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A SURVEY OF CLOUD COVER OVER MĂGURELE, ROMANIA, USING CEILOMETER AND SATELLITE DATA

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Abstract. This study is focused on the combination of ground–based and satellite observations for the derivation of temporal variability of cloud cover fraction (cloudiness) over Magurele (44.35N; 26.03E) in Romania, between December 1st 2008 and December 31st 2011. Ground-based measurements from a mini lidar–ceilometer were combined with measurements of the Aqua and Terra satellite instruments of MODIS (Moderate Resolution Imaging Spectroradiometer) system.

Key words: cloud cover, satellite, ceilometer, cloud's types.

1. INTRODUCTION

The role of clouds has been identified as the area of research of highest priority in many climate change programs. The principal reason is the important radiative effect of clouds in both the solar and thermal regions of the electromagnetic spectrum. Clouds, generally, have opposite effects in these two spectral regions and the net effect for the earth-atmosphere column is the difference between these two forcings [1]. Randall *et al.* (1984) [2] estimated that an increase of 4% in the cloud cover with stratocumulus can compensate the global warming caused by CO_2 doubling. Duynkerke and Teixeira (2000) [3], using the observations obtained in Regional Experiment of ISCCP (FIRE1) Project [5] determined the cloud cover with stratocumulus. Jacob (1999) [4] compared the cloud cover in the European Center for Medium Range Weather Forecasting (ECMWF) with observations from ISCCP and found a model underestimating of stratocumulus cloud cover over the west coasts of subtropical continents by 15%.

Cloudiness/cloud cover is a meteorological parameter important not only for meteorology but also for climatology [6]. An interesting study of cloud types and cloudiness over oceans was given by [7, 8]. Norris (1999) [9], using observational data has also analyzed the cloud cover over ocean. Zhang and Ramanathan (1999)

[10] have shown the importance of the spatial extent of cloudiness in the study of climate variability. Filipiak and Mietus [11] have shown the most important features of temporal and spatial structure of cloudiness variability in Poland.

The aim of this paper is to evaluate the cloud fraction variations using data sets obtained from ceilometer measurements and the MODIS system. Therefore, in the second section titled Data and Methods the files from satellite and ceilometer were presented. Results on partial and total cloud cover over Măgurele were presented in Section 3. The paper is ended with conclusions.

2. DATA AND METHODOLOGY

The present study exposes research on the most important features of temporal variability of cloudiness in the Măgurele area (44.35N; 26.03E) in Romania (Fig.1), between December 2008 and December 2011, using satellite cloud data retrieved from MODIS (Moderate Resolution Imaging Spectroradiometer), in conjunction with ceilometer cloud data.

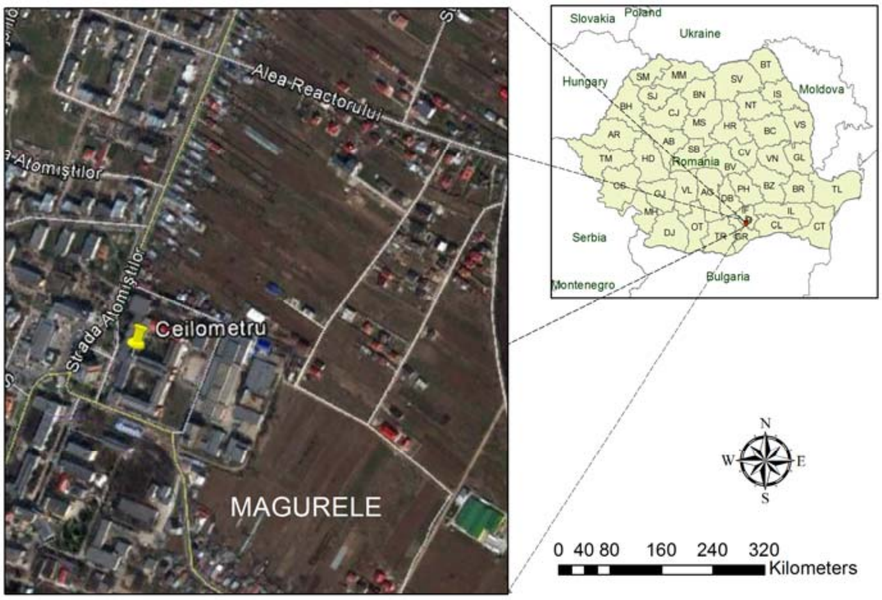


Fig. 1 – Map of Măgurele, showing the location of observational site (Google Earth).

