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INVESTIGATION OF THE CLOUD COVER AND PLANETARY BOUNDARY LAYER (PBL) CHARACTERISTICS USING CEILOMETER CL-31*

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Abstract. The aim of the present paper is to present applications of the ceilometer measurements for the study of the cloudiness, cloud types and the characteristics of the Planetary Boundary Layer (PBL).The PBL is the layer where earth's surface interacts with the large scale atmospheric flow. The ceilometer CL-31 is a mini-lidar used in remote sensing measurements, especially for the cloud bases. The data used for this study were obtained as results of the measurements performed in Magurele (44.35 N, 26.03 E) for a long winter (November 2008-March 2009). The CL-VIEW and Lab-View programs were used for data processing to obtain the images and vertical backscatter profiles. The images allow to determine the cloud types, the presence of the aerosol layers, precipitation and the fog. The results of the images and vertical profiles analysis have shown the most cases of stratus clouds in this period. The appearance of altocumulus or cirrus clouds is connected to the air masses advection. The special cases with precipitation or aerosol intrusions were discussed in connection with meteorological parameters, using HYSPLIT4 model and synoptic situations. The large cloudiness and precipitation periods were confirmed by meteorological data. This emphasizes the applicability of the ceilometer's data in characterizing of the PBL.

Key words: ceilometer, clouds, aerosols, PBL.

1. INTRODUCTION

Clouds are an important regulator of the Earth's radiation budget. About 60% of the Earth's surface is covered with clouds. Clouds cool the Earth-atmosphere system on a global average basis at the top-of-the-atmosphere and at the surface of the Earth. The cooling is explained, especially by the known reflectivity properties of the clouds [1, 2]. They have also a great importance in the hydrological cycle. Therefore, the clouds' observations and studies were intensified in last decades.

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Since 1990, especially in the USA and Canada, the observations at the surface have been replaced with remote sensing measurements using LIDAR equipments. These have a great potential in atmospheric research and air quality monitoring. The ceilometer CL-31 is a mini-LIDAR used to determine the bases of clouds and some characteristics of Planetary Boundary Layer (PBL), such as aerosol layers, dust intrusions or mixed layer depth/ height (MLD) [3].

The PBL is the layer where the earth's surface interacts with the large-scale atmospheric flow and its height or MLD is a key parameter in air pollution studies [4]. Height of the PBL can be useful in air quality monitoring, aviation applications and other forecast applications where knowledge of the spatial variation of the depth and strength of near surface mixing is important. The presence of the aerosol layers can also be detected in the ceilometer's images and associated backscatter profiles. The variability of heat, momentum and vapor fluxes within PBL determines the turbulence and meteorological phenomena [5, 6]. Therefore it is very important to know the characteristics of the PBL.

There is not direct method available to determine the MLD. The most common method uses the vertical profile of atmospheric state curve (temperature versus height) obtained from radio soundings. Thus, it is relevant to develop and evaluate new methods and techniques in order to mitigate the uncertainty involved in the determination of the MLD.

A new method for estimating the mixing height is based on ceilometer measurements, using the lidar-technique, which measures the aerosol concentrations profile. Generally, aerosol concentrations are lower in the free atmosphere than in the mixing layer and then can be expected that MLD is associated with a strong gradient in the vertical back-scattering profile [7]. Eresmma et al. (2005) determined MLD using the idealized backscatter profile, performing a comparison between ceilometer's and radio soundings data (Holzworth method).

The aim of this paper is to study the PBL in connection to meteorological conditions, by using the images of backscattering profiles obtained from ceilometer's measurements. The analysis was applied to individual ceilometer profiles (Section 2 – Data and Methods). The results obtained by processing ceilometer's data, presented in Section 3, were comparatively discussed in synoptic context, using radio soundings and meteorological data and as well as air mass back trajectories [9]. The conclusions are presented in the final of the paper.

2. DATA AND METHODS

The ceilometer CL-31 is installed at Faculty of Physics in Magurele (44.35N; 26.03 E). The Vaisala single-lens ceilometer is a mini-lidar that measures the optical backscatter intensity of the air at a wavelength of 910 nm. Its laser diodes are pulsed with a repetition rate of 10 kHz. The backscatter ceilometer profiles can be obtained every 2 s. The hourly data were organized into database also containing six hours and daily files. The study used data sets for long winter period, during November 2008–March 2009.

