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NEW ALGORITHM TO IMPROVE THE CLOUDINESS DATA SET OVER EASTERN PART OF ROMANIA*

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Abstract. Synoptic surface clouds observation is important in investigating cloud-climate system interaction. Study of interannual variability on regional scale is relevant because the variation in cloudiness is relatively large. This paper examines spatial and temporal distribution of cloudiness for Moldavia, eastern part of Romania, using an observational cloudiness database. The observed information (total and partial cloudiness, cloud types) is used inside the algorithm to compute low, middle and high cloudiness (in oktas). Analysis of cloudiness on regional scale showed certain peculiarities. Middle cloudiness is dominant in this area. Contribution of the middle clouds to the total cloudiness is above 60%, for both seasonal and interannual variability. In winter, low cloudiness has a greater contribution to total cloudiness, while high cloudiness remains constant. For further studies, the cloud database, obtained by application of the algorithm, could be used both to validate parameterization schemes of numerical weather prediction models and in data assimilation.

Key words: clouds, cloudiness, variability, synoptic conditions.

1. INTRODUCTION

Cloudiness is one of the most important variables that influence the radiation balance of the climate system due to the effect of clouds on solar radiation, terrestrial radiation and rainfall. The presence of clouds lead to a cooling effect by reflection of short wave radiation back into space and absorption of heat due to long wave radiation emitted from the Earth surface. These effects depend on the characteristics of the whole cloud (height, thickness, horizontal expansion, water content, phase and size of cloud drops and ice crystals) and the space-time

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characteristics (geographical location of the clouds, albedo, temperature near the surface, time of day and season of the year). For these reasons, studies involving surface cloud observations are crucial for investigating cloud–climate interaction [1].

Studies related to cloudiness and climate changes were developed especially in the last three decades. Many authors have described the importance of the influence of cloudiness and types of clouds in global radiative forcing [2].

Because the radiative effects of clouds depend on their types and weather factors, it is important to know the regional and global cloudiness as well as the space-time distribution of different types of clouds.

For example, Zhang and Ramanathan (1999) [3] suggest that the cloud scale need to be included in the parameterization of clouds. From investigations on global cloudiness over the ocean**,** Norris (1998) showed that observational data should be carefully handled and be taken into account all possible errors that could alter the results [1].

A comprehensive study of global cloudiness and cloud types over the ocean was made by Warren *et al*. [5] and Norris [6, 7, 8]. Many studies were also made on cloudiness variability in continental areas [9, 10, 5, 11]. An important issue in cloudiness analysis is observational data accuracy, in order to obtain unaltered results [6, 9].

Therefore, the observational studies of clouds from surface synoptic data are important in investigating the cloud-environment interaction, by pursuing and studying of cloudiness on certain geographical regional areas. For this reason it is essential to study the variation of cloudiness on smaller regions due to their specific peculiarities.

This paper analyses spatial and temporal distribution of cloud types and cloudiness, in the Moldavia, eastern part of Romania. Moreover, a database with low, mid-level and high-level cloudiness was achieved for 2006 in order to be used for regional forecasting models.

To examine the variability of cloudiness, the observational data for 2006 from 14 synoptic surface stations of Moldavia, Romania, were used (Section 2). In the same section a new processing algorithm of observational data from synoptic stations is presented. Results regarding the observational data processing and algorithm validation were presented in Section 3. The conclusions end the paper.

2. DATA AND METHODOLOGY

2.1. DATA USED

The cloud cover was analyzed for 2006 year, in the eastern part of Romania, county Moldavia (longitude 26:00–28:25 E, latitude 45:50–48:50 N). The hourly observational data from 14 synoptic surface stations were used: five synoptic stations are located in western part of Moldavia, eastern Carpathian Mountains, and nine of them in eastern part of Moldavia, a region dominated by plain (Fig.1). The year 2006 was selected because during this year a lot of extreme events have occurred. Total and partial cloudiness data, cloud ceiling, and information about types of clouds were used.

