UMBC
AN HONORS UNIVERSITY IN MARYLAND

Ad-Hoc Ceilometer Evaluation Study (ACES): Evaluation of Lidars and Ceilometers Mixing Layer Heights

Ruben Delgado[1], Belay B. Demoz[1], Kevin C. Vermeesch[1], Brian J. Carroll[1], Tahmid Abtahi[1], Benjamin Tucker[1], Ricardo K. Sakai[2], Jasper Lewis Jr. [3], Ellsworth J. Welton[4], Michael Hicks[5], Dennis Atkinson[5], Timothy A. Bonin[6], Travis Knapp[7], James Szykman[8]

[1]JCET/CREST/UMBC, [2]NCAS/HU, [3]JCET/NASA GSFC, [4]NASA GSFC, [5]NOAA/NWS, [6]CIRES/NOAA ESRL, [7]SSAI/NASA LARC, [8]EPA/NASA LARC

21st Annual George Mason University Conference
Atmospheric Transport and Dispersion Modelling
June 13, 2017

UMBC Atmospheric Lidar Group Research Areas

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

- Boundary Layer Dynamics (Air Quality and Wind Energy)

- Continental and intercontinental plume transport to Eastern US and Caribbean.

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

- New remote sensing technologies for atmospheric observations.

http://lidar.umbc.edu

Observations Lead The Way

NRC study: Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks (2009) → Thermodynamic Profiling Technologies Workshop 12-14 April 2011

- National Research Council has recommended a "network of networks"[1]
  - After 60 years of remote sensing research, it is astounding that the PBL is not measured regularly throughout its diurnal cycle.
- NWS response to report: archiving the full data profile of the Automatic Surface Observing System's (ASOS) ceilometer network, as proof of concept.
- UMBC and Howard University (HU), in collaboration with NOAA/NWS and NCEP, has been engaged in a pilot study to utilize the full data profile of NOAA/NWS ASOS ceilometer network.

Mixing Layer Height (MLH)

- MLH is a diagnostic variable atmospheric transport and dispersion forecasting models.
- One of the objectives of this work is defining the technical details of the retrieval of aerosol mixing height as a proxy of the MLH.
- Quasi-real time algorithm have been developed and are being tested and validated using the HU/UMBC regional ceilometers/lidar network.
- Models: inaccurate MLH will not predict surface concentrations correctly and are likely to be compensated by tuning of other parameters, such as chemistry and emissions, in order to adjust surface concentrations to reality.

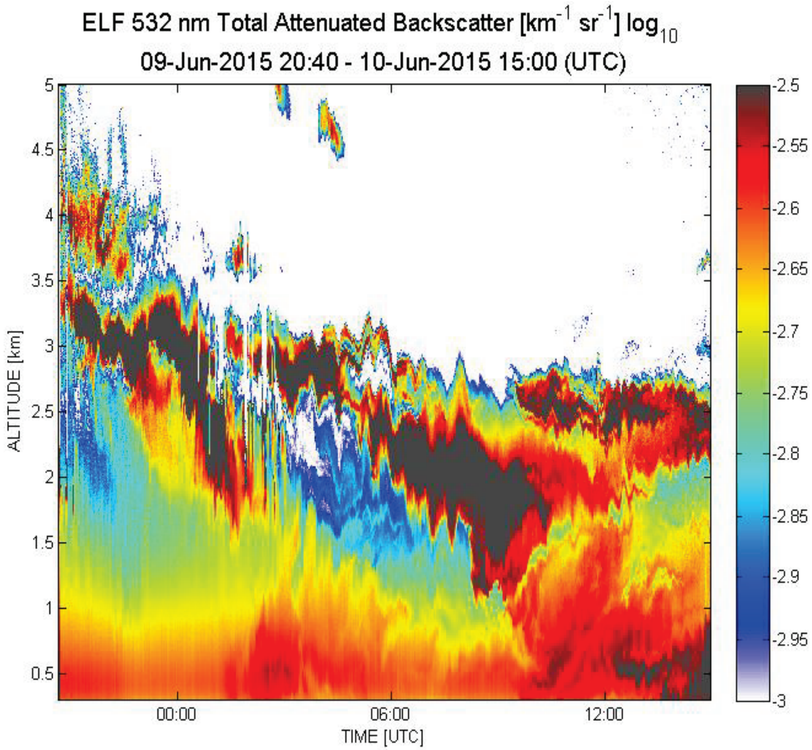
Lidar and Ceilometer Test Bed Activities