Măgurele (44.35 N; 26.03 E) is a small town close to Bucharest, the capital of Romania. It has sub-urban characteristics and a temperate-continental climate. The climate is characterized by the differences between the four seasons, especially between winter and summer. Therefore, the cloud cover is very different from winter to summer, and also from day to day.

At Măgurele, the cloud types and cloud cover are retrieved using a mini-LIDAR called ceilometer. The same information, as well as various microphysics and optical parameters can be also retrieved from satellite data.

The ceilometer CL 31 is installed at about 20 m above the ground, on the roof of the Physics Faculty, a building located at Măgurele. The Väïsäla single-lens CL31 measures the optical backscatter intensity at a wavelength of 910 nm, 10 m resolution and a maximum height of 7500 m. According to Munkel (2007) [12], the optical design of the CL-31 permits a full optical overlap starting at the height of the top of the instrument.

The storage of a large amount of data from this device can give important information about cloud bases, fog and precipitation, all these being useful in modeling the radiative transfer and energetic budget in the atmosphere. The CL-View and Lab-View software are used for data processing, to obtain the images and vertical backscatter profiles. The data set contains the hourly cloud fraction, cloud types, backscatter coefficients, and the geometrical thickness.

The satellite data are products of MODIS06, a key system for Earth's Observational System (EOS). The "MOD06_L2" files contain the data from the Terra satellite, and the "MYD06_L2" files contain data from the Aqua satellite platform.

These data are stored in HDF format, representing a data library and files designed to store and organize large amounts of numerical data. In order to verify the retrieved data, the QA_Plan_2000 software is used (http://modis-atmos.gsfc.nasa.gov/).

The infrared and visible data are combined in order to determine the physical and radiative properties of clouds [13]; the wavelengths used are: 0.645, 0.858, 1.240, 1.640, 2.13, 3.75 and 11.03 μm. The data files contain, for the days when the satellite passed over Măgurele, microphysics and optical cloud parameters.

The study was made for a time period starting in December 2008 and finishing with December 2011 (37 months); the data were used for coincident satellite and ceilometer days, and also separately, for ceilometer and MODIS. Classical statistics methods were employed, to obtain the daily and monthly cloud fraction value and the frequencies of occurrence of each type of clouds.

3. RESULTS AND DISCUSSIONS

The study concerns research of the temporal cloud cover over Măgurele in the period 01 December 2008–31 December 2011, using ceilometer data and satellite data. The atmosphere scanning frequency above Măgurele is different for the satellite (75% maximum, in January and 10% minimum, in August) to that of the ceilometer (100% monthly coverage). For the comparative study, data were used from both these instruments. The number of the coincident measurements was 3669 during years 2009, 2010 and 2011.

3.1. FREQUENCY OF OCCURENCE OF DIFFERENT CLOUD TYPES

Due to the fact that the ceilometer measures continuously, the database for the three cloud types (low-, mid- and high-level) has allowed for a statistical analysis of the monthly occurence for each of these types. In Fig. 2 one can see how this frequency is very high for the low-level clouds in January and February, then it decreases beginning in March, and then rises again from September through to December. The mid-level clouds are most encountered in March and August, and the high clouds have a low frequency compared to the other types, with it being larger in the summer months of June and July. The low frequency of high-level clouds throughout all months is caused by the limitations of the ceilometer, which measures up to 7.5 km, only.