The Ceilometer Data Visualization programme developed within Lab-VIEW environment soft analyzes files containing ceilometer's messages. The programme displays cloud intensity time series and the backscattering profile of the individual file selected. Using ceilometer's images and the backscattering profiles were identified the clouds' base and PBL height.

The vertical profiles of the meteorological parameters equivalent potential temperature, relative humidity and the horizontal wind speed were also used in this study. The parameters values were extracted from radio soundings from Bucharest meteorological station, from meteograms obtained from reanalysis data (http://www.ready.noaa.gov/ready/open/hysplit4.html) and using HYSPLIT4 (Hybrid Single Particle Langrangian Integrated Trajectory) model developed by the National Oceanic and Atmospheric Administration (NOAA)'s Air Resources Laboratory. The synoptic maps were used to complete the results.

3. RESULTS AND DISCUSSIONS

The cloud types, their bases and statistics were analyzed for the long cold season, since November 2008 and ended at March 2009. The evolution of clouds and phenomena in PBL can be observed in the imagines obtained by data processing from ceilometer. Figures 1 and 2 show the cloud base heights, phenomena as precipitation and backscatter profiles, respectively, during different periods of the day: in midday for 5th March and in evening for 19th of February.

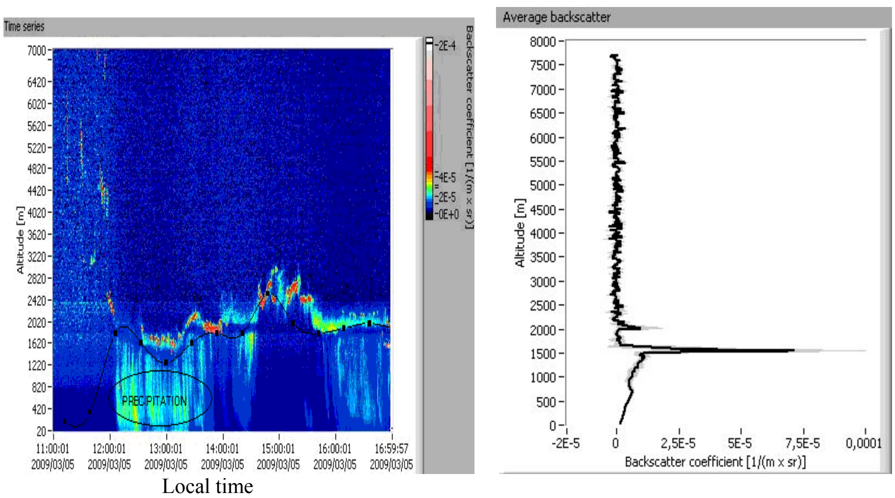

Fig. 1 – Imagine of the PBL (left) and associated backscatter profile (right) for 05th of March 2009. The solid curve marks out the mixed layer height; the period with precipitation is also marked. The backscatter profile shows the mixed layer at the same height as in imagine (appropriate on 1500m).

One can observe the evolution of the structure of the PBL (Fig. 1) and that it has had the highest value in hours after the precipitation ceased. Backscatter coefficient profile shows similar evolution of PBL height.

In Fig. 2 on can also observe the presence of the rain in afternoon and the dependence of variation of the PBL height on the both state of the atmosphere and phenomena. The backscatter vertical profile shows the same values of the heights of the two stratus layers.

The comparison the ceilometer's observations with the meteograms obtained using the HYSPLIT4 model shows presence of precipitation and the similar values for mixed layer (Fig. 3).