- PM-studies: Scaling Satellite-measured AOD and PM-Correlations
- Night time convection: PECAN experiment [Elevated storm]
- Limited network of Ceilometer: Baltimore-Washington-area-Network
- Evaluation of Ceilometers (CL31, CT12, CL51)
- CL31 data statistics: Cloud base above 12000 ft needs to be reported
- **MLH study: Algorithm Comparison**
- Air Quality Applications
  - Fire and Air quality
  - Volcanic ash monitoring

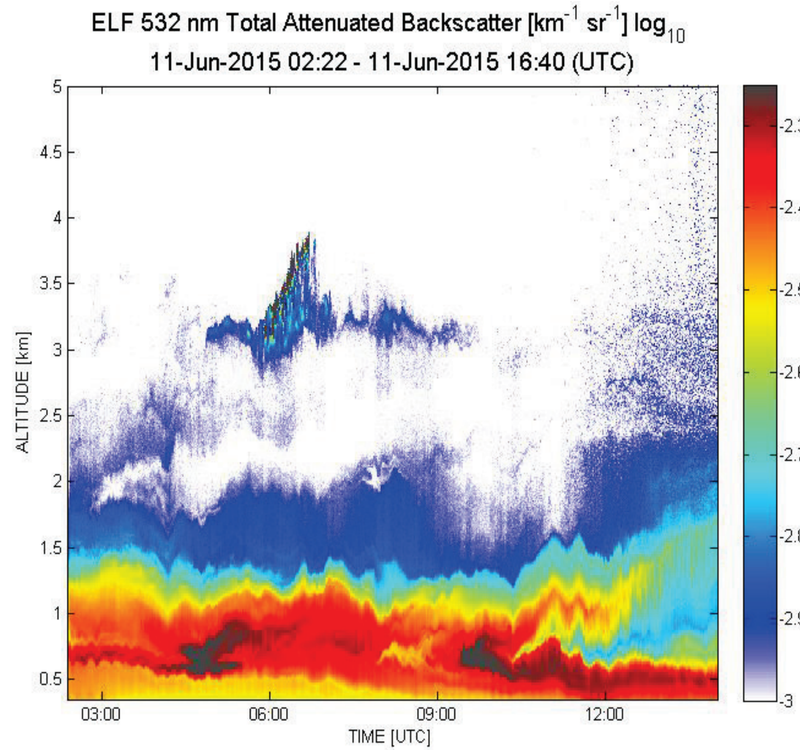
UMBC

A N H O N O R S U N I V E R S I T Y I N M A R Y L A N D

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



Elastic lidar backscatter image shows aerosols aloft (1.5-3 km) on June 10th. The particles began to mix causing increased surface particle pollution.



The 11th shows a homogenous layer, smoke within the mixing layer which extends up to 1.5 km.

Ad-hoc Ceilometer Evaluation Study (ACES)

- Nov. 15-Dec. 16, 2016 @ UMBC (Catonsville, MD)
- EPA/NWS/UMBC Measurements to help guide EPA PAMS program implementation for new hourly MLH requirement and supplement current efforts under NWS ceilometer test bed.

Instruments:
Campbell Scientific –CS135 (Viewpoint)
Leosphere ALS-450 and **200S Windcube (UMBC algorithm)**
Lufft CHM15K (Firmware 0.73)
iMet-1-ABxn 403 MHz GPS Radiosonde
Radiometrics MP-3000
Sigma Space Micropulse Lidar
Vaisala – CL-31 and **CL-51 (BLView 1.19), Digicora MW41 (RS-41 and RS-92)**

Objectives

- Evaluate the range corrected attenuated backscatter from commercial ceilometers with a focus in the lowest 4 kms .
    - UMBC AERONET climatology indicates low aerosol loading (AOD < 0.2) for Nov/Dec compared to the summer months (AOD > 0.5). Providing an challenging environment for the SNR of the ceilometers.
    - Surface daily $PM_{2.5}$ did not exceed 10 μg/m^3.
- Assess the daytime mixing layer height determination from commercial ceilometers:
    - MLH from vendor software and a common algorithm.
    - Focus on transition time periods.
- What additional information can be gained from ceilometers, such as elevated layers aloft and entrainment?