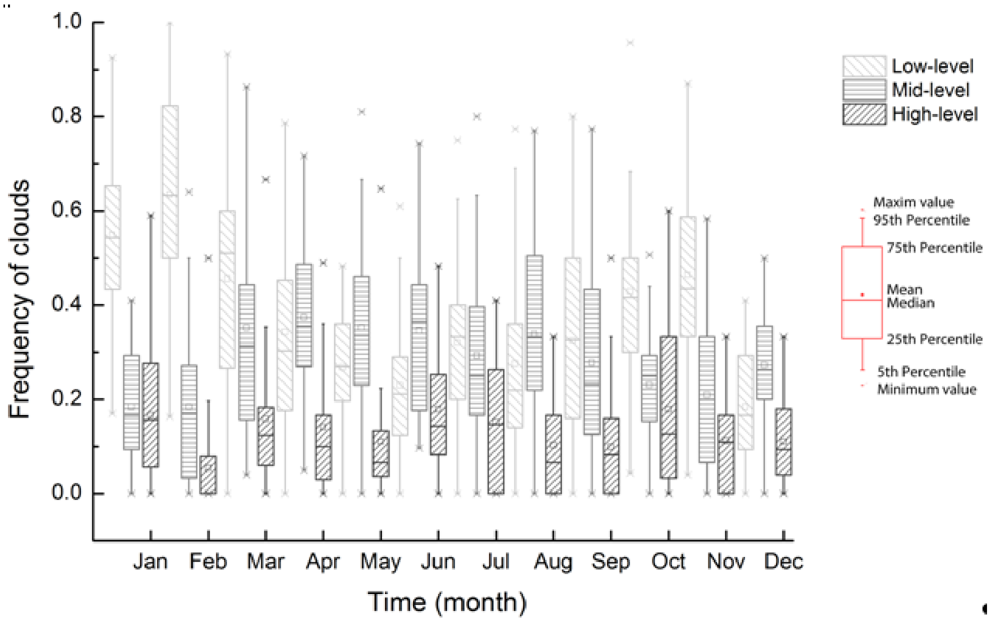


Fig. 2 – Box plots depicting monthly frequency of the three types of clouds for 2009–2011. The box and whiskers present the mean, minimum, maximum and the 1th, 25th, 75th and 99th percentiles.

Using the database with coincident data, the intercomparison between ceilometer and satellite data for the three cloud types was carried out (Fig. 3 a,b,c). As shown in Figs. 3 a, b, c, the ceilometer-observed low-level cloud frequency is evidently higher than that obtained from satellite data, while the opposite is true for the high-level clouds. This difference could be attributed to the fact that ground-based observations (by ceilometer) are much more sensitive to low-level and mid-level cloud fractions than that of the satellite, because the ceilometer measures from Earth's surface upwards and, it having a limited scanning altitude (7.5 km), it does not detect all high-level clouds.

The low-level clouds' frequency of occurrence was the highest (75%) in February 2009 and 2011, from ground-based observations and the smallest (5%) in March 2010, from satellite data.

In the case of mid-level clouds, the monthly frequency is very different for each month, in the satellite and ceilometer data.

In the case of high clouds, the large values from satellite date dominate over the values from ceilometer measurements. The largest value of this cloud fraction was in October 2010 (65%) and the smallest in October 2011, from satellite data.

