Romanian Reports in Physics, Vol. 67, No. 3, P. 1117–1127, 2015

ATMOSPHERE PHYSICS

TOTAL AND PARTIAL CLOUDINESS DISTRIBUTION IN EASTERN ROMANIA

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Received October 24, 2013

Abstract. Within this paper the cloudiness spatial and seasonal distribution is analyzed for the eastern part of Romania (Moldavia Region) for a five years period (2006–2010). Hourly data (total and partial cloudiness) from 14 surface observation stations have been used to build a small data base. In order to increase the cloudiness accuracy, an algorithm to derive the partial cloudiness has been applied. This data base allowed us to generate an improved climatology of total and partial cloudiness for Moldavia Region. As an application, the built data base has been used to validate the cloudiness simulated by the mesoscale numerical weather prediction model ALARO. The model results were compared to observation for one year. The obtained statistics have been used to tune the free parameter of the model cloudiness parameterization scheme.

Keywords: cloudiness, numerical weather model, free parameters tuning, numerical modelling.

1. INTRODUCTION

Due to the important effect of cloud cover on climate it is essential to study its variation in certain geographical areas because their specific features, knowing that cloudiness fluctuations are stronger at regional or mesoscale [11].

Studies on cloudiness, both globally and regionally, have been developed especially in the last two decades [8, 10, 12, 13, 14]. Norris (1998) [5] suggests that studies involving surface observations are crucial to investigate the interaction cloud – climate. Since the clouds are observed from the ground level, medium and/or higher clouds can sometimes be hidden by lower clouds. However, surface weather reports are important because they are available for long periods of time

(Filipiak and Mietus, 2008) [2]. In this sense an algorithm was especially developed for improving the partial cloudiness data accuracy which was validated against the satellite data (Bostan and Stefan, 2012) [1]. In Romania, despite the existence of few analyses of the annual mean of cloudiness distribution for the second half of the last century, the recent knowledge about cloudiness variability is quite poor. In this paper it is analyzed the cloudiness variability and cloud type distribution for the eastern part of Romania, Moldavia region. For this analysis a five years data base has been built by using data from surface observation stations and applying the improving algorithm to process the cloudiness information, as presented in section 2. The main features of the cloudiness (total and partial) are contained in section 3.

The same data base was used to validate the cloudiness simulated by the mesoscale numerical weather prediction model ALARO, operationally at the National Meteorological Administration of Romania. The physics parameterisations, mainly those of the moist processes, and the model setup (section 2) justify the choice of using this model for cloudiness analysis at regional scale. The comparison of model results against the observations showed some deficiencies of the model in representing the total and partial cloudiness, especially for high cloud cover values. The one year statistics has been used to tune the free parameters of the model cloudiness parameterisation scheme. The main results are presented in section 4. Finally the conclusions of this study are summarized in section 5.

2. DATA AND METHODS

Two data bases were built for the analysis of the spatial and seasonal distribution of the cloudiness in the eastern part of Romania: one for observed data covering a period of five years and the other with simulated values by the ALARO model, covering only one year.

2.1. OBSERVATION DATA

We were using cloudiness information from 14 surface observation stations in the region of Moldavia, located between 26:00–28:25 E longitude and 45:50–48:50 N latitude (Fig. 1a) for the period 2006–2010. To diminish the potential errors in the data base we have excluded the observations from the stations with incomplete program of observations and from the mountain stations as well. Hourly data regarding cloudiness (total and partial) and information about types of clouds were processed accordingly to the synoptic code (WMO 1974) [15].