MLH Determination

Radiosondes:

- Potential Temperature Ascending rate – 3-5 m/s.

- Launch times: 7:00, 9:00 and 11am, 4:30 and 6:30pm (Local Time).

- MLH calculation

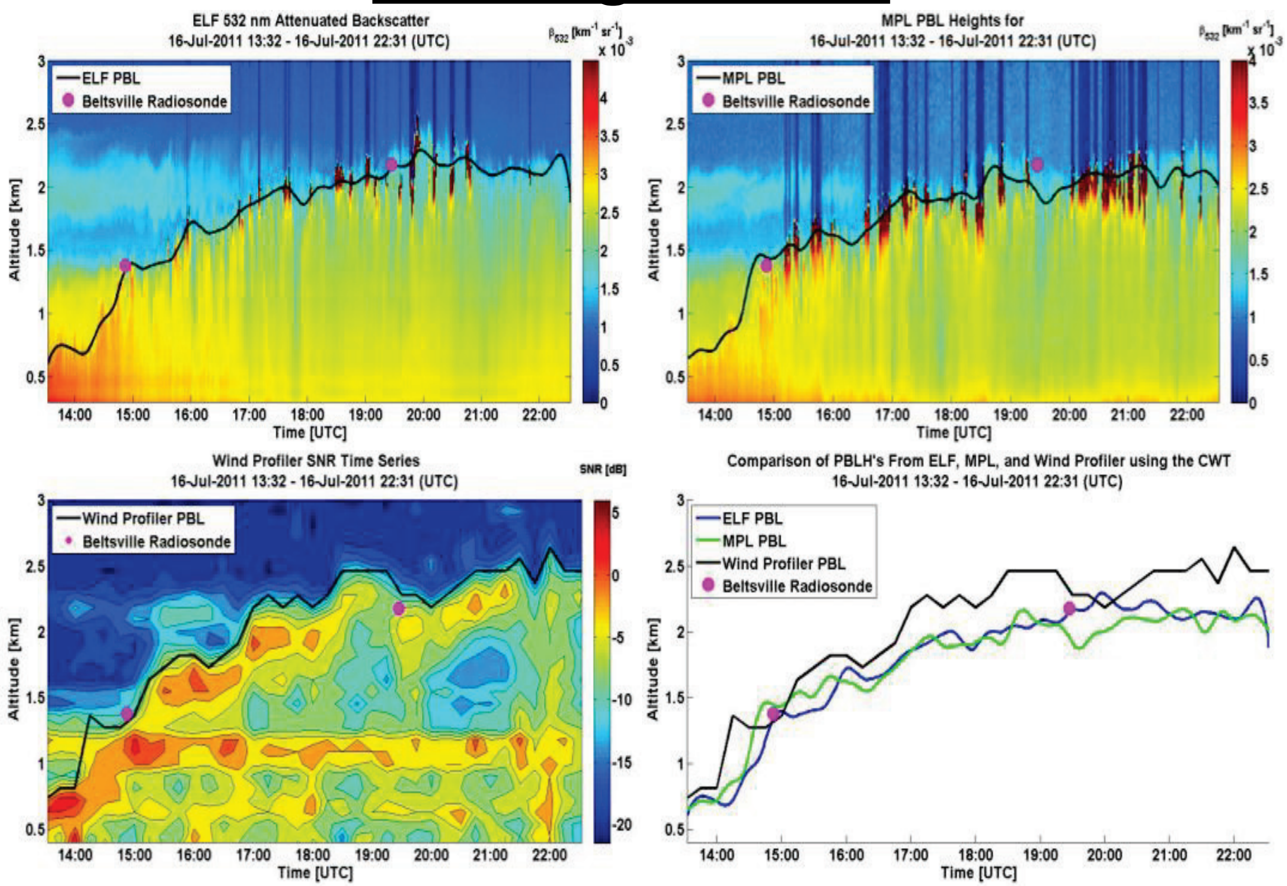
  Hefter Method: $\Delta\theta/\Delta z > 0.005\ K\ m^{-1}$

  $\Delta\theta > 1.5\ K$

Lidar/Ceilometers:

- Aerosol Gradient on Backscatter Profile.
- 15 min average MLH from Commercial Software.
- Covariance Wavelet Transform (CWT) to Leosphere 200S Vel. Variance.
- Over/Underestimation: Difference Sondes to Lidar/Ceilometer

