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Atmospheric Measurement Techniques
Discussions

# *Interactive comment on* "Mixing layer height retrievals by multichannel microwave radiometer observations" *by* D. Cimini et al.

**D. Cimini et al.**

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Response to Anonymous Referee 1

**General comments**

The purpose of the manuscript is relevant to the journal, as it is pointing out a new instrumental technique to retrieve mixing layer height from a multichannel microwave radiometer. This is an added-value product for the new constituting microwave radiometer networks. However, the description of the method it is not clear and further analysis is needed to improve the general understanding of the manuscript to make it suitable for publication.



We are grateful to the reviewer for the constructive comments. Our replies are shown in red hereafter, while modifications to the text are highlighted in yellow within the revised manuscript.

**Major comments**

It is completely missing an analysis on stability of the retrieval algorithm. If both training and out-of-sample databases are changed in dimensions, how this will affect the results?

We agree with the reviewer that little discussion was provided concerning the stability of the retrieval algorithm. Being a linear approach, we expect our algorithm to be stable with respect to the dimension of the training/test datasets. In fact, by inverting the training/test sample ratio from 4/1 to 1/4 we obtain rms and correlation coefficients that are within 10% with respect to those presented in Table 2 (except for May and June for which the sample is too little to make such a test meaningful).
**We have added the information above to Sections 3 and 4.**

Training the algorithm separately month-by-month is statistically risked. This choice is not justified in the paper. What is it the impact on results if, for example, the training is done separately night from day-time? Or seasonally?

Monthly or seasonal training is quite common for inversion techniques based on MWR data (see overview papers such as Westwater et al. 1993). For example, the operational Atmospheric Radiation Measurement (ARM) MWR retrievals change the set of coefficients every month. We have performed sensitivity tests to choose the training approach that provided the best retrieval accuracy with respect to the reference. As described in Section 3, training is already performed separately for night- and day-time. The performances obtained when using an unique training from all months (i.e. semi-annual) have been added to Table 2.

**These information have been added to Section 4 and Table 2.**

It is not mentioned the uncertainty in Tb measurement. Moreover, given a certain error in Tb, how it translates into MLH retrieval? How is it the training affected?

We agree with the reviewer that information on Tb uncertainty was missing. Typical Tb noise level is within 0.5 K (Rose et al., 2005). However, systematic differences with respect to radiosonde-based simulations may account for several degrees (Löhnert and Maier, 2012). Since our regression approach is trained with actual measurements, Tb systematic and random errors are inherently accounted into the process, contributing to the overall performances given in Table 2.
**We have added the above information to Sections 2.2 and 3.**

Tb from lower elevation angles (let's say up to 19 degrees) results from different sounded volumes respect to the lidar pointing vertical (I am assuming it, but it is not specified anywhere in the paper). How these Tb measurement weight on retrieval?

The reviewer is correct: MWR multi-angle observations sample different volumes with respect to lidar zenith observations. However, this is a standard procedure in passive microwave sounding, which increases the information content on temperature profile by assuming horizontal homogeneity (Westwater et al. 1993; Löhnert et al. 2009). This assumption is solid for opaque channels (i.e. frequency>53 GHz), though it depends on atmospheric conditions for transparent channels (specially in presence of broken clouds). Since the estimate of MLH by MWR is based on the thermodynamical structure of the lower atmosphere, we expect multi-angle observations to improve the accuracy of MLH.
**We have added these information to Sections 2.2 and 4.**

An operational algorithm should be robust and work under different meteorological condition. I suggest to show some results of how the MLH retrieval by MWR under diverse atmospheric and meteorological conditions (no wind, strong wind, clear sky, boundary layer clouds, high aerosol load...)



Indeed, we intentionally applied our method to a dataset covering nearly seven months and thus a large variety of meteorological conditions. Our intention is to show the overall performances to be expected for operational deployment. To address the reviewer's comment, we have added more meteorological information to the discussion of the time series in Figure 4 (Section 4). The information come from the Figure below: time series (for the same four periods in Figure 4) of Integrated Water Vapor (IWV) and Liquid Water Path (LWP) from MWR and Wind Speed (WS) and Direction (WD) from a standard cup anemometer at 10m AGL. The Figure below has not been added to the revised manuscript.

