Continuous Mixing Layer Structure Monitoring Using the Vaisala CL51

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The Mixing Layer

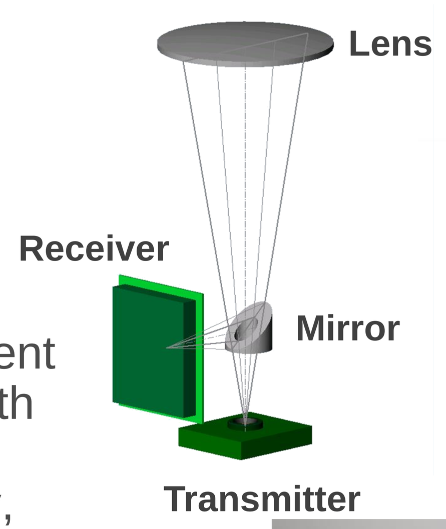
The Planetary Boundary Layer Height (PBLH) continues to be an important meteorological variable that impacts the operations of many portions of the atmospheric science industry. The growth and subsequent depth of the boundary layer is of interest to entities such as air quality agencies, weather forecasters, and most recently, the renewable energy industry. Historically, specification of the PBLH has been limited to using sounding information provided by radiosondes or field study datasets consisting of a some combination of meteorological instrumentation on towers, aircraft measurements, and more recently, ground based remote sensing platforms. These datasets typically suffer from poor spatial and/or temporal resolution. As a result, Numerical Weather Prediction (NWP) has been used in practice to specify the PBLH for regions without measurements and for times between measurements.

For the past 7 years, Vaisala has made available the BLVIEW software package to users of the Vaisala CL31 and CL51 ceilometers. Embedded within this software is a boundary layer structure retrieval algorithm that looks for sharp changes in negative backscatter gradient. For any ceilometer location, BLVIEW provides a vertical depiction of the attenuated backscatter density above the instrument and overlays structures that are identified using the algorithm. An example of classic structures such as the mixing layer, nocturnal boundary layer, and residual layer are depicted using this algorithm in Figure 1.

For applications in air quality, the mixing layer is of key importance given its ability to disperse pollutants. Defined as the vertical extent of a boundary layer that is uniformly mixed through surface induced forcing, the mixing layer can often be observed from ceilometer data. The mixing processes inherent to the mixing layer will distribute moisture, aerosols, and other particles that exhibit strong backscattering behavior vertically. Since the top of the mixing layer is typically marked by a strong negative gradient in attenuated backscatter, the gradient method is well suited as a retrieval mechanism.

Challenge: How can we accurately and routinely assess the structure of the boundary layer, including the mixing layer height?

Vaisala CL51 Ceilometer



The Vaisala CL51 is a single lens ceilometer designed to measure high range cirrus clouds as well as low and middle layer clouds, and vertical visibility in harsh conditions. In recent years, the CL51 has been used in applications associated with monitoring the boundary layer. The CL51 employs a pulsed diode laser LIDAR (Light Detection And Ranging) technology, where short, powerful laser pulses are sent out in a vertical or near-vertical direction. The reflection of light (backscatter) caused by clouds, precipitation or other obscuration is analyzed and used to determine the cloud base height.

- Measurement Resolution : 10m
- Wavelength: 910nm
- Cloud reporting range: 10m to 13,000m
- Backscatter profiling range: 10m to 15,000m)
- Field proven fully automatic 24/7 operation in all weather conditions

Continuous Monitoring of the Mixing Layer

Known most widely for its ability to provide cloud base height estimates and sky cover information, ceilometers have become powerful tools for continuous monitoring of boundary layer structures including the mixing layer. Its ability to give users a glimpse of the evolution of the lowest few thousand meters of the atmosphere makes it valuable in applications spanning from wind energy to air quality.

The selected references listed below provide a number of modern examples in literature showing a range of applications for the ceilometer that include mixing layer height monitoring and dust and particle concentration estimates. Figures 1 through 3 are provided to depict similar examples of these applications.

For validation purposes, a radiosonde soundings launched at the instrument location is overlaid in Figure 2. The mixing layer height from sounding data is identified by a sharp gradient in relative humidity and temperature. It is clear that the mixing layer height from radiosonde agrees well with the ceilometer retrieval. Soundings from within 40km of the CL51 displayed in Figure 3 are overlaid for similar validation.

Figure 3 is particularly interesting for air quality applications. A shallow nocturnal boundary layer with high concentrations of aerosols is evident during the early hours of the time series as indicated by the high backscatter intensity (reds). As the mixing layer grows in response to daytime heating, diffusion of the high concentrations is clearly evident. For locations highly susceptible to air quality reductions, the ceilometers is a proven tool for continuous monitoring of these events