Observational data contains 27 categories of clouds, 9 for each of 3 types: low (LC), middle (MC) and high (HC). The data processing procedure includes as well an algorithm for improving the accuracy of the observed partial cloudiness. The types of middle and high clouds were transformed into values of mid-level (N_{MC}) and respectively high-level (N_{HC}) cloudiness (in oktas) [1]. In the first stage, the algorithm redistributes the total cloudiness on all observed levels. Thus, the low-level cloudiness is determined 100% while the middle-level and high-level cloudiness only partially. In the next stage the mid-level and high-level cloudiness are completed in two ways, depending on the observing conditions. When only one of the types of clouds (middle or high) is present the difference between total and low cloudiness is redistributed. In the case of simultaneous presence of middle and high clouds in the "synop" report, each type of cloud receives the most frequent statistic value obtained in the dataset. Thus, for each type of cloud reported by the surface stations it was allocated a contribution to the cloudiness. In this way, the obtained data base contains, besides the total cloudiness, values of low-level, mid-level and high-level cloudiness, expressed in oktas.

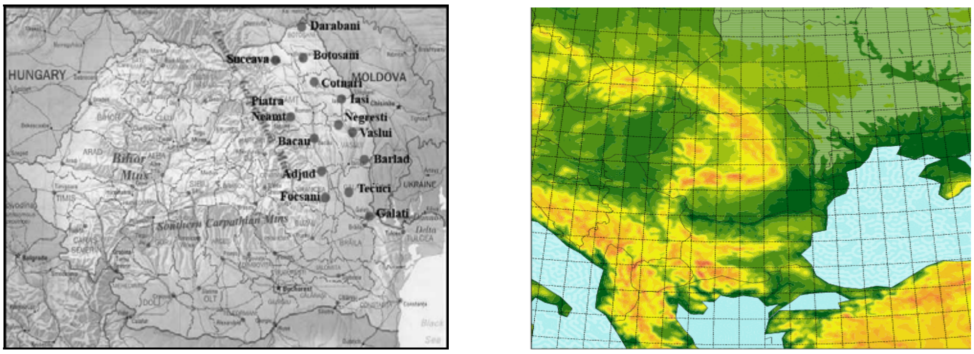


Fig. 1 – a) Map of Romania and distribution of synoptic surface stations in Moldavia region (left); b) ALARO domain and orography (right).

2.2. MODEL DATA

The ALARO numerical prediction model is a refined version of the operational limited area ARPEGE-ALADIN model (Horany *et al.*, 2006) [4]. From the start it was designed to work at higher resolutions, less than 10 km, by increasing the complexity of physical parameterizations while keeping the numerical solution robustness and efficiency.

The prognostic and integrated approach of moist physical processes (Gerard *et al.*, 2009) [3] led to a specific organization of their parameterizations with the possibility of keeping memory from one time step to the next. The microphysics, including five prognostic water species (water vapour, cloud liquid water and ice, rain and snow) and diagnostic graupel, involves interactions with both resolved and sub-grid parts of the precipitation parameterization.

The resolved condensation scheme takes into account the cloud geometry. For the cloud fraction the formula of Xu and Randal (1996) [6], slightly modified, is used.

$$f = \left(\frac{q_v}{q_{sat}}\right)^r \left[1 - \mathrm{e}^{\frac{-\alpha q_c}{(q_{sat} - q_v)^\delta}}\right], \tag{1}$$

where q_v is the vapour content, q_c the condensate content and q_{sat} the water vapour content at saturation. For the cloud area a constant intensive condensate flux is assumed and in the non-cloudy area a critical relative humidity profile is prescribed. The balanced values of cloud fraction, water vapour and condensate contents are obtained through a Newtonian iterative algorithm.

The deep convection parameterisation is a mass flux type scheme where a single updraft represents the sub-grid variability. It includes prognostic equations for the updraft vertical velocity and its mesh fraction (obtained by the cloud). The scheme output contains, besides the convective condensation flux, the transport fluxes of water species and dry static energy and the detrained area increment used for convective cloudiness computation.

The fractional cloudiness computation at model levels uses as well the Xu and Randal formula, where for the convective condensate content the convective cloudiness for the previous time step is used.