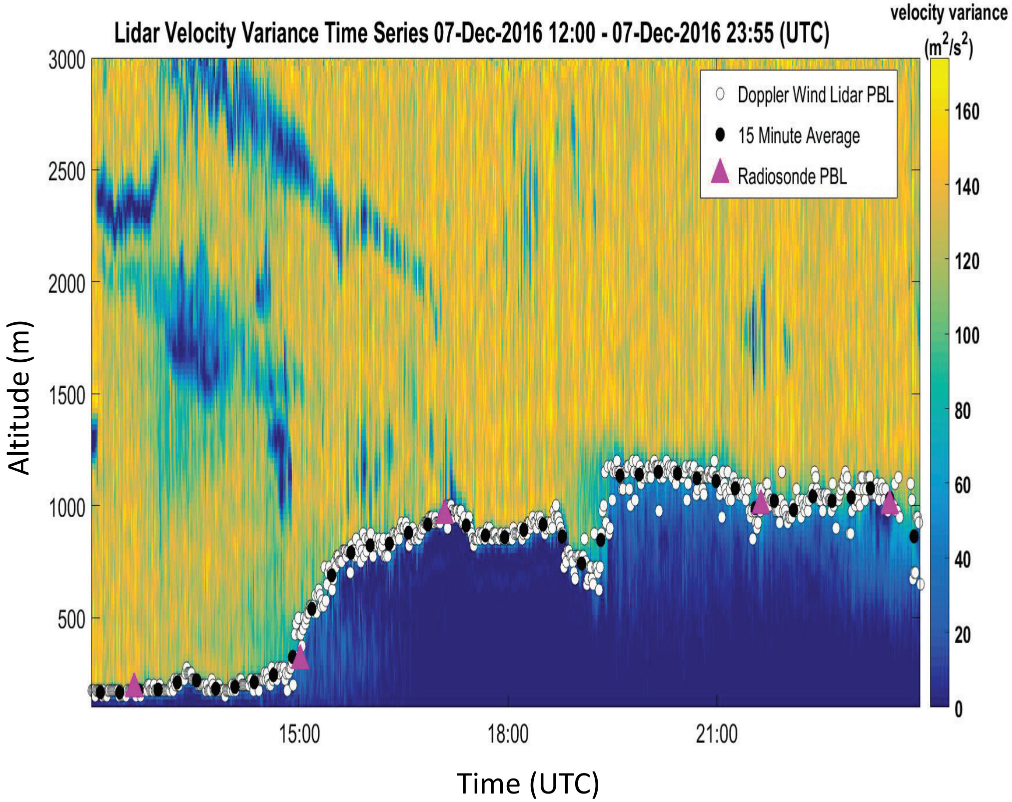
MLH Algorithms

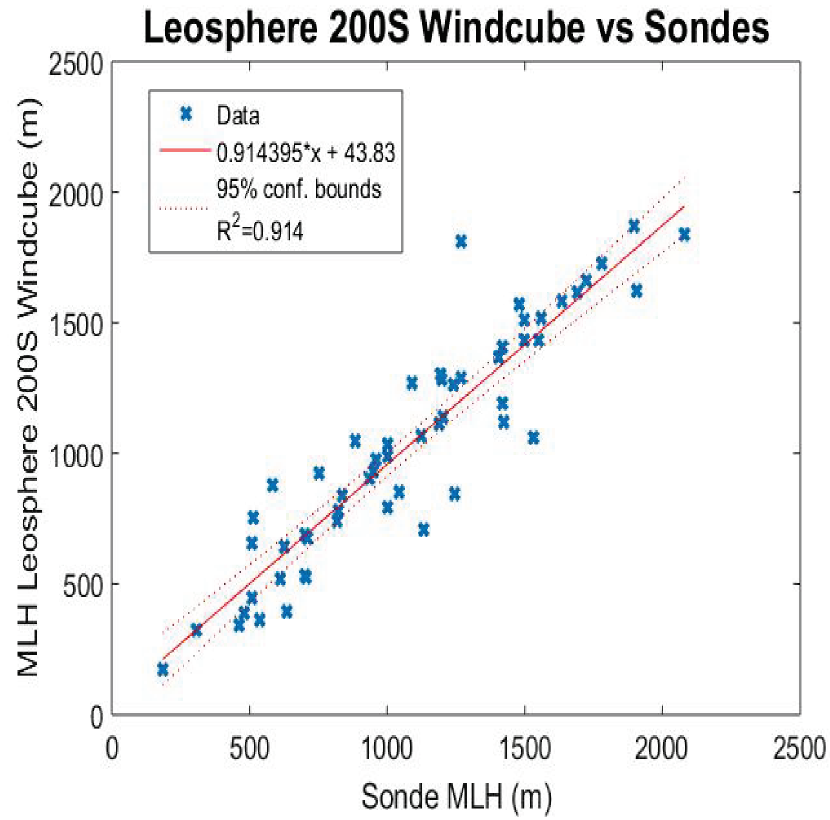


- Lidar and wind profilers MLH can provide continuous temporal resolution atmospheric profiles for verification and validation of forecasts and models, on whether the physics and dynamics packages are correct in models.

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

