci. Cloud heights



Software Evaluated

- Vaisala CL 51: BL-View
- Vaisala CL 31 : CL-View
- Campbell Scientific CS135: Viewpoint
- Lufft CHM8k and CHM15k: Lufft Viewer

CWT Set of rules
CWT Clouds
Commercial software