The ALARO model is operational at NMA since February 2010. It is integrated four times per day over a domain covering Romania and its surroundings (Fig. 1b) at a horizontal resolution of 6.5 km. The number of the vertical levels is 49, the lowest level being around 14 km height.

3. CLOUDINESS CLIMATOLOGY FOR THE MOLDAVIA REGION

The cloudiness study of the cloudiness for Moldavia region for the year of 2006 (Bostan and Stefan, 2012) [1] was extended to a period of five years, using the data basis described in section 2. The average of the total and partial average cloudiness confirm the previous results, as one can see in Fig. 2 compared with Fig. 3. The presence of Eastern Carpathian on the west side of Moldavia and the flat terrain (plateaus and plains) on the east one, mainly determines the spatial variability of the observed meteorological parameters in this area. The average cloudiness has slightly different values for the eastern and western Moldavia. For the eastern part of Moldavia the low cloudiness is dominating while the medium cloudiness is more significant for the western part (where Suceava, P. Neamt, Bacau, Adjud and Focsani surface observation stations were taken into account). The differences of the ratio between low and medium/high cloudiness is visible as well in the average values for each station (Fig. 4).

The seasonal variation of the cloudiness shows a decrease of the averaged values for all cloudiness types during the warm season (S2: JJA – June, July, August) and maximum values during the cold season (S4: DIF – December, January, February). The transition seasons (S1: MAM – March, April, May and S3: SON – September, October, November) are characterized by a quite similar repartition of the total and high cloudiness. During spring the medium cloudiness has the tendency to have lower values than those of medium cloudiness while in autumn the situation is opposite (Fig. 5).

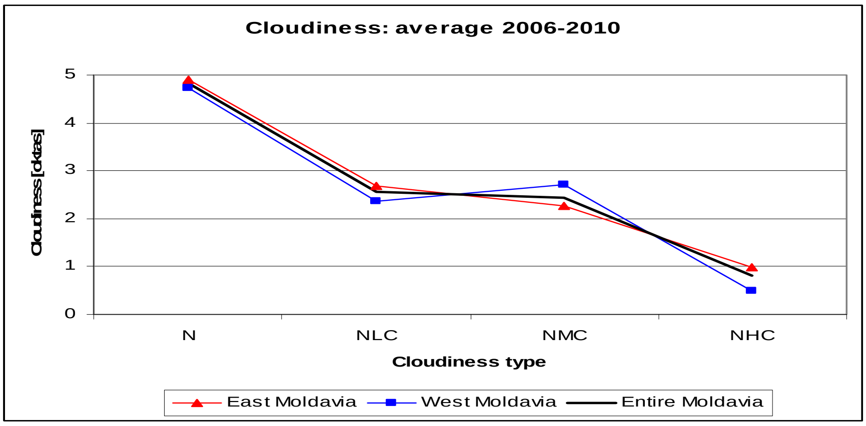


Fig. 2 – (Color on line) Total (N), low (NLC), medium (NMC) and high (NHC) cloudiness average for 2006–2010). Moldavia: entire region – black line, Eastern part – red line, Western part – blue line.