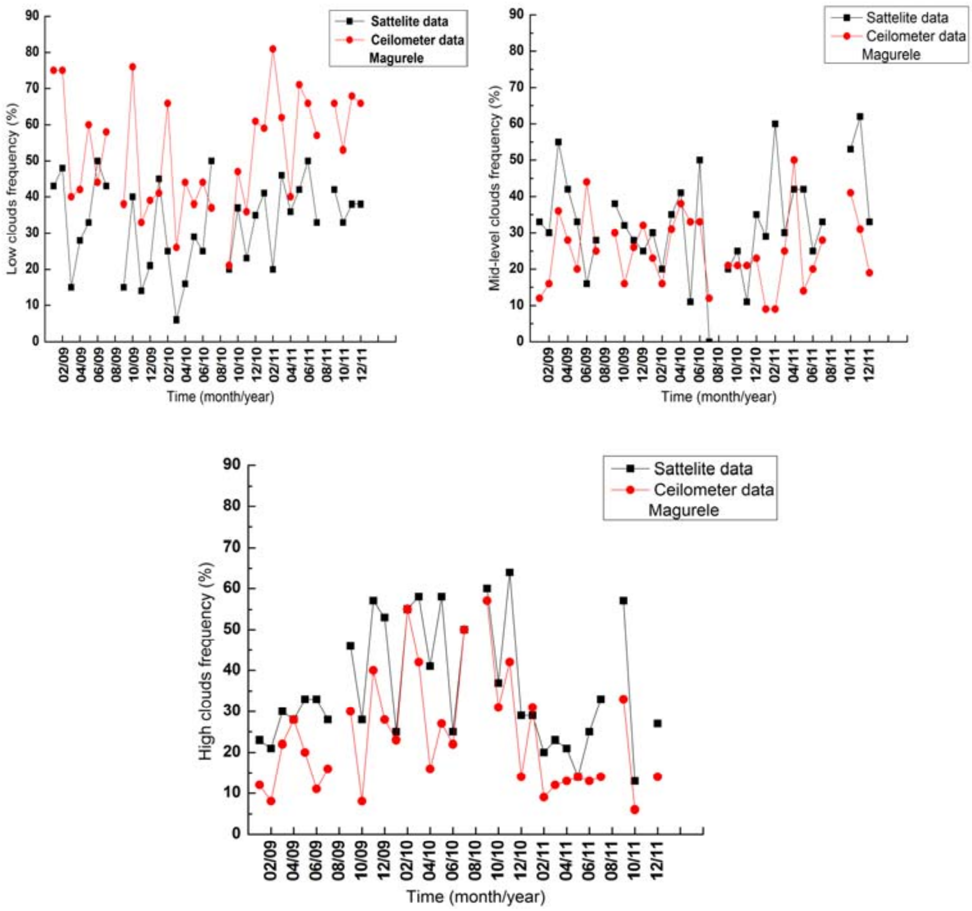


Fig. 3 – Monthly average of low-level (a), mid-level (b) and high-level (c) clouds at Măgurele for 2009–2011 period, using coincident data.

3.2. MONTHLY AND SEASONAL VARIATIONS OF CLOUD COVER FRACTION (CCF)

The cloud cover or total cloudiness is a very important parameter used in climate model or weather forecasting models (Jacob, 1999). Local cloud cover was studied for Măgurele using the ceilometer measurements and satellite data.

To quantify the relative agreement among the two data sets, the correlation coefficients were computed. The calculation is applied to the cloudiness (CCF) over Măgurele for coincident data of whole period, 2009-2011. Results confirm the consistency among the satellite-ceilometer derived cloudiness and the correlation coefficient is 0.54.

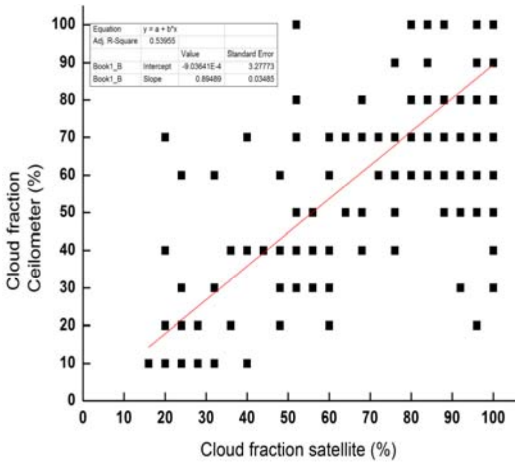


Fig. 4 – Correlation between satellite and ceilometer CCF coincident data for whole 2009–2011 period.

