# Could LIDAR methods automatically detect the top of ABL? – Case studies for Santa Maria / CHUVA-SUL

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*The data presented here were obtained using measurements performed during the CHUVA-SUL campaign. The current authors list indicates, for divulgation inside the project, the main actors of this study.*

## Introduction

The Planetary Boundary Layer (PBL) is the region of troposphere situated in its lower part. Due to its direct contact with the surface and it's responsible for the main energy exchanges with the Atmosphere [5], influencing directly the climate. Therefore, the understanding of its behavior and the main factors that influence the PBL are very important to allow for a reasonable description and comprehension of the main process occurring at low altitude. The LIDAR technique has been appointed by many authors as one of the best tools to investigate the PBL thanks to its good spatial and time resolutions, besides enabling the realization of data capture without to influence the study object.[1,2,3]

The main objective of this work is to perform a comparison of the behavior of three algorithms (Gradient Method, Wavelet Covariance Transform and Richardson’s Number) retrieving the height of the PBL and to correlate the atmospheric conditions with their respective performance.

## Methodology

A case study is performed on relevant days of the multi-instrument campaign CHUVA-SUL held 2012, in the city of Santa Maria – Rio Grande do Sul - Brazil.

In this campaign a mobile LIDAR system was used for data capture. The analysis of the ABL height was done with three mathematical algorithms: the Gradient Method (GM), using the derivative of logarithm, the WCT (Wavelet Covariance Transform); and finally the method of the Richardson Number, which used for validation purposes, as it depends solely on radiossounding.

- **Gradient Method (GM)** In this case was used the derivative of logarithm the LIDAR signal corrected with the square of height $(P(z).z^2)$:

$$\frac{d}{dz} log(P(z).z^2)$$

which minimum value is the top of ABL [2].

- **Wavelet Covariance Transform (WCT)** This method consists in detection of change in range-corrected signal by the realization of the covariance between the wavelet function and the LIDAR signal corrected with the height $(P(z).z^2)$. It is very important that the function chosen has characteristics similar to the analyzed signal. For this case the most indicated function is the Haar wavelet [1].

$$h\left(\frac{z-b}{a}\right) = \begin{cases} -1 : b - \frac{a}{2} \leq z \leq b \\ 1 : b \leq z \leq b + \frac{a}{2} \\ 0 : Other\ Cases \end{cases}$$

where *b* and *a* are the vertical translation and dilatation of function, respectively (values given in literature [5]), and z is the height. To this method, the point where the function has its maximum corresponds to the top of ABL.

- **Richardson's Number (RN)** This algorithm does not depend of the LIDAR data, but it depends of radio-sounding data. The RN is obtained from the following equation:

$$R_{bs} = z \frac{g}{\theta_{average}} \frac{[\theta(z) - \theta_s]}{U(z)^{2}}$$

where: z is the height, g is the value of gravity, $\theta_{average}$ is the average value of potential temperature of layer, $\theta(z)$ is the potential temperature in z point, $\theta_s$ is the potential temperature at ground level and U (z ) is the wind speed at the altitude z. The altitude of the top of PBL is the first point where $R_{bs}$ is below 0.25. Note that due to the low resolution of the radio-sounding data at low altitude, the Richardson number was determined using interpolated profiles, thus delivering an indicative rather than strict reference value.

## Cases study

### *Stable Conditions*

On November 29th the atmosphere presented stable conditions with high clouds and a well defined PBL (Fig 1-A). These conditions facilitated the detection of the PBL top by all algorithms. The WTC didn't need parameter value departing from their standard values, but the profile was most detailed for low values to b (for example b = 10). The GM and WCT presented results close to each other, correlating well with the NR (Fig. 1-B).