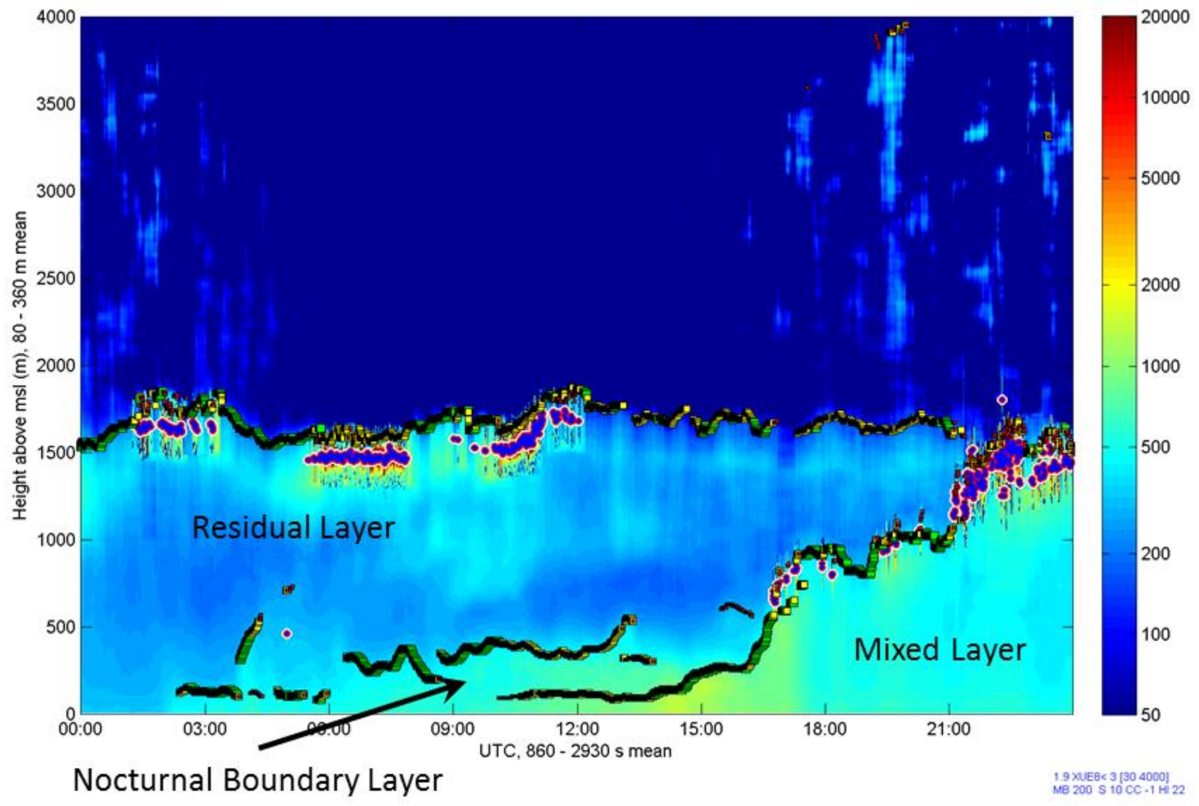


Figure 1 – Classic Boundary Layer Structure from CL51

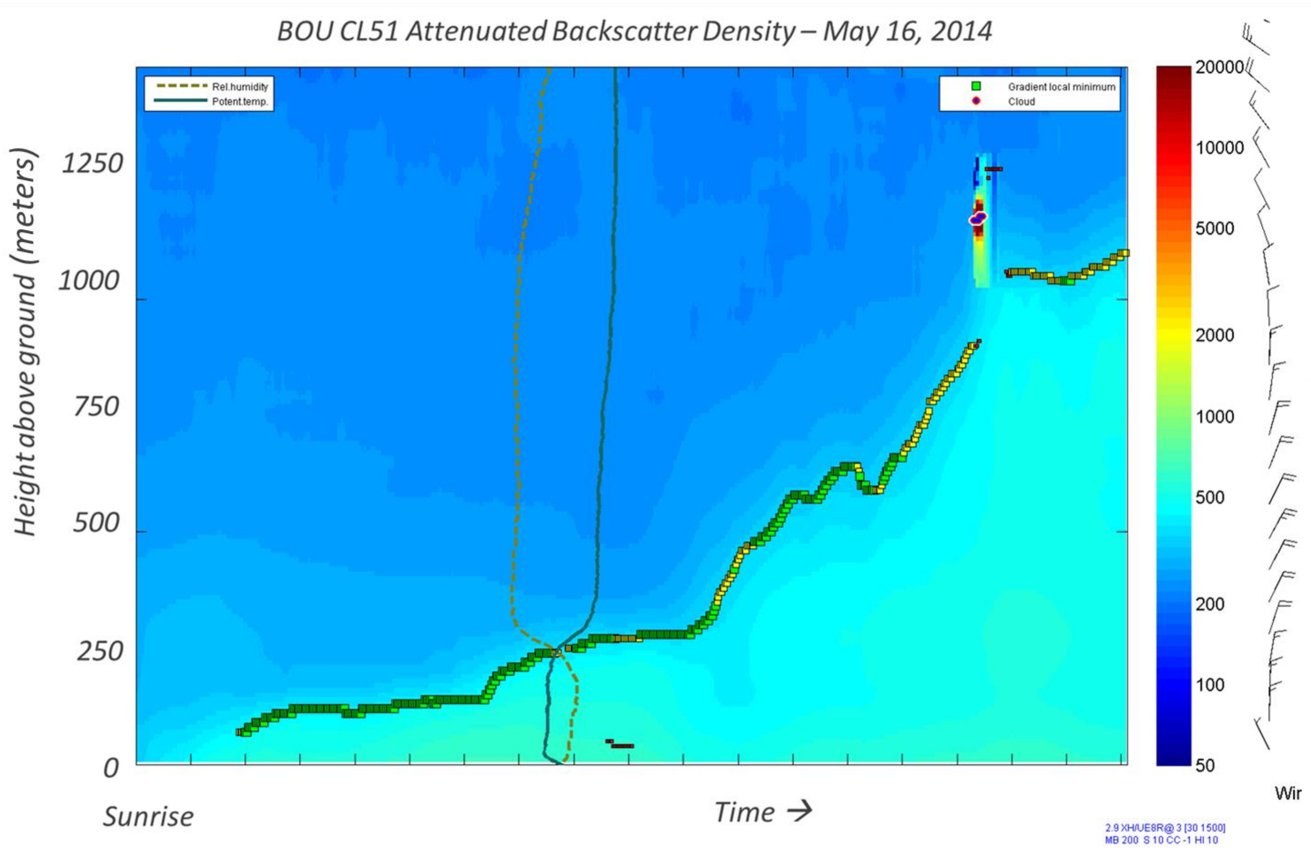


Figure 2 – Mixing Layer Growth with an RS41 radiosonde sounding overlaid for validation.

