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ABLH retrievals using multi sensors approach

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Abstract: An intensive observation period (IOP) for simultaneous measurements of ABLH by using radio soundings and remote sensing techniques is planned at CNR-IMAA Atmospheric Observatory (CIAO) starting from April 2024. During the IOP all the CIAO sensors relevant for the study of the ABLH will be operative 24 hours a day and seven days a week. At least 6 radiosoundings per day will be performed, adopting GRUAN (GCOS Reference Upper Air Network) procedures and algorithms. This experimental set-up will provide an optimal dataset for the characterization of ABLH using different techniques and sensors. Additionally, the measurement campaign will provide the opportunity to optimize MIPA (Morphological Image Processing Approach) algorithm for the retrieval of ABLH from lidar data.

1. Introduction

The atmosphere boundary layer (ABL) is the lowest part of the troposphere that is directly influenced by Earth's surface and responds to surface forcing over a short period of time. Accurate estimation of the atmospheric boundary layer height is important, and it based on the detection of the vertical profiles of atmosphere variables or aerosols.

Starting from April 2024 to June 2024, an IOP will take place in Potenza (40.6N, 15.72E, 760m asl) at CNR-IMAA Atmospheric Observatory (CIAO). The main goal of this measurement campaign will be to establish a complete reference dataset for ABLH retrieval. To achieve this objective different types of both remote sensing and in situ sensors will be involved, operating simultaneously and continuously 24/7. Additionally, frequent radiosonde launches will be performed in order to get a representative reference for the ABLH to assume as truth. Indeed, the different retrievals for the estimation of ABLH are based on different assumptions, hence the large number of instruments participating in the campaign will be an added value to evaluate the impact of these hypothesis in different atmospheric conditions. For example, ABLH retrievals from lidar measurements, use the atmospheric aerosols or water vapour as tracers of the ABL [1,2,3]. This approach assumes that water vapour or aerosols are well-mixed in the ABL and their concentration is high enough to guarantee accurate ABLH estimations. Consequently, when these conditions are not met, the corresponding ABLH estimations can be affected by critical issues. Furthermore, lidar measurements cannot be carried out in rainy conditions. Moreover, particularly low ABLHs (typically observed during nighttime conditions) cannot be detected if they are below the lidar full overlap height independently of the retrieval algorithm. In addition, there are different conditions under which the ABL is formed (non-turbulent, convective, cloud-driven, wind shear, etc.) and, consequently, lidar ABLH retrievals should be assessed in each one of those. In this context, the use of other sensors like Doppler lidars and radars can help in showing the limitations in getting ABLH from Raman or elastic lidars. Moreover, these additional sensors can provide useful information about the ABL regimes to correlate against the ABLH retrievals.

Besides lidars, the main instrument for the ABLH detection are radiosondes which allow to get ABLH based on thermodynamic definition of the ABL. However, radiosoundings are expensive in terms of both men power and expenses and typically they are not available with a frequency high enough to follow the diurnal evolution of the ABLH. For this reason, the frequency of radiosonde launches during the

IOP is a crucial factor for providing a big reference and representative dataset for the assessment of the ABLH retrieved by using remote sensing approach. CIAO is the ideal site for performing this kind of experiment, as it is equipped with two radiosounding systems (one of them automatic). We plan to perform at least 6 lunches per day and to process them by using GRUAN standard procedures and algorithms. The exact scheduling of the radiosonde launches will be evaluated case by case. In general, we plan to have a denser launch scheduling in correspondence of ABL transition periods (mainly sunrise and sunset) or during special events like dust or biomass burning intrusions.

Aerosol in situ measurements will be continuously running during the campaign providing a useful characterization of the aerosols at the ground at 1 minute time resolution.

2. Instruments

The instruments participating to the CIAO Atmospheric Boundary Layer Height measurement campaign are reported in Tab. 1.

Table 1. Instruments participating to measurement campaign

Sensor type	Instruments
Lidar	1) Fixed Multiwavelength Raman Lidar 2)Mobile Multiwavelength Raman Lidar 3) CONCERNING Lidar (Unibas)
Doppler Radar	MIRA36 (35.5GHz) Halo Photonics Stream LineXR (1.5 µm)
Ceilometer	CL 51 (905 nm) CL31 (905 nm) CHM15k (1064nm)
Microwave Radiometer	RPG-HATPRO-G5
Radiosounding system	MW41 (manual) AS13 (automatic)
In situ	Aethalometer AE33, Nephelometer Aurora 3000, Aerodynamic Particle Size APS 3321, Condensation Particle Counter (CPC 3750), Scanning Mobility Particle Sizer (SMPS 3938), ToF-ACSM, PMx samplers

