AN AUTOMATIC PLANETARY BOUNDARY LAYER HEIGHT DETECTION WITH A COMPACT UV AEROSOL LIDAR

L.Sauvage[1], S.Loaec[1], S. Lolli[1], M. Boquet[1],A.El Filali[1]

[1]*LEOSPHERE, 76 Rue Monceau, 75008 Paris, France, lsauvage@leosphere.fr*

ABSTRACT

The Planetary Boundary Layer (PBL) height is a complex meteorological fundamental for air quality modelers. Its diurnal variations induce vertical dilution of the pollutants at daytime, and concentrate them at nighttime. Urbanized cities in the world are exposed to atmospheric pollution events. To understand the chemical and physical processes it is necessary to describe correctly the PBL dynamics and height evolution. For these proposals, a compact and rugged eye safe UV Lidar, the EZLIDAR™, was developed together by CEA/LMD and LEOSPHERE (France) to study and investigate structural and optical properties of clouds and aerosols and PBL time evolution.

A new 2D method of PBL detection, developed by LEOSPHERE's Science team and based on image processing, is working on a large set of temporal profiles, typically 6 to 24 hours. It allows the use of the temporal correlation between the profiles and the integration of atmospheric parameters about PBL evolution in the detection algorithms.

This method, based on the gradient of the range corrected signal, is using a unique automatic threshold algorithm that will adapt to any atmospheric conditions. No specific parameterization is required before measurements and the final result is more robust than a profile per profile method.

We have validated our algorithm during the second campaign of the ICOS (Integrated Carbon Observation System) project. This campaign took place in Mace Head (Ireland) under very different and complicated atmospheric situations, with frequent showers, windy situations and no significant inversion layer.

Furthermore, this algorithm is able to detect accurately clouds and rain episodes.

1. MEASUREMENT SET-UP

EZ Lidar™ ALS450 was deployed in Trainou, France (47.9 N 2.1W) from the 6 to the 23 October 2008 and in Mace Head (53.3N, 9.9W) , Ireland from the 8th to the 28th of June 2009 during the ICOS campaign.

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) and visibility, 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 time of the day. This instrument is equipped with a cross-polarized detection channel which allows discriminating non-spherical particles from the others.

Figure 1: EZ Lidar™ ALS450 during the ICOS Campaign

2. 1D PBL HEIGHT DETECTION METHOD

1D 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. In figure 2 and 3 we show a sample of 1D detection.

The real time software AEROSOFT™ provided with the ALS lidar is detecting automatically three main layers in the raw lidar profile, using this gradient technique, optimised from the one described by Flamant et al. (1997)[1].

The Presence of low clouds, detected with a specific threshold algorithm, is taken into account in the calculation of the PBL height.

Once detected these layers are treated in the EZPBL™ software, and a better guess of the layers is provided with a short delay of 15mn by a filtering and classification module.

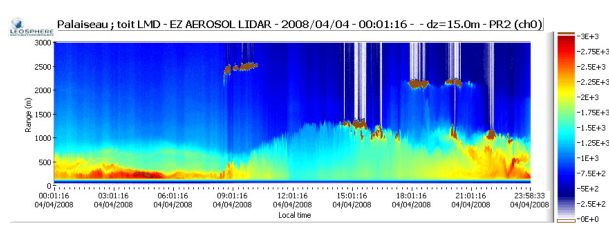
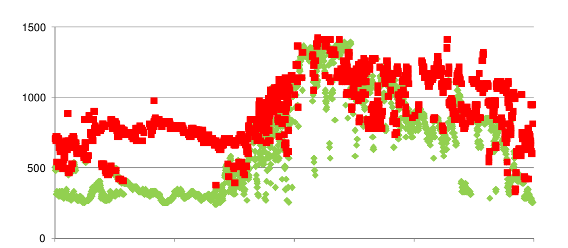


Figure 2: Lidar measurements from the 4 April 2008 from 0000 till midnight. We observe a nice diurnal evolution, with a convective PBL up to 1400m.