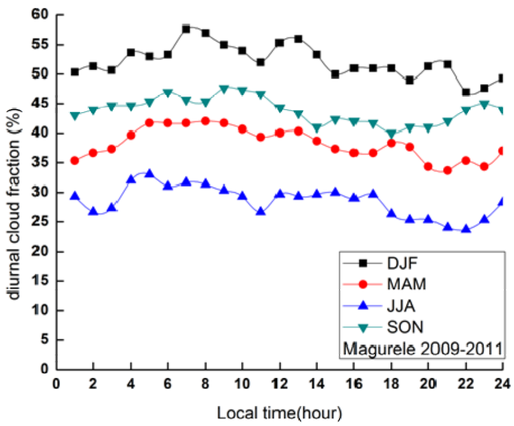
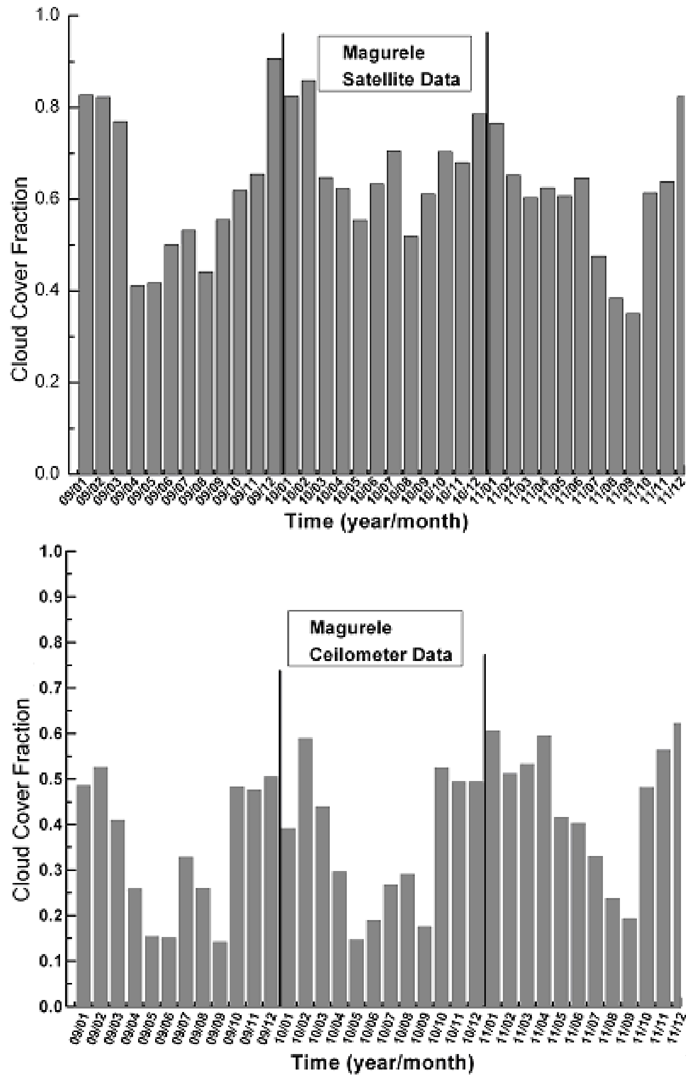


Fig. 5 – Diurnal variations of cloudiness (%) over Măgurele, from ceilometer data.

From the analysis of daily variation, one can see how CCF is higher during the winter (52.15% on average), comparatively to summer (28.51% on average). Similar results were obtained for few synoptic stations from Moldavia, Romania [6], using observational data.

The maximum value of CCF (60%) appears in DJF, and the minimum value (20%) in JJA. The average daily values for spring and autumn are 38.25% and 43.87%, respectively. Over one day, CCF varies from large values during daytime (60% in DJF) to small values during the night (45% in DJF).



a.

b.