**Specific comments**

**ABSTRACT**

"...full overlap limit (=200m)". This statement it is not correct. ALS450 is set up for upper troposphere studies. Full overlap is reached more realistic at 350m (Lolli, S. L. Sauvage, I. Stachlewska, and R. Coulter, 2008: Assessment of the EZ LIDAR and Micro Pulse Lidar (MPL) performances at ARM Southern Great Plains (SGP) Central Facility for the measurement of clouds and aerosols, Geophysical Research Abstracts, Vol. 10, EGU2008-A-11091). Even if identical instruments may have slightly differences, 200m full overlap is way too optimistic.

Other researchers applied ALS450 for the investigation of optical properties of aerosol particles and showed profiles of particle backscatter and extinction coefficients from a height starting around 150-200 m. For instance, Royer et al. (2011) used the mobile version of ALS450 and determined optical properties of aerosol particles from 200 m AGL. They also found the height of the full overlap to be 150-200 m (see, Table 1 in Royer et al. 2011 and Table 1 in Pal et al. 2012). The ALS450 optical configuration used in this paper is the same as the one used by Royer et al. (2011).

**We added the reference to Royer et al. (2011) in Section 4 of the revised manuscript.**

**INTRODUCTION**

p. 4974, line 26. Modify the sentence to read: "Thus, this approach is independent of..."

Agreed.

**MWR Data**

p. 4977 line 15: Modify the name to read : "Löhnert"

Agreed. Thanks for spotting this typo.

**LIDAR Data**

"MLH is derived from lidar backscatter data". Is it the backscattering coefficient profile or the range corrected signal as I am supposing? Please specify.

The reviewer is correct, the data we use is the ALS450 range-corrected signal, which is a non-calibrated range corrected attenuated backscatter profile.
**Section 2.3 is changed accordingly.**

STRAT2-D provides 4 different layers, but there is not an explanation about the criteria on how the "recently upgraded algorithm" picks up the MLH (if the profiles with rain are discarded, case of boundary layer clouds...). A brief explanation is needed to make the paper more clear..

Agreed. The recently upgraded algorithm is now available in a publication (Pal et al. 2013). Our manuscript now refers to this paper. A short description of the lidar-



anemometer MLH retrieval algorithm is provided to make our paper self-sufficient.

"A variance analysis is performed on the lidar backscattering profiles" Again, is here referred to the aerosol backscattering coefficient? How is it retrived? Or is it the range corrected signal? In this hypothesis, the variance is not a good indicator of stability, as the ALS450 lidar signal is not normalized to the laser energy, and especially during the warmest hours, the laser may have some fluctuations in energy.

We concur these information were missing. Hourly variance profiles are determined using vertical profiles of range-corrected lidar backscatter signal. This retrieval provides a proxy for the location of maximum turbulent mixing within the ABL; thus obtained mean ABL depth guide the attribution by searching for the appropriate minimum of the gradients.
**We have added these information to Section 2.3.**

Previously, several researchers (e.g., Menut et al., 1999; Lammert and Bösenberg, 2006; Engelmann et al., 2008; Pal et al., 2010) and very recently Pal et al. (2013) used the variance-based technique for the determination of mean ABL depths using lidar systems covering the entire spectrum of wavelengths starting from UV to IR. Please refer to Pal et al. (2013) for a complete description of this method, which is beyond the scope of our paper.

Engelmann, R., Wandinger, U., Ansmann, A., Muller, D., Zeromskis, E., Althausen, D., and Wehner, B.: Lidar observations of the aerosol vertical flux in the planetary boundary layer, J. Atmos. Ocean. Technol., 25(8), 1296–1306, 2008.
Lammert, A., and J. Bösenberg (2006), Determination of the convective boundary layer height with laser remote sensing, Bound.-Lay. Meteorol., 119, 159-170.

**METHODOLOGY**

See Major Comments

See reply to major comments above.