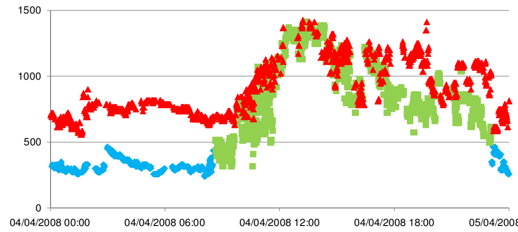


Figure 3: PBL height detection (First in green and second in red) and classification method (Nocturnal (blue), convective (green) and residual layer (red) for the measurements of the 4 April 2008

COMPARISON WITH WAVELETS METHOD

Among all the PBL height retrieval methods, one currently used is the wavelet method. The EZ PBL has been tested against STRAT wavelet retrieval algorithm, currently developed by CNRS [2] (Figure 4). A very good correlation has been found, of 95%, for the eleven days duration of the test.

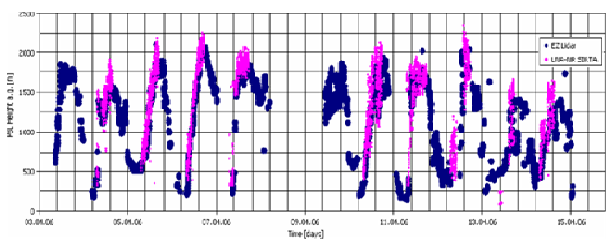


Figure 4: Mixing layer height detection (Wavelets method (Fuchsia); gradient method (blue)).

3. PBL HEIGHT DETERMINATION DURING ICOS

In the frame of ICOS (Integrated Carbon Observation System) program ((Xuef, 2009)[3], were performed PBL height retrievals over three weeks at Orleans, France.

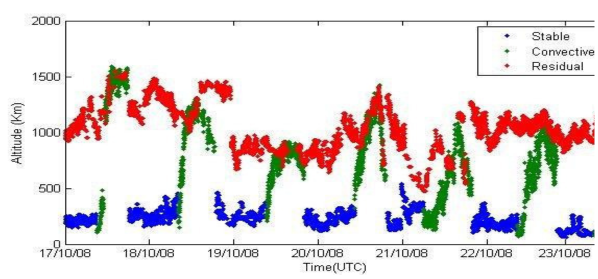


Figure 5: PBL height detection from the 17/10/2008 to the 23/10/2008 (nocturne (blue), convective (green) and residual (red))

From 7 to 14 October 2008 several instrumentals flights and daily radio-soundings were performed by LSCE.

The method has been successfully applied during the first ICOS campaign in Traînou with a very good correlation with the radio-soundings (Figure 6).

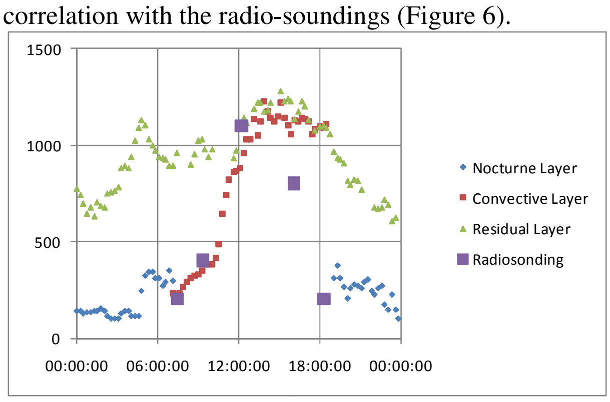


Figure 6: Detection of the nocturnal (blue), mixing layer (red) and residual layer (green) heights during the ICOS campaign.

MLH retrieved by radio-soundings are shown in purple squares.

Thanks to the scan capabilities, a 3D measurement of PBL height around the measurement site was done, as showed in Figure 7.

Like 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 7).