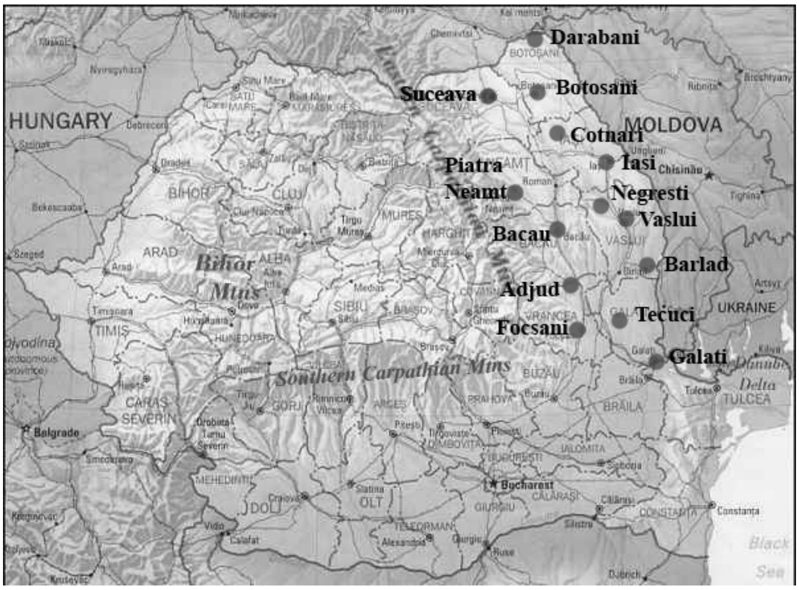

Fig. 1 – Map of Romania and distribution of synoptic surface stations in Moldavia.

In order to avoid errors in our data base we excluded stations with limited operation period (less than 12 hours) and mountain stations. A number of 122 584 hourly data for each type of cloud (low, middle and high) was processed. These data represent diurnal (the day and night) total and partial cloudiness, ceiling of clouds. For this reason, the daytime (defined as the daylight plus twilight) cloud cover data and nighttime cloud data were segregated to estimate the difference in total cloudiness; in this case it is observed the overestimating or underestimating of the total cloudiness. Monthly mean total cloud cover was obtained by averaging all data from both the individual diurnal observations and daytime observations.

Cloud classification used by the synoptic surface stations is standard classification (by their appearance), as defined in the synoptic code [12]. Total cloudiness, N, is expressed in the oktas, so that $N = 0$ is the clear sky and $N = 8$ is overcast. If the sky was obscured (most commonly due to fog), $N = 9$. In case of the any break in overcast, no matter how small (usually for Altocumulus and Stratocumulus cloud types), $N = 7$.

The cloudiness of the lowest clouds is similarly estimated: $N_h = 0$ indicates the absence of low and middle clouds and $N_h = 8$ means that the sky is completely covered either by low clouds (if $CL \neq 0$) either by middle clouds (if $CL = 0$ and $CM \neq 0$).

Because the data come from observations of ground stations, higher clouds may be obscured by the presence of low clouds [11]. However, observational data from ground stations remain important because they are available for a long time.

2.2. ALGORITHM FOR OBSERVATIONAL DATA PROCESSING

Observational data about clouds from the synoptic surface stations contain 27 types of clouds, nine for each of three categories of cloudiness (low, *LC*; middle, *MC* and high, *HC*); each type contributes with a fraction of the total cloudiness. By using an automatic algorithm the clouds categories were transformed into values of low (N_{LC}), mid-level (N_{MC}) and high (N_{HC}) cloudiness (in oktas) in accordance with the rules of synoptic code.

Algorithm has the following steps:

Step 1. Redistribution of total cloudiness in levels as follows:

– if the cloudiness of lowest clouds, $N_h = 0$, then total cloudiness is due to high-level clouds, $N = N_{HC}$.

– if the cloudiness of lowest clouds is nonzero, then total cloudiness is due to low-level clouds, for $CM = 0$, $N = N_{LC}$; or is due to mid-level clouds, for $CL = 0$, $N = N_{MC}$.

