Atmospheric boundary layer, wind, and air quality

ebook

VAISALA

The crucial science of air quality

Air quality assessment and forecasting is a complex science with many variable involved.

The rewards of building a modern air quality assessment system are high, however, since it can have direct and substantial economic and social implications. Increasingly, meteorological agencies, governments, and private industry are closely regulated and accountable for protecting public health and the safe operations of business and industry.

An ideal air quality forecasting system leverages several types of models, which describe and predict the emission, transport, and ambient levels of pollution. As described by Committee on Environment and Natural Resources (CENR) Air Quality Research Subcommittee, these include:

Emissions modeling

Simulates the behavior of pollutants across time and space, as well as how secondary pollutants originate and behave.

Meteorological modeling

Describes the conditions that affect mixing, movement, and other influences such as solar intensity and temperature. Produces trajectory models to forecast ambient pollution levels.

Two pillars of air quality management

Two components of air quality management are especially important and can be addressed with modern observation tools:

- Atmospheric boundary layer (ABL) assessment
- Wind assessment

ABL assessment is crucial because it provides visibility into highly influential, specific weather phenomena that are often more difficult to assess and predict than broad meteorological patterns. These phenomena are especially important to air quality and pollution management, and managing a day-to-day assessment of the ABL has become a valuable tactic for many agencies, government departments, and companies.

Furthermore, wind behaviors that affect pollutant generation and transport can vary significantly in scale. It is usually ideal for forecasters to work from largest to smallest wind phenomena, characterizing their strengths and corresponding impacts. Accurate, local wind assessments show the transport of pollutants by wind, local-level recirculation, horizontal dispersion, and other factors — creating a full, essential picture of both large- and small-scale effects.

Together, these ABL and wind assessments are highly valuable to forecasters and the communities they serve. A successful forecasting system must include sound methodologies, quality observations, and continual optimization to deliver forecasts that serve the needs of users. ABL and wind assessments are key parts of that process.

Key applications for air quality assessment

- Emission source identification and mitigation
- Pollution management and tracking
- Public safety and air quality alerting
- Industrial area safety and compliance

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Atmospheric boundary layer assessment

The boundary layer, which is the region of the atmosphere closest to the ground, contains almost all pollutants. Because of this, an accurate understanding of daily ABL fluctuations can provide excellent hour-to-hour awareness of pollutant levels, their travel, and their danger to communities. This situational awareness has direct applications for public safety alerting and many kinds of decision-making.

Unlike other atmospheric regions (the "free atmosphere" and higher), the ABL is directly responsive to the solar heating and cooling of the earth. This is important because convective action mixes and moves ABL air, dispersing or concentrating pollution. The top of the boundary layer is essentially a cap beyond which pollution rarely goes, so a comprehensive understanding of ABL activity provides a very complete understanding of pollution behavior and other important phenomena.

Why the ABL is so important

- Pollution is trapped in the ABL.
- Agriculture and biological activities (crops, pollen distribution, etc.) take place in the ABL.
- Severe weather events are tied to ABL behavior.
- Many aviation, shipping, and other transport activities take place in the ABL.
- The ABL is the atmosphere we actually live in.

General ABL patterns

During the day, as the earth warms, the convective boundary layer circulates air that was more or less stable during the night. This mixed layer follows predictable behavior but varies day by day as weather, temperature, and other factors change — often in ways not predicted by large-scale regional forecasts or weather models.

At night, the boundary layer cools and returns to a nocturnal, or residual, state closer to the ground, with less mixing. (Notably, it is possible for a daytime ABL convective layer to interact with the previous night's residual layer.)

In practice, these patterns suggest that there might be higher pollution levels in the morning, before surface air has been circulated upward into the cleaner, higher air. Throughout the afternoon, pollution will disperse and distribute throughout the boundary layer, eventually settling back down. By the evening, the ABL and the pollution it contains will have returned close to the ground, sometimes so low that very tall buildings extend higher than the top of the residual layer.

These generalities are only part of the picture, however. Because the ABL changes each day as the weather and other influences come and go, predictive modeling is often insufficient for useful air quality forecasting. Direct, daily ABL and wind observation are the missing elements.

Free atmosphere

This is the region just above the ABL that does not "feel" the surface of the earth. In other words, it is independent of frictional phenomena, ground solar heating, and other surface-level influences. Pollutants usually do not cross into the free atmosphere, meaning that the upper boundary layer is essentially a "cap" to their travel that contains them closer to the ground (and closer to humans).

Vaisala solutions:
Atmospheric boundary layer assessment

CL51 Ceilometer

Ceilometers are the primary means of directly measuring the ABL and its behavior throughout the day and night. They are capable of reporting the mixing layer height, as well as the heights of other atmospheric layers. This provides a full ABL profile that can be integrated with other forecast data, distributed to relevant stakeholders for air quality alerting and actions, and retained for advanced modeling or further study.