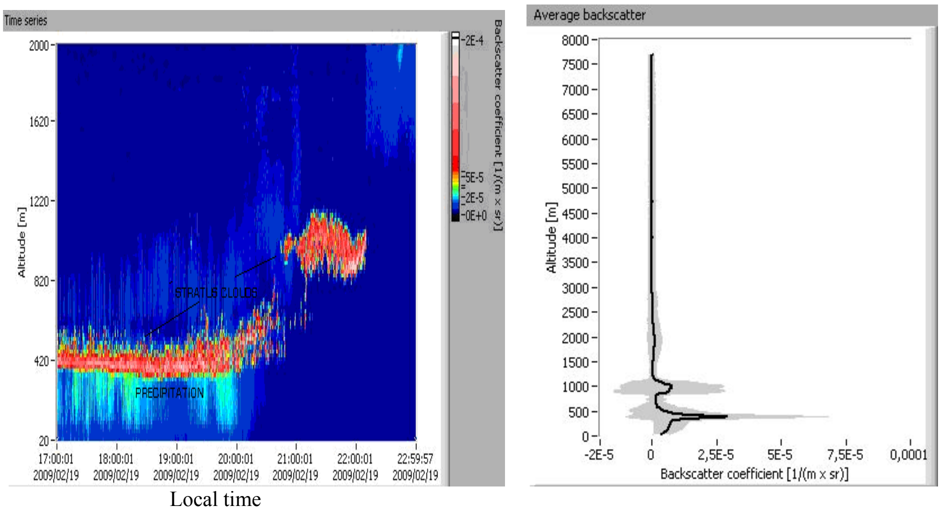

Fig. 2 – As in Fig. 1 but for 19th of February 2009 in evening hours. In backscatter profile can be observed the two levels of the PBL marked by the cloud bases.

So, the meteograms confirm the presence of the precipitation and the evolution of the PBL height for the two chosen days.

The top of the PBL or mixed layer depth (MLD) is often marked with a temperature inversion, a change in air mass and change in wind speed and/or a change in wind direction. Inversions traps air within the PBL and do not allow convection to occur into the middle and upper atmosphere.

The evolution of meteorological parameters (wind vector, temperature, pressure, humidity) shown a good agreement with ceilometer's data. Wind direction, humidity and temperature profiles have been obtained from radio sounding observations. Values of the mixing layer height obtained from ceilometer's data and the radio sounding data profiles are very close each other (Fig. 4, right).

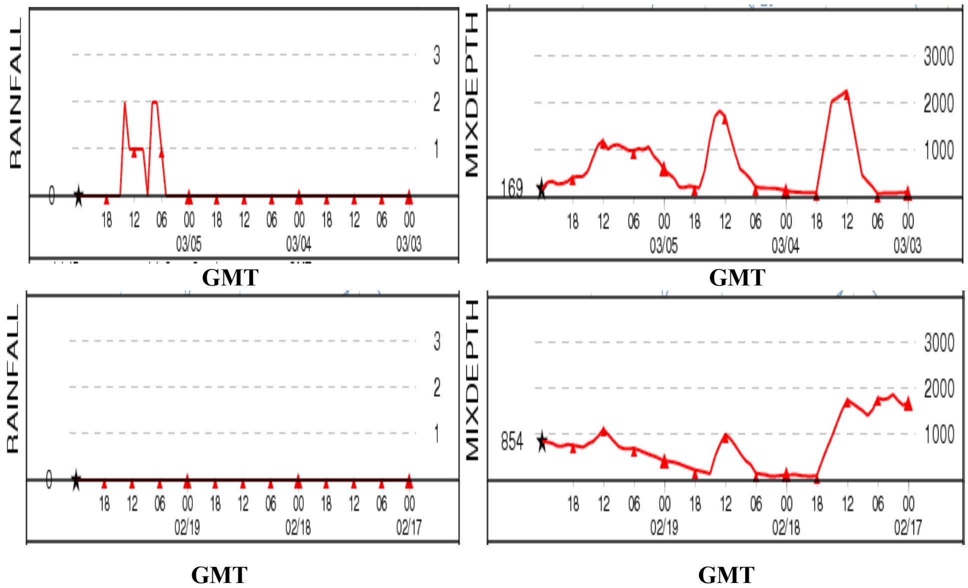

Fig. 3 – Meteograms obtained using HYSPLIT 4 [9]: precipitation left column and mixed layer height on right column; upper panel 05th of March 2009 and lower for 19th of February 2009.

Height of the mixed layer depth (MLD) marked in Fig. 1 on image from ceilometer is comparable to the both synoptic situation (a bridge over Romania, left part of Fig. 4) and radio sounding profiles of potential temperature, wind direction and relative humidity (right part of Fig. 4).

For the discussed case from 19 February, the synoptic map and radio sounding data have also confirmed the value of MLD (not shown).