Step 2. For $N \geq N_h$ and $N_h \neq 0$ mid-level and high-level cloudiness is completed as follows:

For mid- level cloudiness:

– if there is low level clouds but no high level clouds, then mid-level cloudiness, N_{MC}, is equal with $N - N_h$, plus one okta, that represent minimum value of their overlapping;

– if there is both low level and high level clouds, then mid-level cloudiness, N_{MC}, is equal with the value most frequently obtained from the set of data processed (by redistributing the total cloudiness obtained at step 1).

For high-level cloudiness:

– if there is no mid-level clouds, then high-level cloudiness, N_{HC}, is equal with $N - N_h$, plus one okta, that represent minimum value of their overlapping;

– if there is mid level clouds, then high-level cloudiness, N_{HC}, is equal with the most common value obtained from the set of processed data (by redistributing the total cloudiness obtained at step 1).

When total cloudiness is due to low level clouds, then mid level and high level clouds is not determined, so the mid-level and especially the high-level cloudiness is underestimated.

3. RESULTS AND DISCUSSIONS

3.1. RESULTS OBTAINED BY APPLYING THE ALGORITHM ON OBSERVATIONAL DATA

In the data sets obtained from synoptic stations, the presence of low clouds reduces the contribution of middle and high clouds to total cloudiness. The use of the algorithm corrects the middle clouds contribution. The analysis of data obtained by applying the algorithm is presented below. A rate of 21% of the total number of cases corresponds to the clear sky and the remainder of 79% are cases of partial or total sky overcast (between 1 and 8 oktas). Significant underestimation of cloudiness of medium level and low level clouds are observed for values between 6 and 8 oktas of low cloudiness.

The use of algorithm results in the redistribution of cloudiness of medium and high clouds at a rate of 63.6% and 15.4% remains undetermined (8,3% in case $N_{CL} = 8$ oktas and 7,1% for N_{CL} with values of 7 and 6 oktas). The remainder of 21 % corresponds to the clear sky.

Applying the algorithm to obtain the types of cloudiness expressed in oktas, led to:

– Step 1 of the algorithm determines all low-level cloudiness and partially the mid-level and high-level cloudiness;

– Step 2 of the algorithm improves the contribution of mid-level cloudiness to total cloudiness, in the presence of low level clouds.

Increase over the values obtained in the first step is about 39% for mid-level cloudiness and 100% for high-level cloudiness (Fig. 2).

Underestimation of high-level cloudiness could be mitigated by using satellite information about clouds.

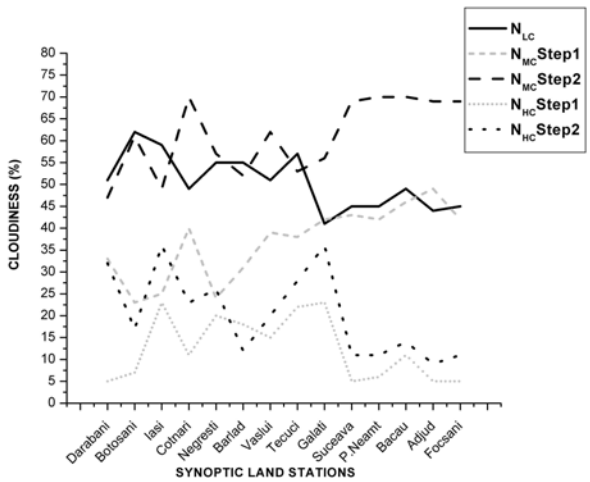

Fig. 2 – Annual average contribution of low (N_{LC}), mid-level (N_{MC}) and high-level (N_{HC}) cloudiness to total cloudiness, after applying the first step of the algorithm, for 2006 year.

3.2. ALGORITHM VALIDATION

With regard to the validation of the results obtained by using the improved data sets, few comparisons were done.