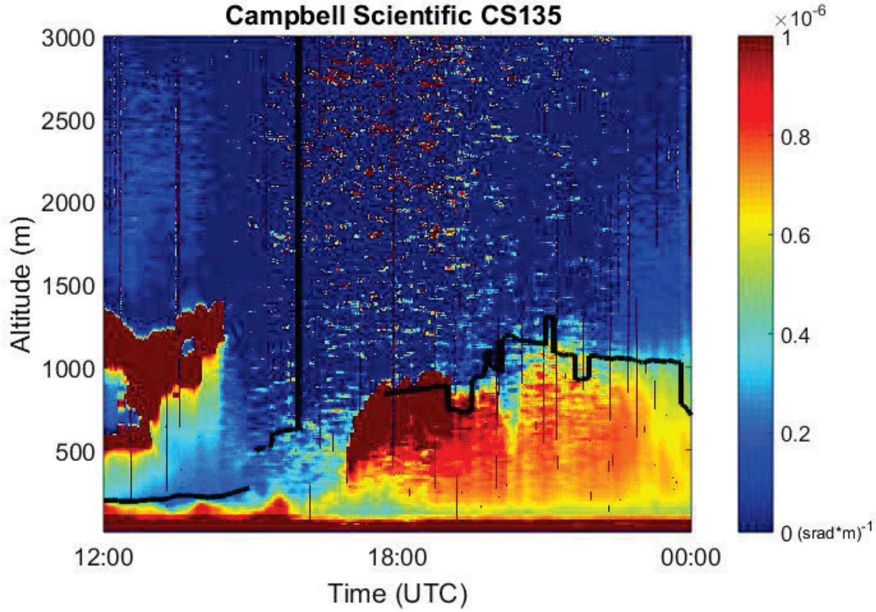
Leosphere Doppler Wind Lidar

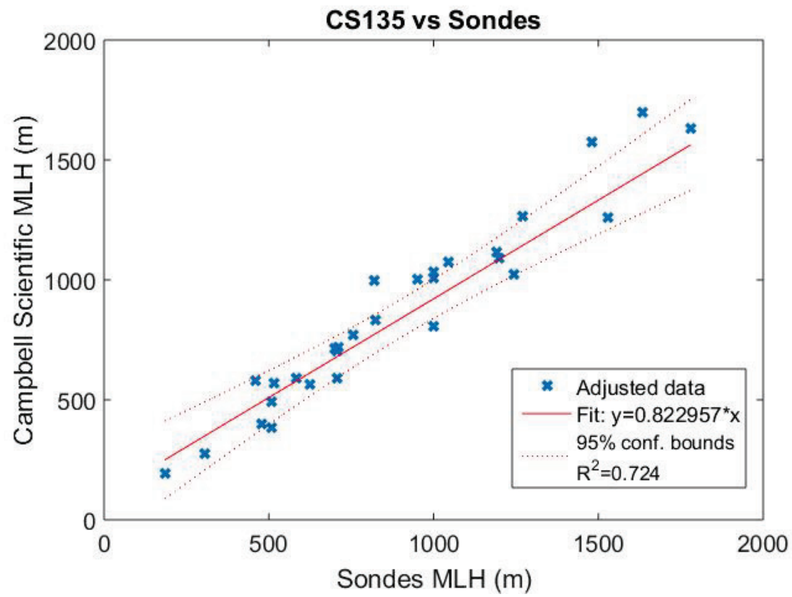




- CWT Doppler Wind Lidar Velocity Variance.
- Number of 15 min. observations/coincidence with sondes: 55.
- Algorithm captures transitions: CWT parameters varied for best agreement.
- Doppler Wind Lidar Underestimates MLH: Median 76 m.