### RESULTS

"However, lidar system performances have some impact on optical overlap factor". This statement is wrong, as the overlap function depends only optical geometry of the system (the field-of-view of the laser beam and the field-of-view of telescope). The atmospheric conditions are different, and sometimes (for example during high aerosol load or high humidity) some stronger signal is detectable from lower range bins. But still, this signal is in a region where full overlap is not reached. How is reliable the training from MLH retrieved in a region where full-overlap is not reached? Lidar data under 350m should be corrected with the measured overlap function to be used.

We agree that the statement made was not transparent enough to discuss the lidar system performance and thus needs some modification. We also agree that the overlap function of any lidar system solely depends on the transceiver geometry of the instrument. During the measurement period discussed in the paper, some maintenance and repairing of some its parts were performed which most probably made a slight change in the height of the full overlap. Please also note that the overlap function does not change like a step-function with height/distance from the lidar receiver, rather like an exponential function with its value from 0 (fully incomplete overlap) through fractional values (between 0 and 1, partial overlap) to 1 (full overlap). We agree with the reviewer that in the region of partial overlap, sometime, some stronger signal intensity in the lidar signal is obtained depending on the atmospheric conditions though the overlap factor does not change. Indeed, this is the reason that we did not use the information obtained below the height of full-overlap of 150-200 m (same value as in Royer et al. (2011)).
**In the revised version, we clarified this issue and modified the relevant sen-**



**tence:** “However, lidar backscatter maximum can be detected in a region below the full overlap because the overlap function grows from 0 at the ground to 1 following an exponential function. Therefore detection below 200 m is possible at times, as can be seen in Figure 3 during the first week of March.”

### SUMMARY AND CONCLUSIONS

see RESULTS about the possibility of detecting MLH under 200m

The clarification above apply here as well. We hope this satisfies the reviewer’s comment.

"showing a consistent seasonal variability" This is a dared statement, as the dataset is not climatologically significant

We agree with the reviewer that the dataset available to us is not climatologically significant as it covers less than one full year. **We have added this information in the revised Section 5** to smooth the statement above.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/6/C2257/2013/amtd-6-C2257-2013-supplement.pdf

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 4971, 2013.

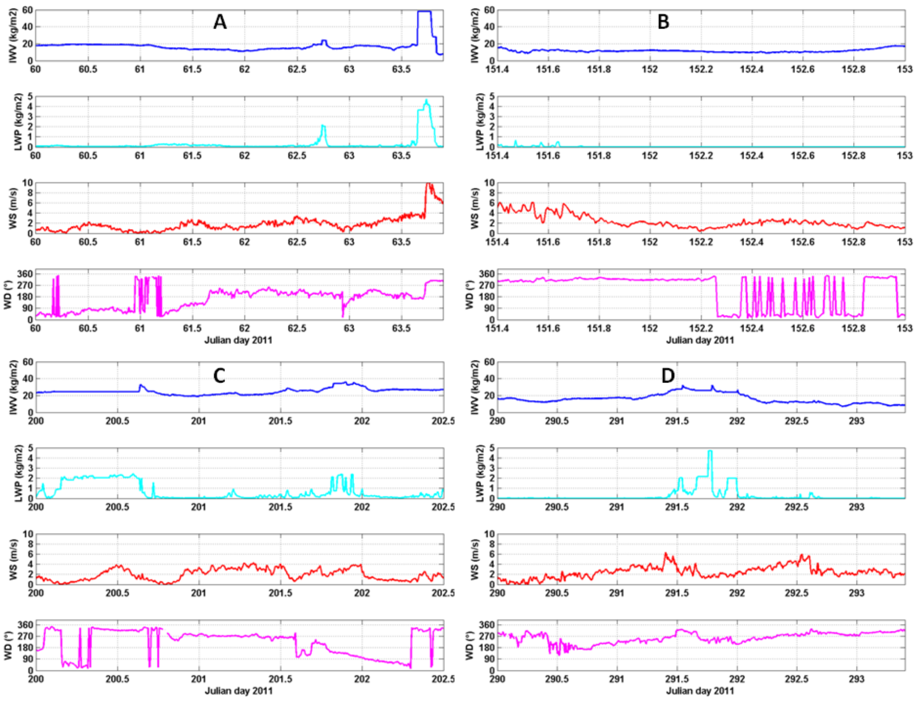


**Fig. 1.**