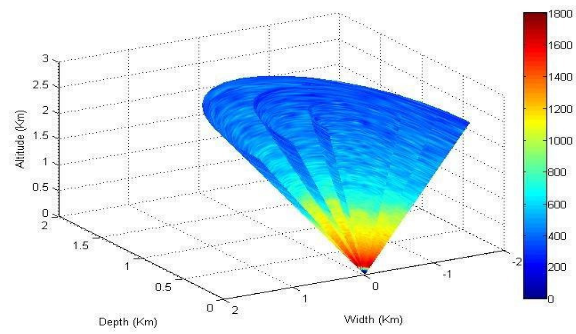


Figure 7: Volume scanning realized on13/10/2008 at Orleans, France

4. 2D PBL HEIGHT DETECTION ALGORITHM

The developed algorithm performs different PBL heights retrieval through multiple steps, as showed in figure 8.

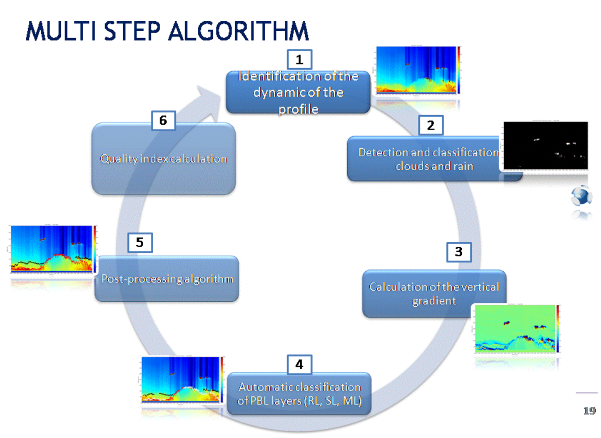


Figure 8: Multi Step algorithm to detect PBL different heights using 2D-method.

If we retrieve the PBL height on the same case of Figure 2, the first step is to identify the profile, then the algorithm detects if clouds or rain are present and a filtering is performed. Now the 2D gradient is calculated to obtain the multi structure determination as shown in Figure 9.

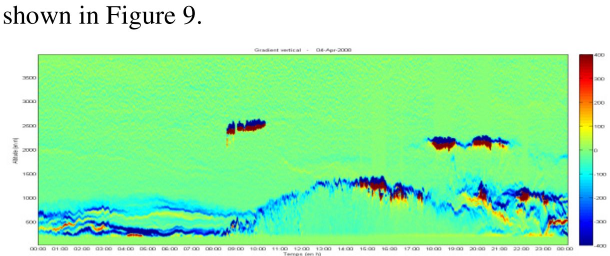


Figure 9: Filtered and 2D gradient calculation.

Then, an automatic classification is performed, furnishing a guess of nocturnal, convective and residual layers if present in the PBL structure (Figure 10).

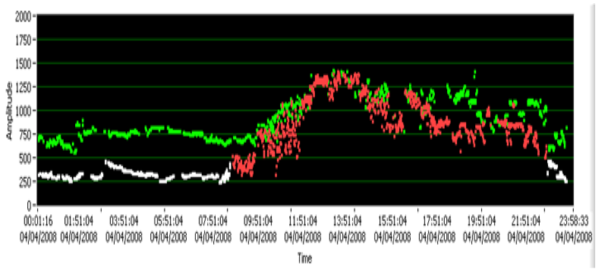


Figure 10: Automatic classification of the PBL height of the different layers.

The last step, the algorithm is calculating a confidence index of the results, taking into account the presence of clouds and rain, the quality of the signal and homogeneity of the layers.

5. CONCLUSIONS

We have shown that the EZ Lidar, and its software suite, is able to track the PBL with high availability in every meteorological condition. During ICOS campaign, the system running rate was near 98%. 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, down to 50m. Moreover, thanks to its 3-D scanning capability, it is possible to provide the variability of the PBL height around a site, enabling the scientists to better take into account the various sources and sinks.

A first gradient detection method has been developed, tested and validated during several campaigns. In order to obtain a more autonomous detection, a 2D algorithm has then been developed. The validation procedure is on going and we are confident in providing a robust routine. Comparison with other sensors will be conducted in the validation process.

REFERENCES

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