Fig. 6 – Monthly variations of cloud cover fraction for satellite data (a) and ceilometer data (b) from 1th January 2009 to 31th December 2011.

The monthly variations of cloudiness, from satellite and ground-based measurements with the ceilometer show generally higher values from satellite than from ceilometer (Fig. 6a, b). The monthly values of cloudiness over Măgurele vary from 15% to 60% for ceilometer data and from 36% to 90% for satellite data. The annual trend is similar. The explanation of differences consists in two reasons: (i) the satellite "sees" the clouds downwards (from-up-to-down); (ii) the ceilometer detects the cloud bases up to 7.5 km.

The monthly trends can be seen in Fig. 7, by the slopes computed for the three years. The behavior of the trends is similar for the two data sets except August, September and October, when a positive trend in cloud cover was spotted in the ceilometer data and a negative trend in the satellite data; the differences are small. In December, the trend is the same, but it is larger in ceilometer data than in satellite data by a factor of 5. This large difference can be explained as a consequence of the method of cloud detection by satellite and ceilometer.

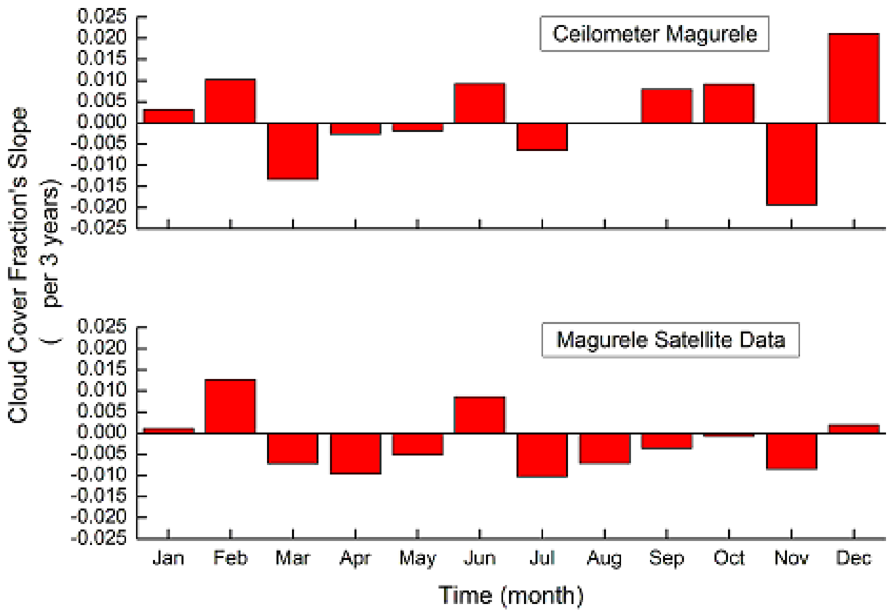


Fig. 7 – Monthly trends in cloud cover fraction (CCF per 3 years), for the period 2009–2011.

The seasonal variations of cloud cover fraction were also analyzed (Fig. 8), in satellite and ceilometer measurements. One can note how total cloudiness is larger in the satellite data than in ceilometer data. The previous results (Fig. 6) announced this result.

The trends of the cloud cover fraction over winter and summer time season for 2009 and 2010 are opposite, yet the differences are insignificant. The same trend can be noted in the spring of 2009 and autumn of 2011. The slopes derived from data in Fig. 9 confirm the trends observed in Fig. 8.

