An automatic Planetary Boundary Layer height detection with the compact EZ Lidar™

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Introduction

The Planetary Boundary Layer (PBL) is the lowest part of the atmosphere that is directly influenced by the presence of the Earth's surface, and responds to surface friction about an hour or less [1]. Surface forcing includes frictional drag, evaporation and transpiration, heat transfer, pollutant emission and terrain-induced flow modifications. The Boundary Layer thickness is variable in time and space, ranging typically from a few hundred meters up to 1-3 km, depends on the nature of the surface (land or ocean) and on the meteorological conditions. Characterization and temporal evolution of the PBL are required to trace pollutants in large metropolitan areas. The objective of this work is to assess the performances of an automatic PBL height detection method with classification into different layers (nocturnal, convective and residual). Moreover, this method is currently validated in the framework of ICOS (Integrated Carbon Observation System) project, in which E.U is conducting a pioneer project in order to constraint its Greenhouse gas emissions (CO2, CH4, N20,PFC,..), targeting 80% of carbon emission reduction within the next 40 years . The pilot project has been launched in order to create and maintain a coordinated, integrated, long-term high resolution network of atmospheric and ecosystem observations. During the initial platform design phase, one EZLidar and ceilometers have been deployed nearby Orleans, France, to retrieve continuous PBL heights and aerosol structures. Under all weather conditions, clear sky, fog, low clouds, the EZ Lidar™ has been able to detect the different layers, residual, nocturnal and convective, from 75m up to 2km during the whole month of October 2008. Moreover, thanks to its 3D scanning capability, the EZ Lidar™ was able to provide the variability of the PBL height around enabling the scientists to estimate the flux intensities that play a key role in the radiative transfer budget and in the atmospheric pollutants dispersion.

Measurement set-up

EZ Lidar™ ALS450 was deployed in Trainou, France (47.9 N 2.1W) from the 6th to the 23rd October 2008 during the ICOS campaign and in Mace Head, Ireland from the 6th to the 28th June 2009.

The EZ Lidar™ ALS450, is a rugged and compact eye safe aerosol Lidar, that uses a tripled pulse laser source Nd:YAG at 355nm wavelength with an energy of 16mJ and pulse repetition frequency of 20 Hz. Both analog and photon counting detection are available. The Lidar system, validated through several measurement campaigns, provides a real time measurement of backscattering and extinction coefficients, aerosol optical depth (AOD), automatic detection of the planetary boundary layer (PBL) height and clouds base and top from 100m up to more than 20 km [2] depending on atmospheric conditions and period of the day. This instrument was equipped with a cross- polarised channel which allows discrimination of non-spherical particles from the others.

Figure 1: EZ Lidar™ ALS450 during the ICOS Campaign

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PBL height detection method

PBL layer height detection is based on the calculation of vertical gradient of the range corrected backscattered signal detected by the lidar which is directly proportional to the attenuated backscattering coefficient. The program EZ-PBL, developed by Leosphere, classifies the two PBL heights into three categories, nocturnal, convective and residual layers, through elimination of aberrant values and with the help of an average of 15 minutes.

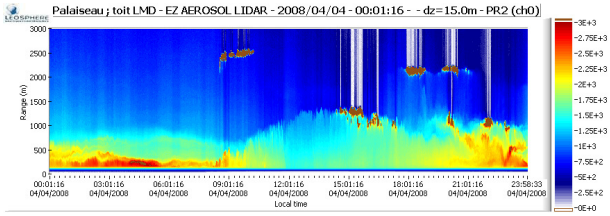

Figure 2: Lidar measurements the 4 April 2008

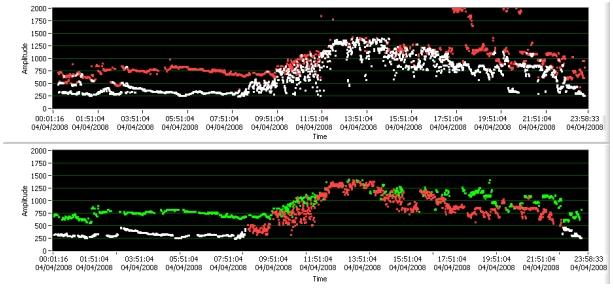

Figure 3: PBL height detection (First (white) and second (red) and classification method nocturnal (white), convective (red) and residual layer (green) for the measurements of the 4 April 2008

COMPARISON WITH 2D DETECTION

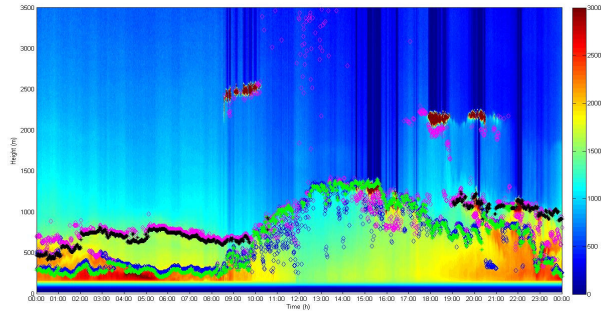

Figure 4: PBL height detection method for the measurements of the 4 April 2008
First (blue) and second layer (pink) with 1D detection
First (green) and second layer (black) with 2D detection

Another method of PBL detection developed by Leosphere is the “2D detection”, working on a large set of temporal profiles instead of 1. This allows the use of the temporal correlation between the profiles and the integration of atmospheric parameters about PBL evolution in the detection algorithms. The figure 4 shows the comparison between the 1D and 2D methods.