Different lidars have different configurations (coaxial or biaxial) and do not all perform the same measurements. Having three lidar systems in continuous measurement therefore allows us to obtain more information. In particular, the fixed multiwavelength Raman lidar system is equipped with two laser sources, one with pulse energy of 150 mJ (at 1064 nm), pulse repetition frequency of 10 Hz and beam divergence < 1.2 mrad, the other with pulse energy of 200 and 100 mJ at 355 and 532 nm, respectively, pulse repetition frequency 10 Hz and beam divergence < 1.2 mrad for both wavelengths. The receiving system includes a Cassegrain telescope with a diameter of 400 mm optimized for far range detection and a Dall Kirkham telescope with a diameter of 200 mm optimized for the near range. Moreover, the system is equipped with Raman detection channels at 387 (nitrogen) and 407 (water vapour) nm for the retrieval of water vapour mixing ratio profiles. This lidar will be able to provide continuous measurements of backscattering coefficient (at 355, 532 and 1064 nm), extinction coefficient (at 355 and 532 nm), and water vapour through the troposphere and lower stratosphere. Balloon-based measurements of humidity, temperature, pressure and wind (speed and direction) up to thestratosphere are performed byusing three different VAISALA MW41 radiosounding systems: two manual (fixed and mobile) and one equipped with an automatic launcher (VAISALA autosonde system AS14). The latter is able to perform up to 24 radiosoundings automatically and it can be controlled remotely. Moreover, the system can also be scheduled for activating up to two spare radiosoundings in order to prevent any faults during the launch procedure.

3. Preliminary case of study

During the measurement campaign the lidar measurements will be continuous in both daytime and nighttime conditions. A preliminary example of measurements is reported in Figure 1 showing the temporal evolution of water vapor mixing ratio profiles obtained from lidar measurements carried out between 16:57 and 23:40 UTC of 22 February 2024. Since the focus of our research is the ABL, we used only the data collected by the small telescope in near range configuration. The temporal resolution is 1 minute while the vertical resolution is 30 meters. The map shows well how the system is able to characterize different humidity structures.As preliminary calculation of the ABLH we have considered the first (from the surface) strong gradient of the water vapour profiles. It is worth to stress that the estimation of the ABLH from the lidar measurements of water vapor has the important advantage of having a lower overlap compared with the one calculated by using elastic range corrected backscattered lidar signals.The black line in Figure 1 represents the retrieved ABLH, which is in excellent agreement with the one obtained from the radiosonde measurements using the potential temperature gradient method [4].

Figure 2 illustrates the evolution of the ABLH height as estimated by several different approaches. Black line represents the ABLH as calculated from lidar water vapour mixing ratio profiles, red line from lidar range corrected signals at 1064 nm and the green line from Vaisala CL51 ceilometer using a proprietary algorithm from the manufacturer. Finally, the green point represents the ABLH calculated from the radiosonde.In general, there is a quite good agreement between the lidar retrieved ABLH by using water vapour and aerosols as ABL tracers for the entire measurement period. However, the ABLHs retrieved by ceilometer using Vaisala algorithm seem to be underestimated before 20:00 UTC.

During the measurement campaign we have also planned to validate and optimize MIPA [METTI LA REF] a novel and promising algorithm to retrieve the ABLH from remote sensing measurements developed at CNR-IMAA.

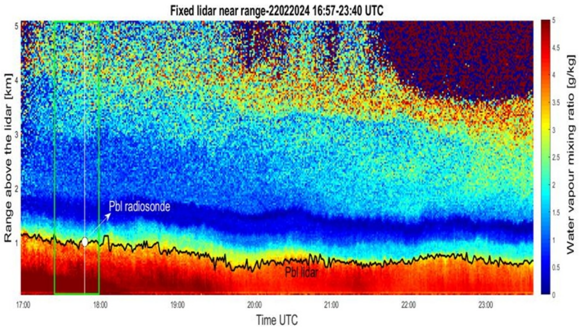

Figure. 1: Time evolution of the water vapour mixing ratios profiles from lidar measurements in the time interval between 16:57 and 23:40 UTC on 22 February 2024. The black line is the retrieved ABLH.

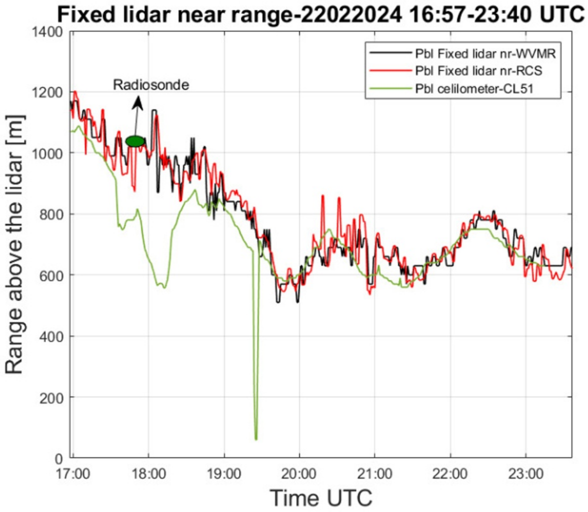

Figure. 2: Comparison of ABLH estimated by using different methods.

Results outcoming from CIAO measurement campaign starting in April 2024 with a statistical analyses will be shown in the conference.

4. References

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