Micro Pulse LiDAR Delivers Accurate PBL

Comparing the performance of atmospheric transport models to real-life measurements helps researchers isolate problem areas and produce more accurate urban air pollution and greenhouse gas (GHG) emission estimates. As cities and states commit to improving air quality to alleviate concerns about public health and climate change, the need for baseline information and ongoing data collection is increasing.

A verification system for monitoring rises and reductions of GHG emissions relies on reducing uncertainties in planetary boundary layer (PBL) simulations in atmospheric transport models at the urban scale. A continuous record of the backscatter of light from aerosols collected by a Mini Micro Pulse LiDAR (MiniMPL) sensor has been successfully used to estimate PBL and residual layer (RL) heights. Model performance is assessed by comparing MiniMPL measurements to simulated measurements.

Inaccurate PBL Simulation Leads to Bias

Since the PBL defines the mixing height of air pollutants in the lowest layer of the atmosphere, simulated PBL height is a key input in air quality models. It is the turbulent domain that connects the surface environment to the large-scale atmosphere and serves as a locus for vertical and horizontal transport. The PBL responds to surface activity within an hour or less, making it very dynamic. Height can range from less than 100 meters to several kilometers in a given day, and air quality changes frequently.

Simulations of the PBL height from numerical weather prediction (NWP) models are often too high or too low in comparison to data from soundings or other traditional measurement methods. If the simulated PBL is lower than the observed PBL in atmospheric transport models, simulated particles in the air are closer to the surface, biasing air pollution levels too high (and vice versa). From an air quality perspective, these biases lead to inaccurate assessments of pollution levels and effects on public health.

Also, the RL that separates the PBL from the free atmosphere is influenced by windborne pollutants from other geographic areas. This transboundary pollution occurring in the RL contributes to ground-level concentrations the next day. Understanding the origin of aerosols and who is responsible for them will be crucial to state and local initiatives tasked with improving air quality.

Verify GHG Emissions and Compare Simulations to Actual PBL

To test the performance of atmospheric transport models and improve estimates of urban air pollution and GHG emissions, researchers from Harvard University, Boston University and Atmospheric and Environmental Research, Inc., joined together to conduct a study[1] in Boston, Mass. To evaluate the daytime PBL and the nighttime RL over a 15-month period, a MiniMPL sensor was installed on the rooftop of a Boston University building to collect data.

The MiniMPL sensor was selected for the PBL study based on its ability to measure the backscatter of light from aerosols in the atmosphere, allowing researchers to image the PBL and RL. Also, the MiniMPL unit is compact and requires little to no onsite maintenance. It can be installed on a rooftop or on the ground and be programmed to obtain continuous measurements with little oversight.

"Historically, PBL soundings have been taken at specific rural locations only twice a day, whereas the high temporal

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> *– Yanina Barrera, Harvard University*

resolution of the MiniMPL provides a complete 24-hour record and reflects conditions in situ,” said Yanina Barrera, Harvard University. “We have developed the first long-term and continuous record of PBL and RL heights in Boston using a MiniMPL sensor.”

From 32 m above the ground, the MiniMPL sensor recorded the backscattering of light from aerosols in the PBL, averaged over 5-min bins at a vertical resolution of 30 m. The team developed an image-processing algorithm that encompassed wavelet filtering to denoise scattering signals. This algorithm helped retrieve PBL and RL heights in Boston using normalized relative backscatter (NRB) profiles from the MiniMPL sensor. NRB signals gradually increase from morning to afternoon as anthropogenic activities on land, such as traffic and industry, emit aerosols. Analysis of data over longer periods of time also revealed monthly and seasonal variations of the PBL and RL.

Results of the Study

The calculated PBL heights were compared to simulated heights in seven configurations of the NWP models. The comparisons revealed discrepancies in PBL height estimates from NWP models ranging from –2.5 to 4.0 km caused by a variety of systemic errors. Results from *Barrera et al., 2019*, show that mean percent error can exceed 350% in NWP models during the morning hours of the winter season, highlighting why atmospheric transport modeling studies are often performed during the afternoon hours to reduce errors. Seasonally, systematic errors varied for each NWP model and from one NWP model to another.

The RL analysis revealed emissions traveling to Boston at night originating from areas of Pennsylvania, New York, and Connecticut that contained emissions from coal mining, power plants, heavy traffic, wintertime biomass burning, and other industrial sources. As cities and states try to minimize their contribution to greenhouse gases, pinpointing emission sources and quantifying the amount of pollution being transported is very important.

“Our work shows how a simple, robust MiniMPL system can help estimate GHG emissions and establish accurate baselines at urban and subnational scales,” says Barrera. “Results of our study published in *Environmental Science & Technology*[2] showed that the time intervals with significant disagreement between the MiniMPL-derived and modeled PBL height were excellent predictors for CO2 errors in models.”

About Micro Pulse LiDAR

Elevating Atmospheric Monitoring

Micro Pulse LiDAR (MPL), part of Hexagon develops innovative solutions that deliver a rich source of atmospheric feature information. Scientists, researchers, meteorologists, and other professionals who monitor and analyze clouds, air quality and safety, rely on MPL instruments to better understand atmospheric structure and uncover changes that can have an impact on our environment & health.

For more information, visit www.micropulseLiDAR.com.

1 Barrera, Y.; Nehrkorn, T.; Hegarty, J.; Sargent, M.; Benmergui, J.; Gottlieb, E.; Wofsy, S. C.; DeCola P.; Hutyra, L. R.; and Jones, T. Using lidar technology to asses urban air pollution and improve estimates of greenhouse gas emissions in Boston. *Environmental Science and Technology. 2019*, DOI:10.1021/acs.est.9b00650.

2 https://pubs.acs.org/doi/10.1021/acs.est.9b00650