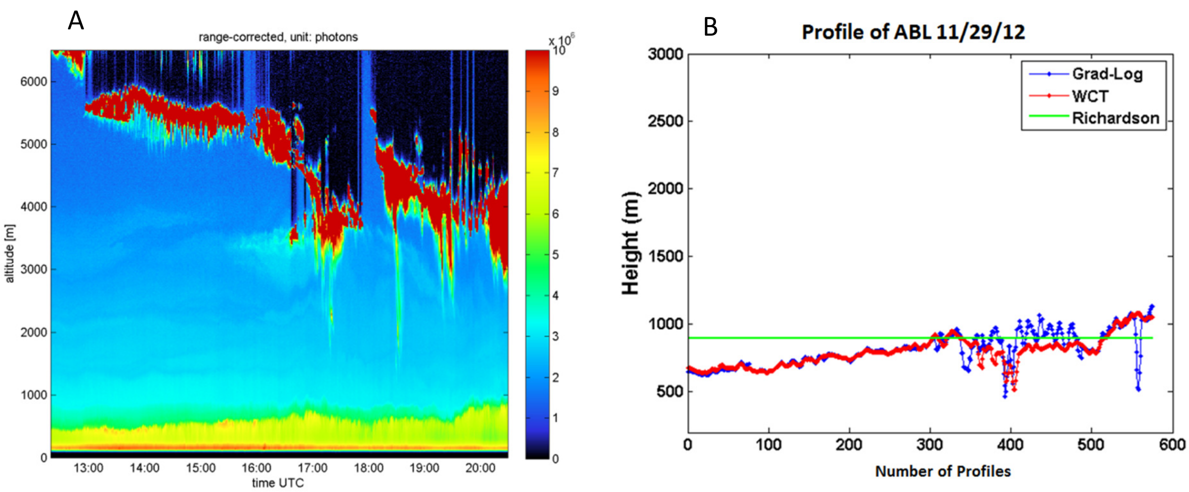


*Fig. 1 - Day with stable conditions - A: Profile LIDAR - B: Comparison among the three methods.*

*Day with Sublayers*

On November 8th some aerosol sublayers inside the PBL were observed, difficulting the retrieval of the LIDAR algorithms (GM and WCT) because initially they could not discriminate the sublayers from the top of ABL (Fig. 2-A). To solve this problem, it was necessary to adopt a threshold value [1] in two methods.

In order to look for the optimal performance of the algorithms, we performed retrievals using several values for the threshold (Fig. 2-B). Values for the WCT ranged from 0.0 to 0.8, while they ranged from -0.01 to -0.001for the GM. For the GM, an intermediate value (-0.005) was sufficient for a robust differentiation of the sublayers from the top of PBL. Lower values induced an excessive loss of information. The WCT behaved as expected for low values to *b* (for example b = 10), allows a great detail in profile. A high value of *a* was necessary (for example a = 200) for the maximum to become more pronounced, thus facilitating the discrimination. A low value of the threshold (0.2) is enough to differentiate the sublayers from the top of PBL, without noticeable loss of information.