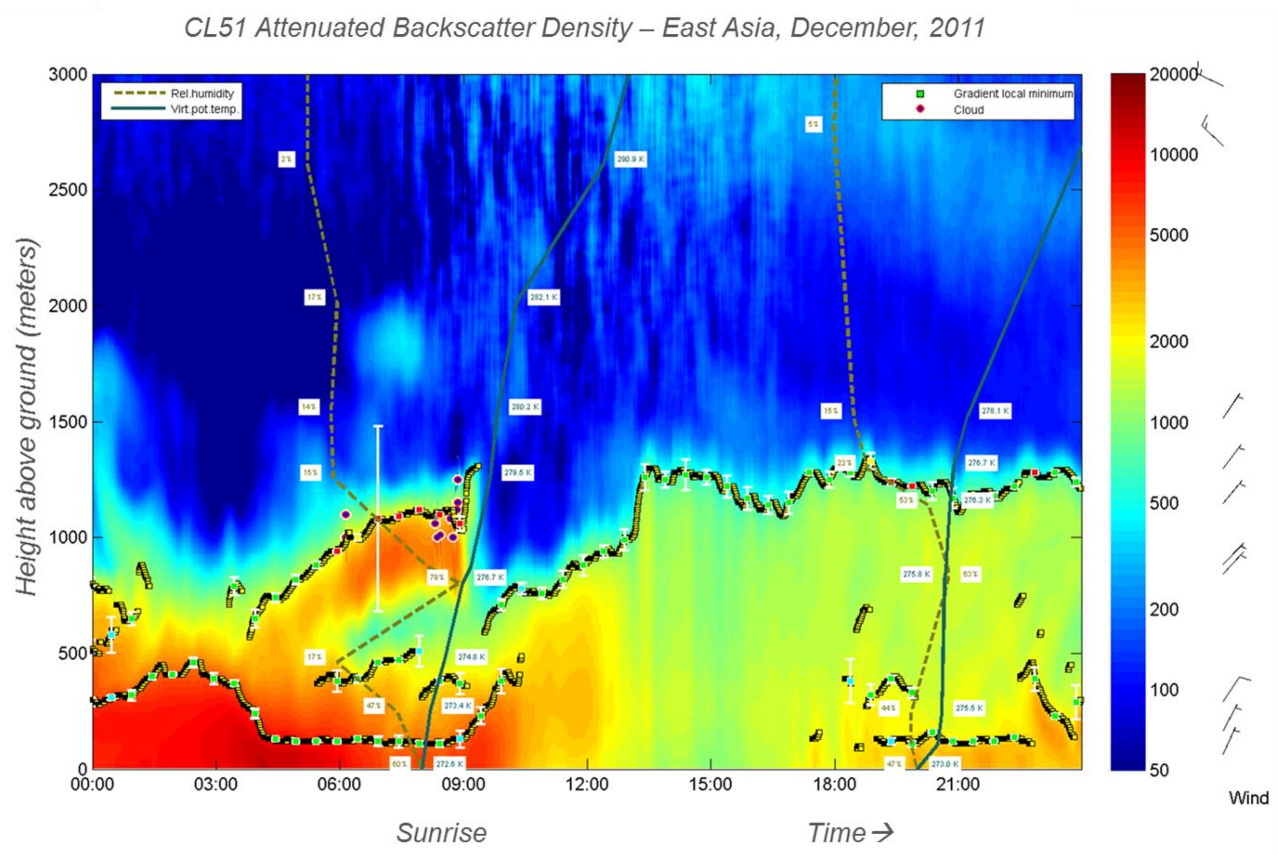


Figure 3 – 24 hour boundary layer evolution with radiosonde soundings overlaid for validation.

Selected References

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