3.2.1. Norris relationship

Low cloudiness determined by using the algorithm was compared with that resulting from the corresponding calculation relationship of Norris (1999) [6]:

$$\bar{N}_h = \frac{\sum N_h}{n_{low}} \times \frac{n_{all} - n_{clr} - n_{obs}}{n_{all}} + \frac{8 \times n_{obs}}{n_{all}},$$

where n_{low} is the number of observations when N_h was reported and $1 \le N \le 8$; n_{all} is the number of all observations; n_{clr} is the number of observations of clear sky ($N = 0$) and n_{obs} is the number of observations of sky obscured ($N = 9$).

Table 1

The values of N_h computed by Norris relationship and those computed by using algorithm

n_{all}	n_{clr}	n_{obs}	n_{low}	$N_h(a\lg orithm)$- oktas	$N_h(Norris)$ - oktas
122584	25153	244	97187	2.92 (3oktas)	2.36 (2oktas)

Results indicated that both values are between 2 and 3 oktas. The value obtained from the algorithm is slightly higher than that obtained from the Norris relationship. A possible explanation of this variation would be due to lower number of cases in which the sky was invisible for the continental area studied (coded in synoptically telegrams with $N = 9$), compared to the ocean where the frequency of such cases is higher.

3.2.2. The comparison with satellite data SAFNWP-MSG

The cloudiness datasets (in oktas) improved by our algorithm were compared with hourly satellite data SAFNWP (Satellite Application Facility for Numerical Weather Prediction) – Meteosat Second Generation. These data were obtained from Centre de Météorologie Spatiale SATMOS, Meteo France.

Data correlation for both winter (January) and summer (July) was carried out by using Bravais-Pearson correlation coefficient [13].

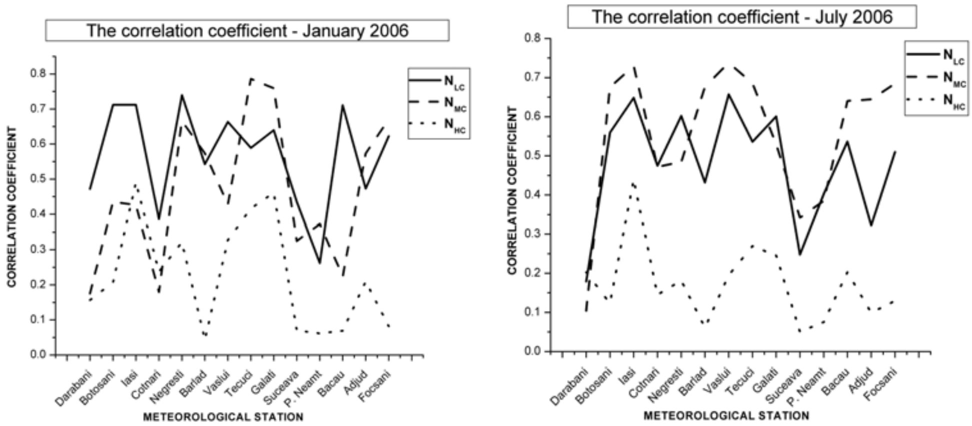

Fig. 3 – Correlation between data sets improved by using algorithm and SAFNWP satellite data (left for January 2006, right July 2006).

The values of correlation coefficient of the low and mid-level cloudiness, for the both seasons, vary between 0.2 and 0.8. One can note very poor correlation for high-level cloudiness for all the stations. In case of low and mid-level cloudiness a good correlation especially for synoptic stations located in central part of Moldavia in the plain part (Negresti, Barlad, Vaslui, Tecuci) can be observed. Mean correlation coefficient for mid-level and low clouds is smaller in western part than that from eastern part due to influence of the relief: mountains in west and plain in east. The average value of correlation coefficient is greater for mid-level cloudiness than low cloudiness particularly in summer season.

3.2.3. Comparison with the predictions of the ALADIN model

The hourly cloudiness data obtained by making use of the algorithm presented above, were compared with the simulated ones, at each three hours, by the operational numerical forecasting model ALADIN (Arie Limitee Adaptation Dynamique Development International). It was considered the initialization at 0000 h UTC for the 24 hours period (from the 78 hours available).