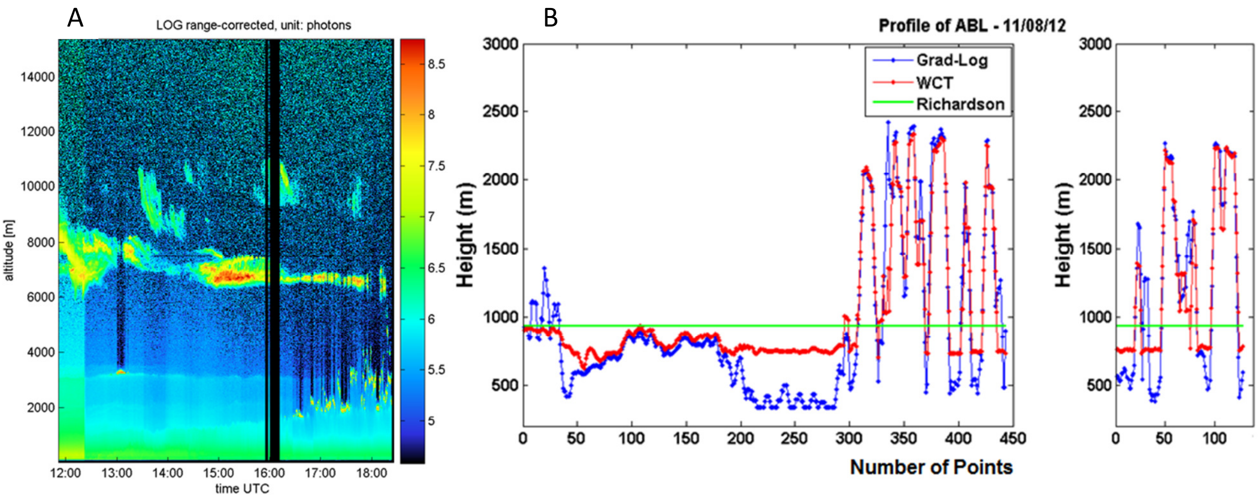


*Fig. 2 - Day with sublayers - A: LIDAR profile – B: Comparison between three methods.*

*Turbulent Day*

The last case is the day November 9th, where clouds and some sublayers where detected by the LIDAR near the supposed top of the PBL (Fig. 3-A), and in such a quantity that the algorithms were at first confounded; It was then necessary to refine the analysis with  other values of the parameters. For GM, only the lowest value of the threshold helped obtaining a height to top of ABL near the one inferred by NR, at the cost of loss of stability. The WCT presented results partially satisfactory only for great values to *b*. A high value for *a* helped the transition from PBL to free troposphere become more pronounced, thus facilitating the detection.

High values for the threshold, enabling greater differentiation between sublayers and top of ABL, had to be used, at the cost of resolution loss (Fig. 3-B).

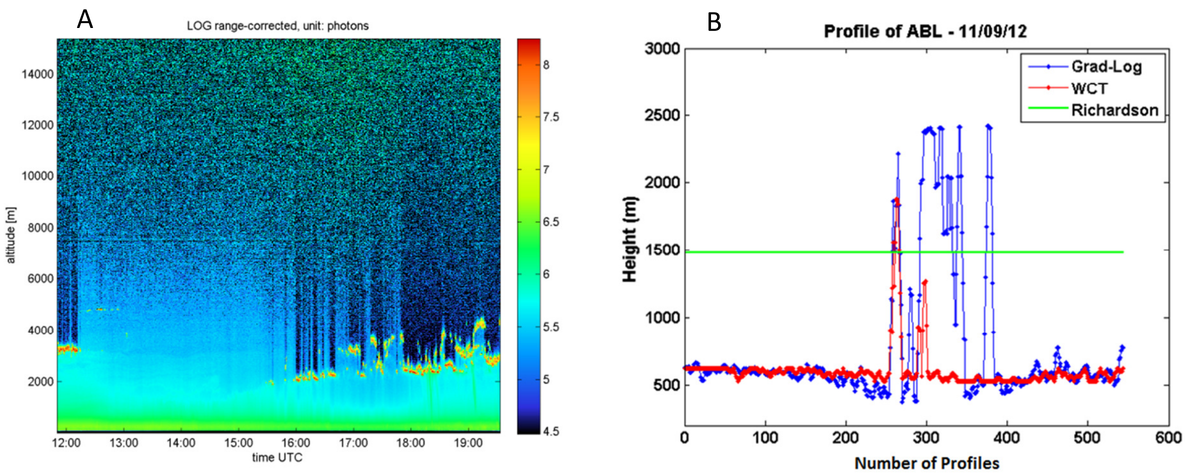


*Fig. 3 - Turbulent Day  - A: LIDAR profile – B: Comparison between three methods.*

## *Conclusion*

GM and WCT retrieved PBL heights within the range of RN. It was also observed that in cases of cloudiness or in the presence of sublayers, their performance is reduced or deceiving, but could be revived using threshold values or adapting their specific parameters, especially for the WCT algorithm. For turbulent days, the choice of the parameters appears to be critical, as we saw that a little variation can generate a big difference in the results, but basic trends could be extracted and value ranges could be identificated. This study could constitute a further step towards an automated PBL height detection where the choice of adequate parameters for WCT could be assisted by a rough analysis of the quantity of perturbing sublayers (to define the ranges of the threshold and parameters *a* and *b* of the WCT), and a minimization method taking into account the history of the LIDAR profiles (to assert PBL height retrieval continuity).

### *References*


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