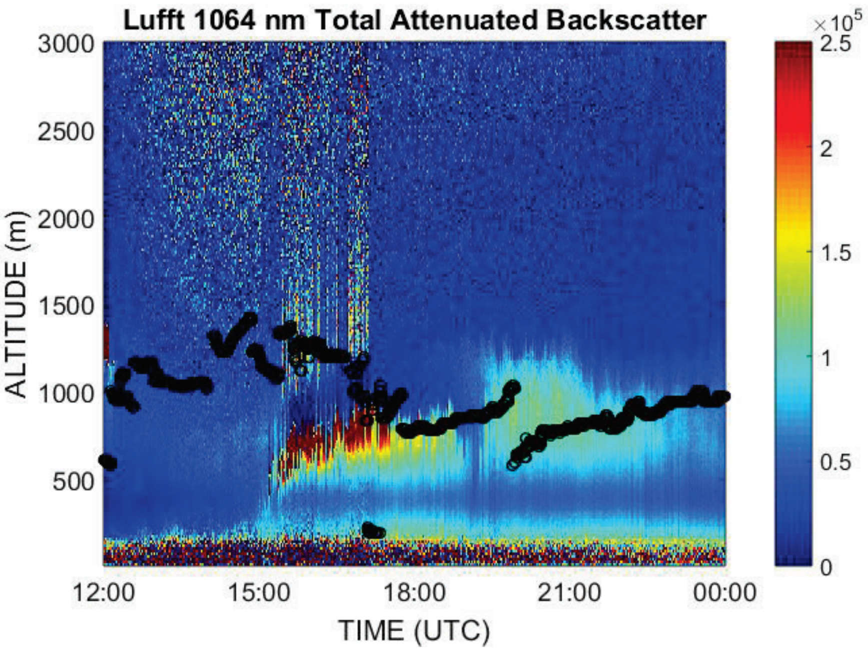
Campbell Scientific CS135

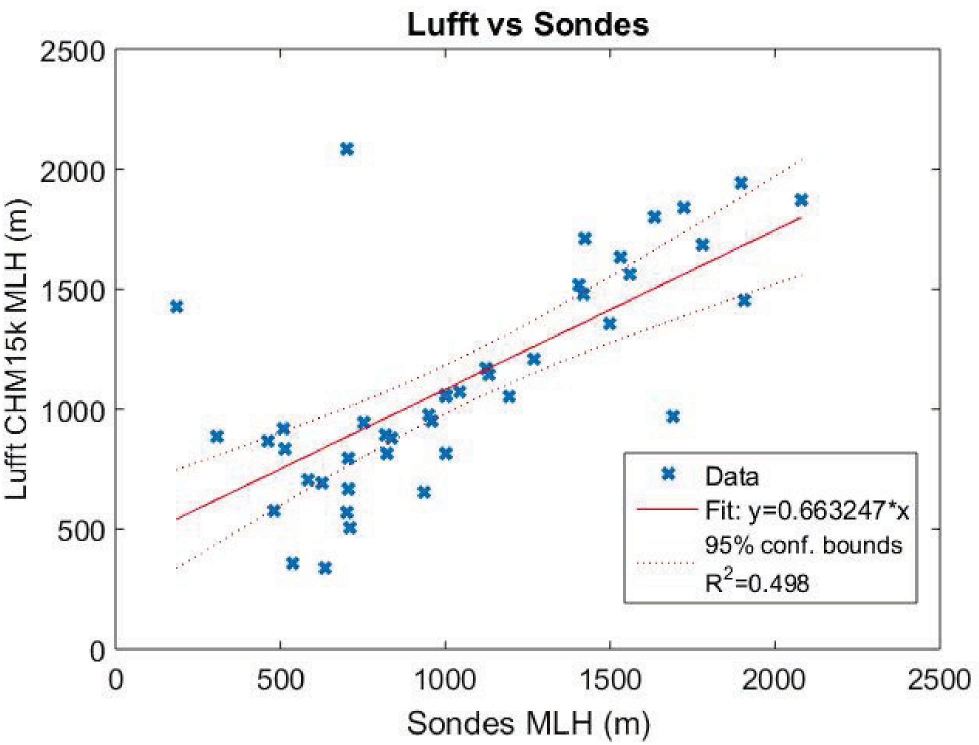




- Number of 15 min. observations/coincidence with sondes: 30.
  - In a few occasions no MLH were reported.
- Viewpoint (CS135) MLH 50% (Over/underestimates) during transition times.
- During daylights hours (09:00-16:00 LST) the Viewpoint software provides