RETRIEVAL OF MIXING HEIGHT BY MULTICHANNEL MICROWAVE RADIOMETER OBSERVATIONS

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ABSTRACT

The mixing layer height (MLH) defines the top of the layer near the surface where turbulent mixing is occurring. In the recent years, new algorithms have been developed for estimating MLH, though the automatic detection of the top of the mixing layer still remains challenging. For example, when the MLH is estimated from lidar data, the lidar overlap limit may mask the early growth of the mixing height under stable conditions. Thus, a synergetic approach, considering different techniques based on different aspects of the boundary layer, may be explored to improve the MLH estimate in all conditions. Here we show the preliminary results of a method developed to estimate MLH from multichannel microwave radiometer data.

1. INTRODUCTION

The atmosphere boundary layer is characterized by turbulent fluctuations that induce mixing. During daytime the mixing layer tends to be unstable as a result of convection. At night a shallow stable layer forms near the surface in which mixing occurs through intermittent turbulence, leaving a residual layer above. The mixing layer height (MLH) defines the top of the layer near the surface where turbulent mixing is occurring. The MLH is a key parameter for boundary layer applications, including meteorology, weather prediction and air quality. The determination of the MLH is crucial to study exchanges between the surface and the atmosphere. In the recent years, new algorithms have been developed for estimating MLH, though the automatic detection of the top of the mixing layer still remains challenging, with frequent missing estimates when the mixing layer is not well defined. Mixing layer height can be determined either using temperature, humidity, and wind profiles from in situ vertical profiles or by tracing gradients in atmospheric constituents or structures using remotely sensed vertical profiles (from instruments like lidar, wind profiling radar, sodar). For example, MLH can be estimated from the detection of the sharp gradient in the lidar backscatter signal due to aerosol decay at the top of the mixing layer. However, in stable boundary layer conditions, the lidar overlap limit causes an offset in the measures of the MLH because stratifications below this height cannot be detected. Thus, a synergy between different techniques, based on different aspects of the boundary layer, shall be explored to improve the MLH estimate in all atmospheric conditions.

2. DATA SET

In this work, we show the potential of ground-based multichannel microwave radiometers (MWR) to estimate MLH. The data set considered here was collected at the Site Instrumental de Recherche par Télédétection Atmosphérique (SIRTA), a French national atmospheric observatory dedicated to cloud and aerosol research. SIRTA is located at Palaiseau (49N, 2E), 20 km south of Paris (France) in a semi-urban environment. At SIRTA, active and passive remote sensing instrumentations are operated, including a multi-channel MWR and a backscatter lidar [1]. The multi-channel MWR deployed at SIRTA is a humidity and temperature microwave profiler (HATPRO) manufactured by RPG. It senses brightness temperatures (Tb) at 14 channels (22.24, 23.04, 23.84, 25.44, 26.24, 27.84, 31.4, 51.26, 52.28, 53.86, 54.94, 56.66, 57.3,58 GHz) and 7 elevation angles (90, 42, 30, 19, 10, 5, 0°). The lidar deployed at SIRTA is a 355nm ALS450 backscatter lidar developed by Leosphere. The MLH is derived from lidar backscattering data using the STRAT2D algorithm [2].

3. PRELIMINARY RESULTS

Two approaches have been tested to retrieve the MLH from MWR data:

1) estimate MLH from MWR-retrieved temperature and humidity profiles [3].
2) estimate MLH from MWR-observed Tb.

The first approach is useful because it can deploy the tools developed for temperature and humidity profiles from radiosonde observations [4]. However, the MLH much depends on the different definition (i.e. tool) that is applied. The second approach is a “direct” estimate from Tb measurements. Here it was used a simple multivariate regression (other methods can be used, e.g. neural networks), with in input Tb at all 14 channels and 6 elevation angles (90-42-30-19-10-5°). The training was performed assuming the reference “truth” taken from MLH estimates from backscatter lidar data, following the STRAT2D algorithm. Two different sets of coefficients are determined for night- and day-time retrievals and these were used alternatively depending on local time. Preliminary results of MLH estimated from direct MWR observations are compared with MLH estimates based on other instruments. Figure 1 shows preliminary results obtained for March 2012 at the SIRTA site, obtained from MWR and lidar observations. It is evident that the MWR-based estimate is able to follow the diurnal cycle indicated by the lidar data. Figure 2 shows a statistical comparison performed on a test set that was not used during the training. Statistics of 1-hour average MLH estimates from MWR show a root-mean-square (rms) error of 162 m with respect to STRAT2D MLH estimates.