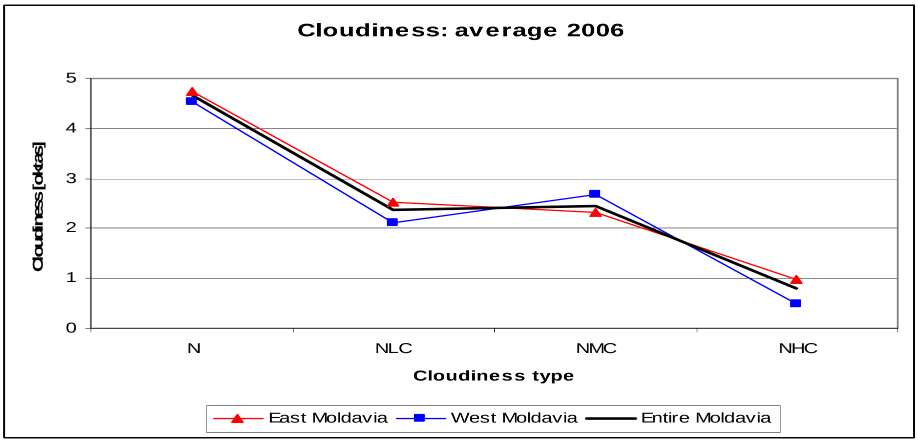


Fig. 3 – (Color on line) Total (N), low (NLC), medium (NMC) and high (NHC) average cloudiness for 2006. Moldavia: entire region – black line, eastern part – red line, western part – blue line.

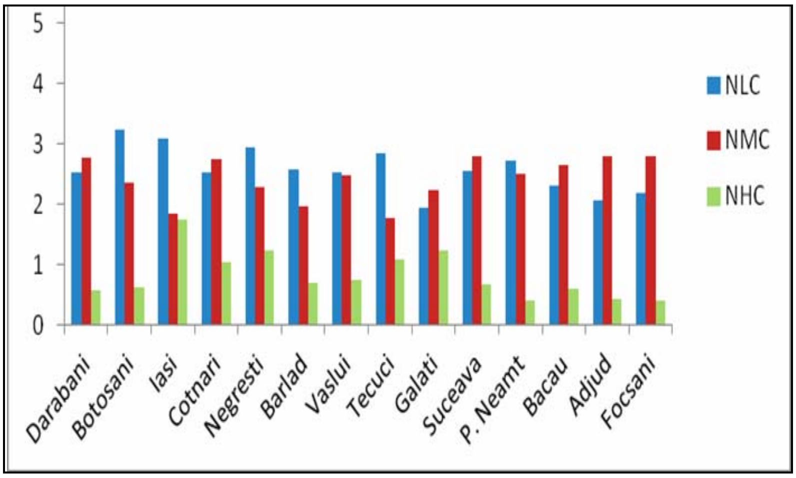


Fig. 4 – (Color on line) Low (NLC – blue), medium (NMC – red) and high (NHC – green) cloudiness average for 2006–2010, for all observation station within Moldavia region.

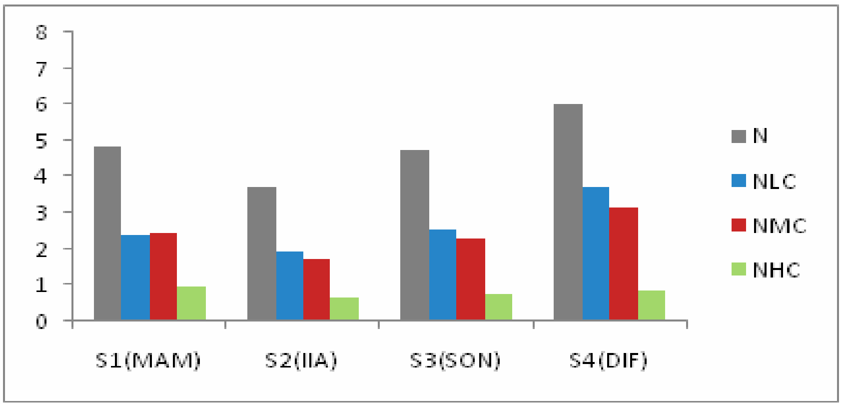


Fig. 5 – Seasonal (S1 – spring, S2 – summer, S3 – autumn, S4 – winter) distribution of the total (N), low (N_{LC}), medium (N_{MC}) and high (N_{HC}), cloudiness; averages for 2006–2010.

The high frequency of the low cloudiness in winter is a mesoscale feature for Moldavia region. During the cold season the north easterly circulations related to the persistence of the East-European Anticyclone, extended towards Balkan Peninsula, and the presence of the Carpathian mountain chain usually involve the appearance of the low stratus clouds, especially in the northern and eastern part of Moldavia. For all seasons, as expected, the main contribution to the total cloudiness is given by the low and medium cloudiness with close weights (Figs. 4, 5).