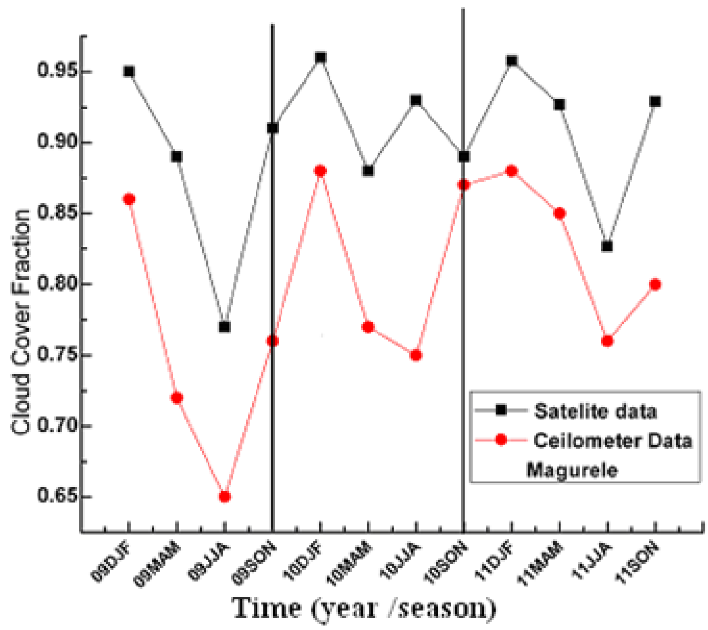


Fig. 8 – Comparison between seasonal CCF frequencies from satellite and ceilometer data.

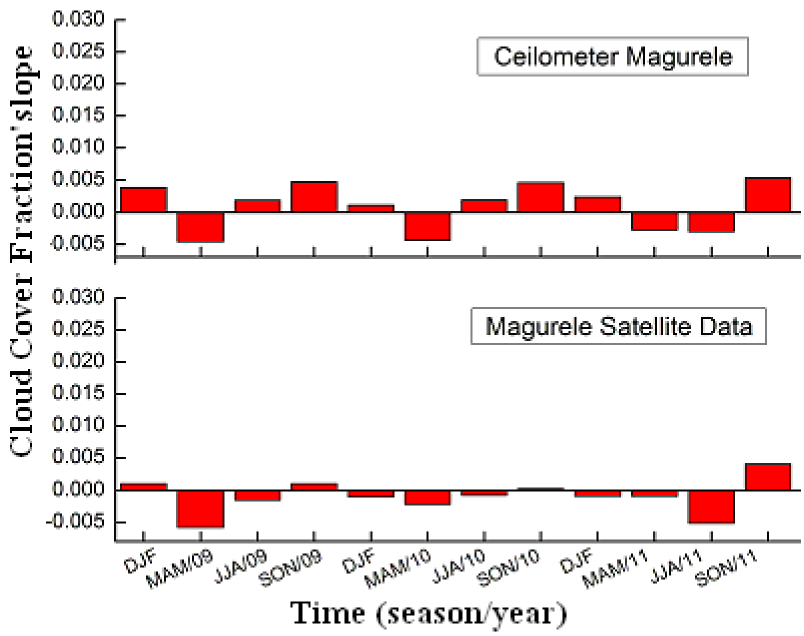


Fig. 9 – Cloud Fraction (CCF) seasonal trends at Măgurele during 2009–2011 period.

4. CONCLUSIONS

For the first time, cloud climatology was produced for the total cloudiness as a quantified physical parameter, using measurements from ceilometer and satellite. The study of cloud types and cloud cover fraction (total cloudiness) at Măgurele during 1st December 2008–31 December 2011 has shown the following:

The ground-observed cloudiness due to low-level and mid-level clouds is obviously higher than the one determined by satellite; the high-level clouds are much better detected in the satellite data than in ceilometer data.

So, combining the measurements gives the real cloud distribution.

The diurnal variation of cloudiness over all seasons shows a similar variation, with a high cloudiness in autumn and in winter as it was expected; in autumn and winter the cloudiness maxima can be seen from 9 to 12 a.m.

The comparison of the cloud cover fraction from satellite data with the one from ground ceilometer data suggests that, although the monthly and seasonal trends are generally in accord with each other, it is difficult to conclude on a general trend.

Finally, one can say that a much better description of the cloud field configuration and cloud bases can be obtained from the combination of ground-based and satellite observations, than using separately the two instruments.

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