To correlate cloud data obtained from the algorithm and the data of the ALADIN model the same Bravais-Pearson coefficient [13] was used. The correlation of data was studied separately, for winter (January) and summer (July) (Fig. 4). One may see that the correlation coefficient in winter, for mid-level and low cloudiness varies between 0.3 and 0.6. The mean value of correlation coefficient is larger for the mid-level cloudiness than for the low cloudiness. The correlation coefficient for the simulated and observed values of the high-level cloudiness is very small, and for two stations from western part it is negative. The similar values of the correlation coefficient were obtained for the July in 2006. One can observe that in case of high-level cloudiness the values of the correlation coefficient are negative. To explain this poor correlation and the differences, a study of uncertainties in our algorithm and in input data of the model will be necessary.

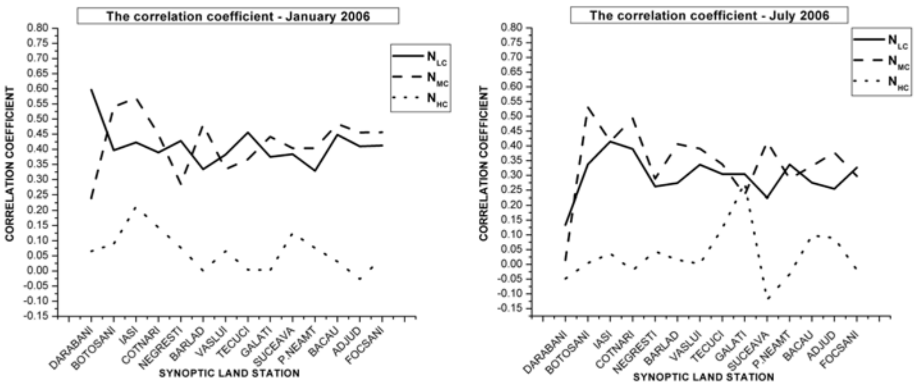

Fig. 4 – The correlation between the algorithm and the ALADIN model, in winter (left) and in summer (right).

3.3. INTERANNUAL VARIABILITY OF THE CLOUDINESS

This paper is focused on the analysis of spatial and temporal distribution of clouds and cloud cover at regional scale by using corrected data sets.

The Eastern part of Romania, Moldavia is geographical placed along the meridian and on its west part, the Eastern Carpathian Mountains are found. This placement determines differences between meteorological parameters on west and east stations. Therefore the comparative study between the west and the east parts of this region has been made.

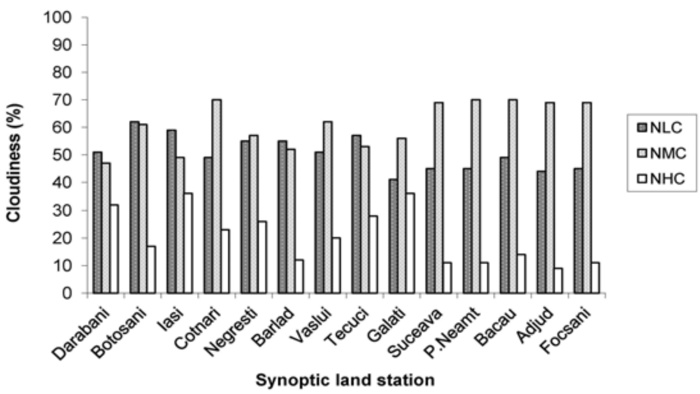

Fig. 5 – Annual average contribution of low (N_{LC}), mid-level (N_{MC}) and high-level (N_{HC}) cloudiness to total cloudiness, after applying the second step of the algorithm for 2006 year.

The contribution of the low cloudiness is biggest in the east part both in winter and summer, but the mid-level cloudiness is present in the west part of the region for both seasons, more obvious during the summer season (Figs. 5 and 6).