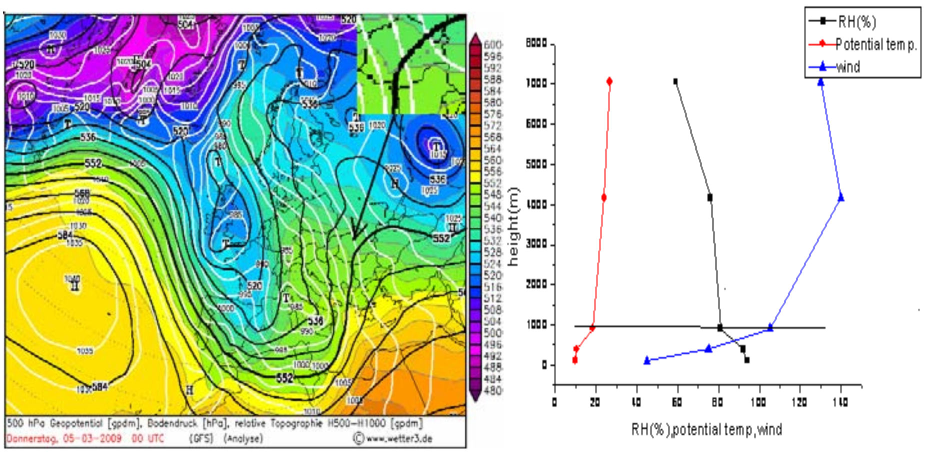

Fig. 4 – Synoptic map (left part, [10]) and vertical profiles of potential temperature, wind direction and relative humidity (right part) for 05th of March 2009.

The aerosol particles layer in the atmosphere cannot be observed because clouds, fog and precipitation hide it. The presence of the aerosol in atmosphere is very well visible on the ceilometer's imagines in clear sky, without clouds. Therefore, in this study we did not study the detection of the aerosol intrusions over Magurele.

In analyzed cold period the lower clouds stratus, covered in largest percent the sky at Magurele (Fig. 5). Cirrus, the highest clouds, had the smallest occurrence frequency; this means that in cold period of the 2009 year the warm atmospheric front crossed seldom over Magurele. The trend of lower clouds (stratus) is decreasing for the long cold period and increasing in the same period in case of middle clouds (altocumulus), excepting February month.

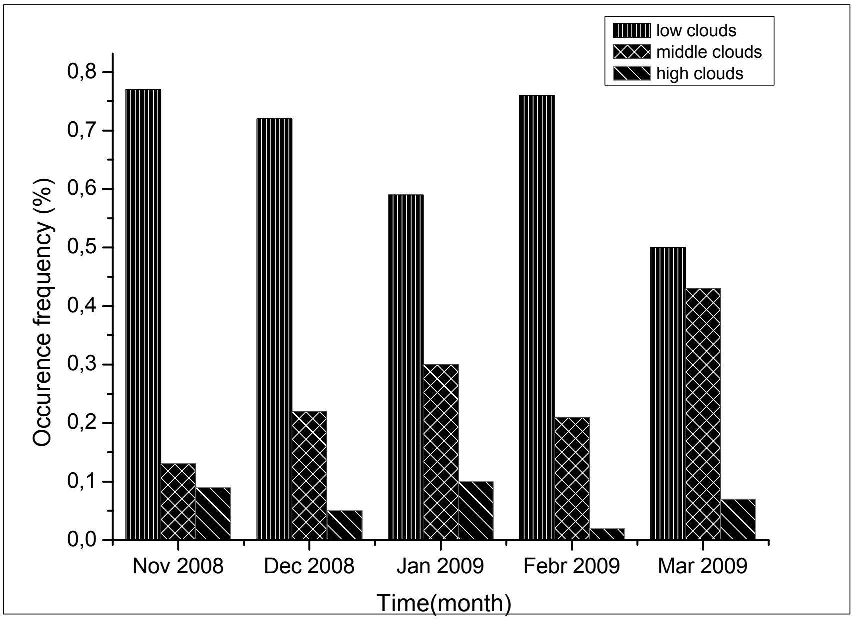

Fig. 5 – Histogram of the monthly occurrence frequency of clouds at Magurele, using CL-31 for cold period of year (November 2008–March 2009).

Figures 6 and 7 show the same findings: the dominance of the stratus clouds in the long cold period and in winter season; the occurrence frequency was computed as number of lower clouds from total number of clouds for the completely cold /winter period.

Fig. 7 shows the highest occurrence frequency for stratus clouds in February and an unexpected occurrence frequency of cirrus clouds (the clouds with the highest base) in January.