Good correlation between the two methods is observed putting in evidence the potential of new 2D methods.

COMPARISON WITH WAVELETS METHOD

Among all the PBL height retrieval methods, one currently used is the wavelet method. The EZPBL has been tested against STRAT wavelet retrieval algorithm, currently developed by CNRS [2]. Next pictures show the intercomparison done on September 2008.

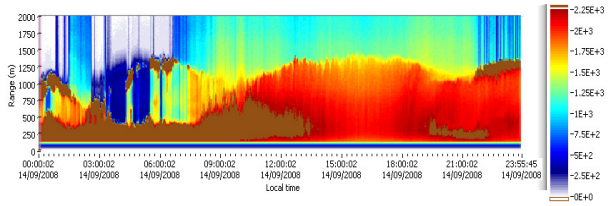

Figure 5: EZ LIDAR® measurements from the 14 September 2008

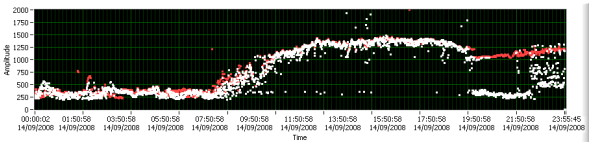

Figure 6: Convective PBL height detection (Wavelets method (red); gradient method (white))
for the measurements of the 14 September 2008

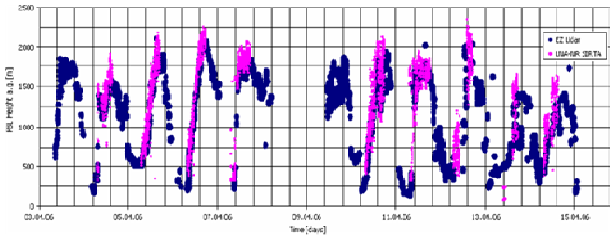

Figure 7: Mixing layer height detection (Wavelets method (pink); gradient method (blue))

The result of the validation campaign (Figure 7) over two weeks shows a correlation up to 95% between the two methods for the mixing layer height retrieval.

MEASUREMENT DATA

In the frame of ICOS (Integrated Carbon Observation System) program, were performed PBL height retrievals over three weeks at Orleans, France.

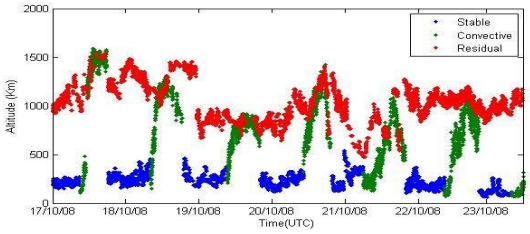

Figure 8: PBL height detection from the 17/10/2008 to the 23/10/2008 (nocturne (blue), convective (green) and residual (red))

From 7th to 14th October 2008 several instrumentals flights and daily radiosoundings were performed by LSCE. Thanks to the scan capabilities, a 3D measurement of PBL height around the measurement site was done, and has shown in Figure 9. Such as vertical scanning, volume scanning allows to determine the homogeneity of the atmosphere. In this representation, we can observe a relative homogeneity of the PBL height (area in red in Figure 9).

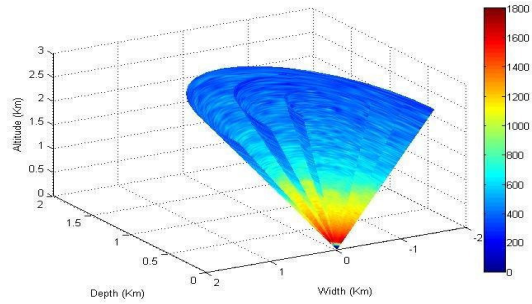

Figure 9: Volume scanning realized on13/10/2008 at Trainou, France

Conclusions

EZ Lidar is able to track the PBL with high availability in every meteorological condition. During ICOS campaign, the system running rate was near 98% of the time. The instrument is self-governing and requires a minimum of maintenance. EZLidar tilts automatically the laser line of sight improving the PBL detection at very low heights. .Moreover, thanks to its 3-D scanning capability, the EZLidar is able to provide the variability of the PBL height around a site, enabling the scientists to better take into account the various sources and sinks.

Our PBL detection method has been validated into several campaigns and compared to different methods. During the first phase of ICOS project in Trainou, our results have been compared to radiosounding with a good correlation. First conclusions about this campaign have demonstrated a strong quality check of our instrument, the ability to detect fine structure and analyze local to regional variability of PBL heigh.

The advantage of our automatic PBL height detection it's classification into three categories, nocturnal, convective and residual layer. The last step will to give a confidence indice of our results. In parallel, Leosphere works in another method, detection in 2D which gives encouraging results.

References

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[2]STRAT: an automated algorithm to retrieve the vertical structure of the atmosphere from single channel lidar data, Morille Y., Haeffelin M., Drobinski P., Pelon J., BAMS 2007.