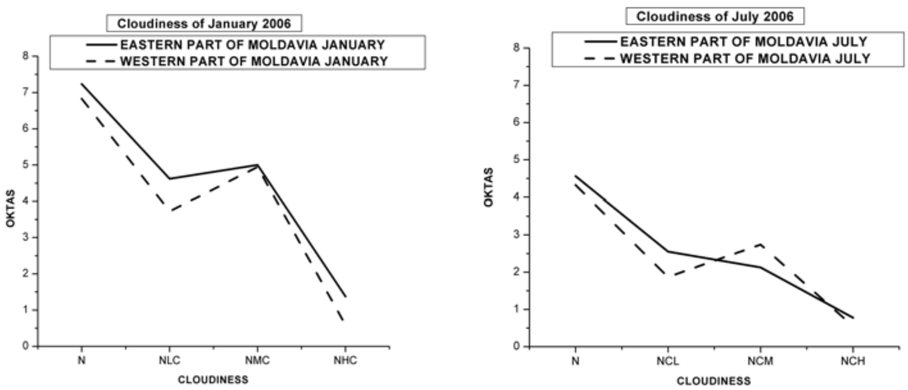

Fig. 6 – Total, low, mid-level and high-level cloudiness in January and July 2006, representative months for winter and summer, respectively.

The analysis of the cloudiness data, for January and July 2006 (Fig. 6), shows that the low cloudiness has a greater contribution to the total cloudiness in January (57%) than in July (40%). The mid-level cloudiness has a slightly greater contribution than the low one in both months and the contribution of high-level cloudiness remain constant.

The seasonal cloudiness variation (DJF: December-January-February, MAM: March-April-May, JJA: June-July-August, SON: September-October-November) indicates a decrease of the cloudiness to all levels in the summer and autumn (Fig. 7). The significant decrease is present in the summer (JJA). The transition seasons, spring and autumn have relative similar types of cloudiness.

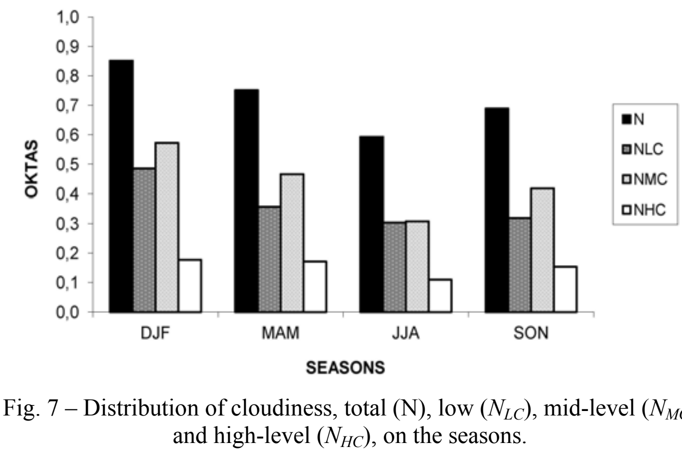

Fig. 7 – Distribution of cloudiness, total (N), low (N_{LC}), mid-level (N_{MC}) and high-level (N_{HC}), on the seasons.

The high frequency of the low cloudiness in winter is a mesoscalar feature of Moldavia. The explanation is related to the presence, during the cold season, of the extended East-European anticyclone causing the occurrence of low cloudiness, especially in the north and east part of the region. This presence more frequent in the second part of the months December and January can be felt until March. Just in January 2006, the analyzed region were, for 25 days, under the influence of the East-European anticyclone, in two major periods (4–17 January, with a maximum value of 1035 hPa and 20–30 January, with a maximum value of 1050 hPa (Fig.8).

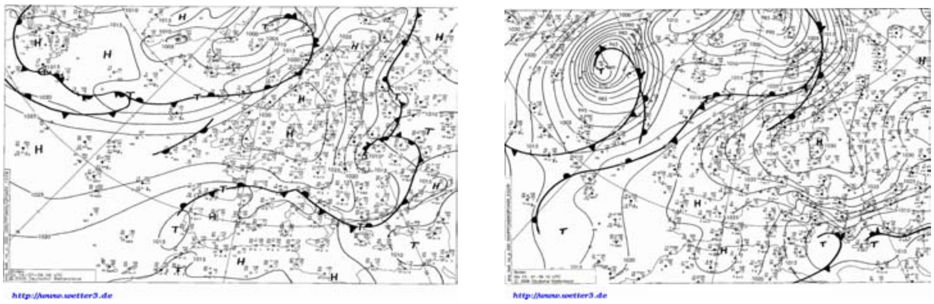

Fig. 8 – Synoptic analysis map (http://www.wetter3.de/Archiv/archiv_dwd.html).
Left 23 January 2006, 1200 h UTC, right 16 July 2006, 0600 h UTC.