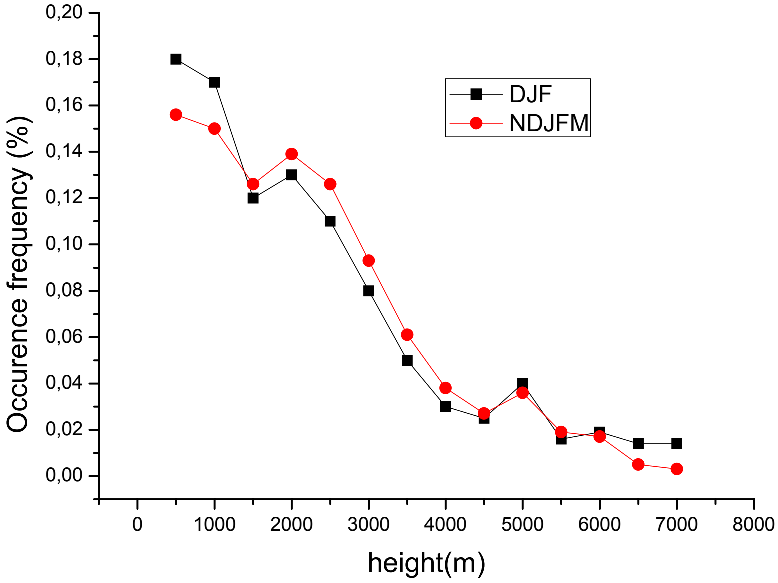

Fig. 6 – Occurrence frequency of clouds *versus* their height base for cold period of year, November 2008–March 2009 and for winter (DJF).

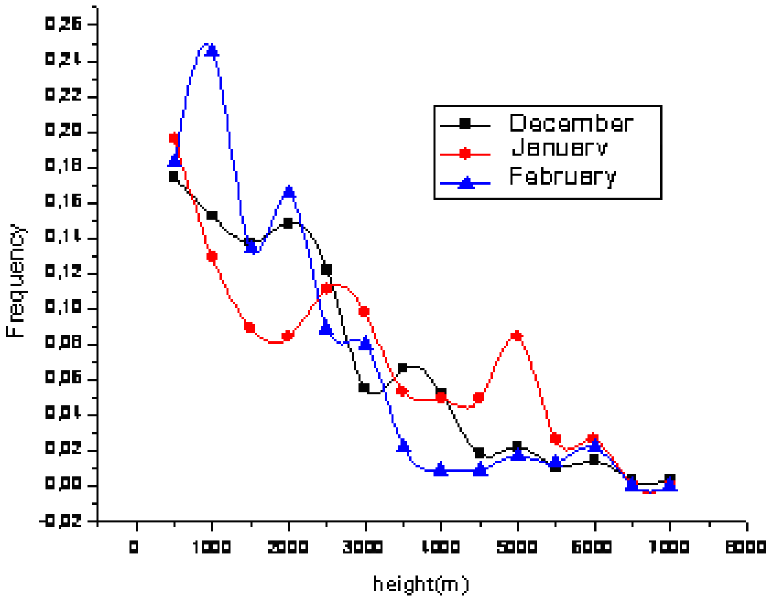

Fig. 7– Monthly occurrence frequency of clouds *versus* their height base for winter season (DJF).

Comparison to cloud occurrence frequency for winter (DJF) has shown a similar trend as for long cold period (Fig. 6). The differences are explained by the unexpected behavior of the January month, much warmer than obviously (Fig. 6).

The explanation consists in warm air mass advection over southern part of Romania in January.

4. CONCLUSIONS

The state of the atmosphere, base and type of clouds, precipitation or fog and the air quality monitoring could be determined using backscattering profiles and the images obtained from ceilometer CL-31.

In the cold period of year (November–March), the stratus clouds were the dominant clouds. Occurrence frequency of clouds in winter (DJF) and in the considered cold months (NDJFM) was similar, emphasizing that the extension of the winter is not significant for local site.

Decreasing trend of the occurrence frequency of the stratus clouds from November to March was obviously and expected due to the changing of air circulation types over southern part of Romania.

Classical methods for determining of Mixed Layer Depth (MLD) have validated the results obtained by using ceilometer's measurements.

All the results emphasize that Vaisala CL-31 LIDAR ceilometer is a reliable tool for characterization of the boundary layer structure.

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