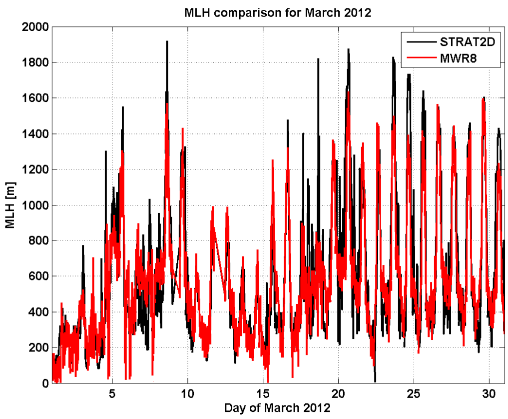

Figure 1. Time series of MLH derived from MWR (red) and from STRAT2D algorithm (black) for March 2012.

4. SUMMARY AND CONCLUSIONS

In this paper we demonstrated the potential for deriving MLH directly from MWR observations. Statistics of 1-hour average show rms error equal to 162 m with respect to estimates based on backscattering lidar data. Note that MLH estimates from MWR are expected to be specially valuable for shallow MLH during stable boundary layer conditions. Thus, the combination of MWR and lidar data, as well as data from other remote and in situ sensing instrumentations, seems crucial for studying the MLH in all stability conditions. Future work includes the development of an automatic procedure to identify stable and convective regime, the extension of the dataset to include the seasonal variability of MLH, and the use of other methods that do not require external reference truth for training.

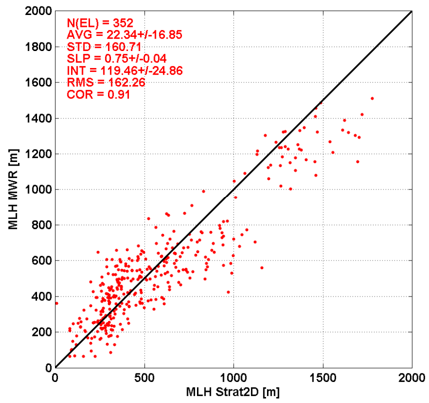

Figure 2. Scatter plot of 1-hour averaged MLH derived from MWR (Y-axis) and Strat2D (X-axis) in Figure 1. Number of elements (N(EL)), average X-Y difference (AVG), standard deviation (STD), root-mean-square difference (RMS), correlation coefficient (COR), slope (SLP) and offset (INT) of a linear fit are included. N(EL), SLP, and COR are dimensionless, while AVG, STD, RMS, and INT are in meters.

5. ACKNOWLEDGMENTS

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6. REFERENCES

1. Haeffelin M. et al., (2005). SIRTA, a ground-based atmospheric observatory for cloud and aerosol research. *Ann. Geophysic.*, **23**, 253-275, doi: 10.5194/angeo-23-253-2005.
2. Morille Y., Haeffelin M., Drobinski P., Pelon J. (2007). STRAT: an automated algorithm to retrieve the vertical structure of the atmosphere from single-channel lidar data. J. Atmos. Ocean. Tech. 761–775.
3. Cimini D. et al. (2006). Temperature and humidity profile retrievals from ground-based microwave radiometers during TUC, *Met. Zeit.*, V.15, N.1, 45-56.
4. Seidel, D. J., C. O. Ao, and K. Li (2010). Estimating climatological planetary boundary layer heights from radiosonde observations: Comparison of methods and uncertainty analysis, *J. Geophys. Res.*, 115, D16113, doi:10.1029/2009JD013680.