Vaisala's CL51 is the industry's leading ceilometer, and it benefits from our years of experience deploying thousands of ceilometers worldwide. It uses proven, reliable lidar technology to measure and analyze attenuated backscatter in the atmospheric layers. This enables it to perform continuous, 24/7 measurement of the boundary layer and reliably report on stable layers at low levels (200m and below).

Key features:

- Uses proven, industry-leading lidar technology made to withstand all weather conditions
- Simple plug-and-play package with easy integration into existing systems
- Fully automatic and independent operation, with no need for a user to run the instrument
- Virtually maintenance-free, with basic maintenance limited to occasional window cleaning
- Accurate attenuated backscatter profiling at ranges up to 15km
- Cost-effective over a long, reliable service life

BL-VIEW software

The BL-VIEW software makes CL51 data visible and even more actionable. It provides immediate situational awareness through intuitive visualizations of the ABL, which allows users to easily understand current conditions and trends. This often helps organizations allocate resources more effectively, such as when ABL behaviors are unlikely to cause immediate issues or do not require attention.

Key features:

- Works online and offline (using the previous day's data, for example)
- Allows for simultaneous viewing of previously logged and current BL data
- Enables users to change the sensitivity and averaging of the calculations if needed to localize the algorithm to local conditions
- Integrates up to 10 ceilometers, making it ideal for fleet management
- Analyses are easily exportable for further analysis or different applications

Vaisala solutions: Wind assessment

WindCube vertical profiling lidar

WindCube is globally recognized as the leading vertical profiling lidar. With more than 1,500 WindCubes in the field,
it is proven over years of use around the world, and it is the ideal tool for providing an accurate wind profile and atmospheric stability assessment in any location or climate.

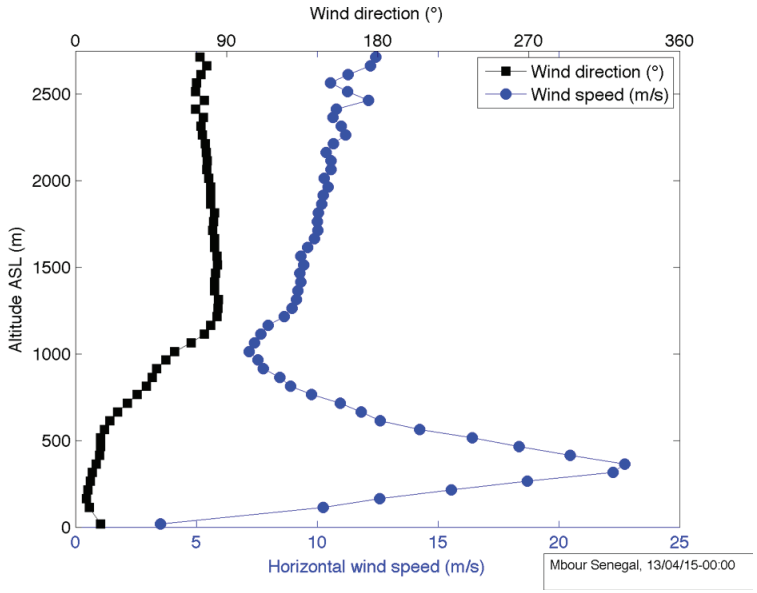
Easily located almost anywhere — including rooftops or other urban structures — it can essentially do the work of a 300m met mast. Its wind data has been routinely validated by the most rigorous international governing bodies, including the IEC.

Key features:

- Compact, lightweight, and discreet
- Little or no permitting required to set up
- Instant setup, autonomous 24/7 operation with cloud-based interface
- Easily integrated with existing systems
- Can be moved and repurposed
- Independently validated
- Low power consumption

Vaisala solutions: WindCube Scan

WindCube Scan provides full, 3D wind awareness at long ranges and enables (optional) aerosol/dust backscatter profile processing, which gives users detailed emissions mapping at ranges of 10km or greater. This functionality can be extremely useful for ports, mines, or other industrial centers that generate substantial particulate emissions that are carried by the wind in hard-to-predict ways.



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Air quality has never been more important.

The technology for assessing it has never been better.

Your communities rely on you to provide the most reliable and accurate air quality information available. You can rely on Vaisala for the globally recognized, reliable technology you need to succeed, even when your industry is changing rapidly.

For decades, Vaisala's environmental monitoring innovations have turned observation into human impact. We are the industry's trusted leader, not just for our sensors and technologies, but for our partnership, training, and guidance throughout the entire project life cycle. Vaisala's decades of investment in science and research are unmatched in the industry, as is our commitment to you and the communities you serve.

Why Vaisala?

As the global leader in weather and environmental measurements, Vaisala provides trusted weather observations for a sustainable future. With over 85 years of experience and customers in 170+ countries, from the North and South Poles to Mars, we help provide the most reliable and accurate weather and climate information for better and safer daily lives.

Our instruments and intelligence are known as the gold standard for precision and reliability. As a sustainability leader we enable meteorology professionals to better understand, forecast and explain climate change. We continue to channel our curiosity into climate action and new ways of enabling a better planet for all.

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