significantly less MLH retrievals compared to BLView and Lufft.
- Median 2 m.

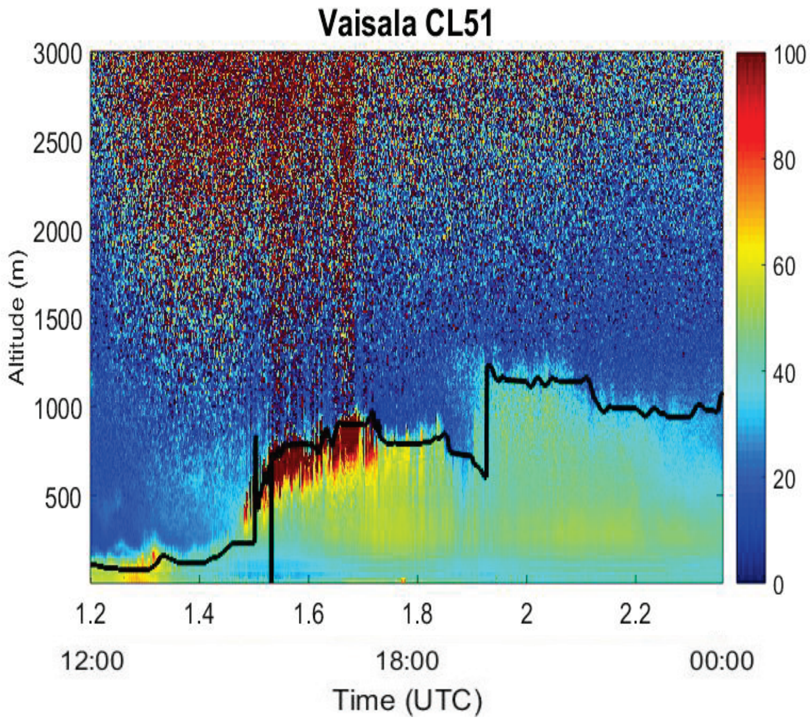
Lufft CHM15k

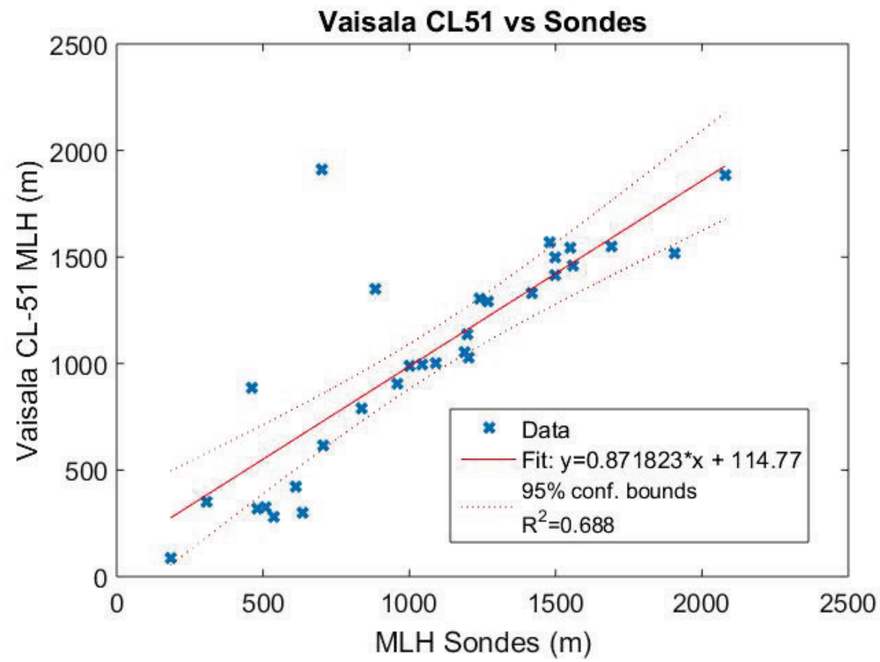




- Number of 15 min. observations/coincidence with sondes: 31.
  - In a few occasions no MLH were reported.
- MLH Software Overestimates MLH 71% during transition times.
- Median 87 m.