In the warm season, the presence of the anticyclone from the east and center part of the continent prevent from occurring the low cloudiness, just transient and for short period of time.

The cloudiness results for 2006 were also validated by the regional climate model REGCM3 used to National Administration of Meteorology. There were used ERA40 data for the year 2006 (Fig. 9 left) but also for the period 1998-2000 (Fig. 9 right) to show the general behavior of the observed cloudiness.

One can observe the dominance of mid-level cloudiness over Moldavia in the both figures but especially in 2006 year. The different distribution of mid-level cloudiness over east and west parts of Moldavia is also proved.

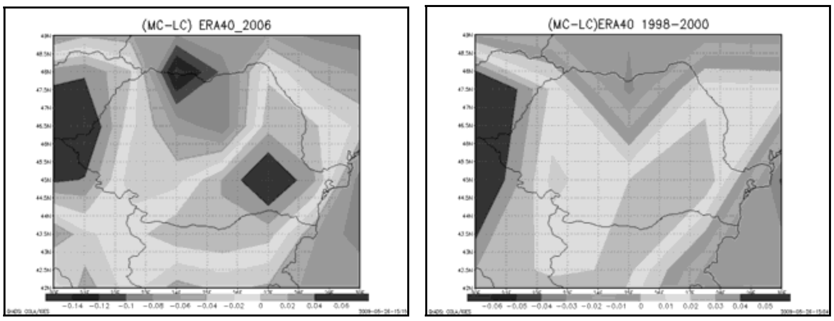

Fig. 9 – Dominance of mid-level cloudiness over Moldavia – data analysis ERA40 ECMWF – for 2006 (left), during 1998–2000 (right).

4. CONCLUSIONS

The cloud cover analysis was carried out on geographic area in eastern part of Romania, for the year 2006.

The observational data sets from land stations were improved by using an algorithm carried out by making use of WMO Manual of Codes.

The validation of the algorithm was performed by making use of the Norris method, the outputs of ALADIN model and the satellite data.

The results have pointed out:

- a good correlation with the data obtained by applying Norris method;
- for mid-level and low cloudiness the correlation between algorithm resulting data and ALADIN model ones is relatively good, while for high-level cloudiness the data are poorly correlated; this may be explained by the underestimation of observational data, when consistent middle and low clouds were present.
- the average value of correlation coefficient is larger for mid-level cloudiness than low cloudiness, particularly in summer season in case of the validation with satellite data.

The analysis of cloudiness interannual variability has shown:

– Mid-level cloudiness is dominant, its contribution to the total cloudiness being over 60%, during the seasons and whole year (Figs. 9 and 5).

– Low cloudiness shows seasonal variations, with a maximum in winter (Fig. 6). The frequent presence of low cloudiness in the winter season is a regional pattern feature of Moldavia. In winter, dorsal of East-European anticyclone spreads, favoring the emergence of the stratiform low cloudiness, particularly in northern and eastern area of interest.

Frequency of low clouds in Galati area, which belongs to eastern part of Moldavia, is smaller than in any western part station because the location of this city at the Carpathian curvature, that changes the air circulation (Fig. 5).

From the analysis of the two separate areas: western one (where it is now the Eastern Carpathians chain of mountains) and eastern one (areas characterized by low relief), one may conclude that the share of low cloudiness is greater in the eastern area, both in winter and in the summer, while the share of mid-level cloudiness is the dominant for western area in both seasons (most obvious in the warm season (Fig. 6).

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