Vaisala CL-51





- Number of 15 min. observations/coincidence with sondes: 31.
  - In a few occasions no MLH reported.
  - User interpretation of MLH: select one of 3 possible aerosol gradients.
- BL View Underpredicts MLH 74% during transition times.
- Median 87 m.

Results

- UMBC CWT, BL View and Lufft MLH Software more robust more at deriving an estimated MLH than Viewpoint (CS135) from the number of coincident matches with sondes.

- CS135 and CHM15k need an overlap correlation between 100-500 m for adequate determination of shallow MLH during cold season.

- Lufft and CS135 good SNR at high altitudes. Ideal to monitor particle pollution associated with long range transport.

- All systems show a MLH difference no greater than 100 m between ceilometers and sondes. Experienced analyst required.

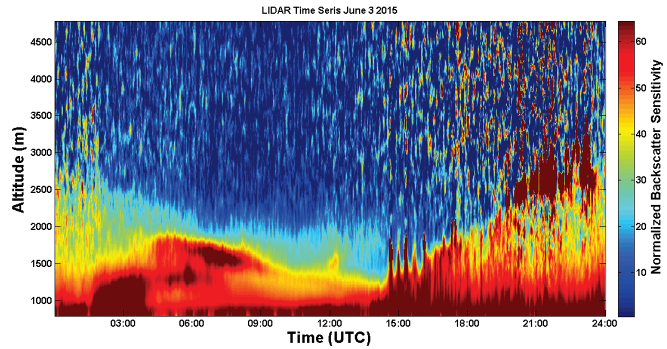
Future Work

- Process all ceilometer data with common algorithm (CWT, Cluster Analysis, Peak Threshold).
- Characterization of instrument/system errors.
- Conduct same measurements Summer 2017, to study the effects of saturated aerosol loading (AOD > 0.5) and elevated layers aloft (smoke).
- Interested in join the Mixing Layer Height Working Group.

  http://lidar.umbc.edu/ad-hoc-mixing-layer-height-working-group/

Cluster Analysis

- Applying clustering algorithm (Kmeans) to detect MLH
- Applying Machine learning Algorithm (linear Regression) for MLH detection

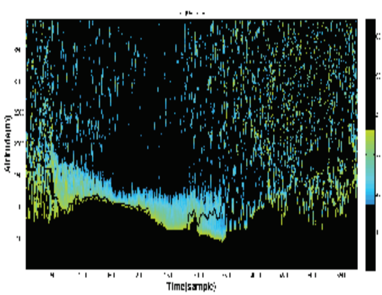


Medium Particle Density

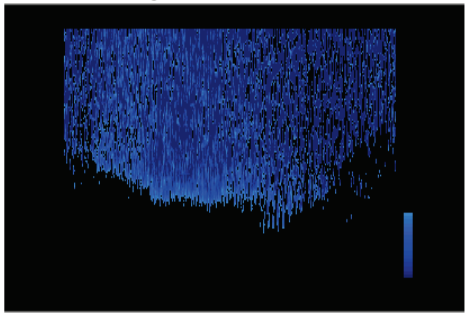
Low Particle Density

High Particle Density

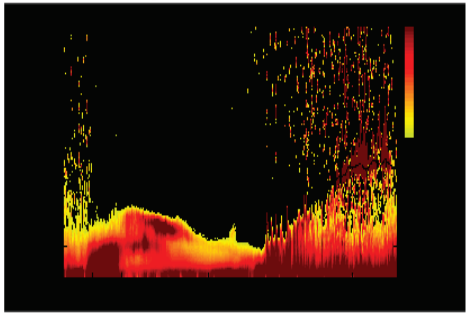
objects in cluster 1



objects in cluster 2



objects in cluster 3



Acknowledgements

- Maryland Department of the Environment
- Environmental Protection Agency
- National Weather Service
- NOAA Office of Education
- Campbell Scientific
- Lufft
- Vaisala
- Leosphere/NRG Systems