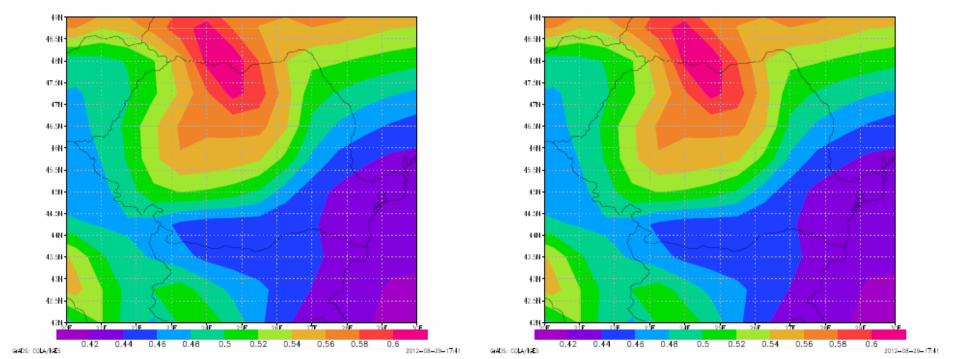


Fig. 6 – Total cloudiness (left) and the difference between medium and low cloudiness (right). ECMWF ERA40 reanalyses averaged for the period 2006–2010.

The re-analyses ERA-40 of the European Center for Medium Weather Forecast (ECMWF) have been used as well to analyze the spatial distribution of the cloud coverage, for the period 2006–2010 [7].

Despite of the coarse resolution of the reanalyses (2.5 × 2.5°) one can notice the increasing of the total cloudiness from the south to the north of Moldavia: this is a consequence of the specific local circulations and the frequent presence of the frontal systems over the north of the analyzed region (Fig. 6, left). As mentioned before the averaged cloudiness over Moldavia has approximately equal values for low and medium cloudiness. The distribution of the difference between medium and low cloudiness emphasizes the dominance of the medium cloudiness for the most Moldavia. Except a small area in the north part of the region, near the Carpathian Mountains (Fig. 6, right) [9].

4. VALIDATION OF THE CLOUDINESS PARAMETERIZATION SCHEME OF THE ALARO MODEL

In the ALARO model the total and partial (low, medium and high) cloudiness, that are operationally used by forecasters and can be compared against observations, is diagnosed from the fractional cloudiness (used for radiation parameterization) taking into account the height of the model levels and the an assumption regarding the adjacent cloud overlap: either maximum either random overlap.

The ALARO – Romania (which uses the maximum overlap assumption) operational verification scores show a negative bias for the total cloudiness, especially for cold seasons.

The existence of more reliable data for the partial cloudiness represented an opportunity for carrying out a more detailed analysis of the ALARO cloudiness forecast. During one year (March 2010–March 2011), the hourly values (up to 24 hour forecast range) of the total and partial cloudiness were compared with the corresponding observations for the Moldavia region. The relative frequency histogram of the observed total cloudiness (Fig. 7) has a bi-modal structure with two maxima at the spectrum limits (N = 0 and N = 8) while the ALARO maximum value is around the class N = 6. There is a clear underestimation of the cloud cover for overcast sky situations.

The model has the same tendency to underestimate the situations without medium or high cloudiness. On the other hand the model generally overestimates the high cloudiness but it is worth to remind that the proportion of observed high clouds is less accurate estimated when they are overlap by low and medium clouds.

In order to analyze the cloudiness evolution throughout the year, the relative frequencies were computed for each season. The bimodal structure of the relative frequency distribution of the observed total cloudiness is kept for all seasons (Fig. 8). The ALARO model underestimation of the overcast sky (N = 8) is more pronounced during winter, autumn and spring to 1–7 cloudiness classes detriment that are obviously overestimated especially during winter.

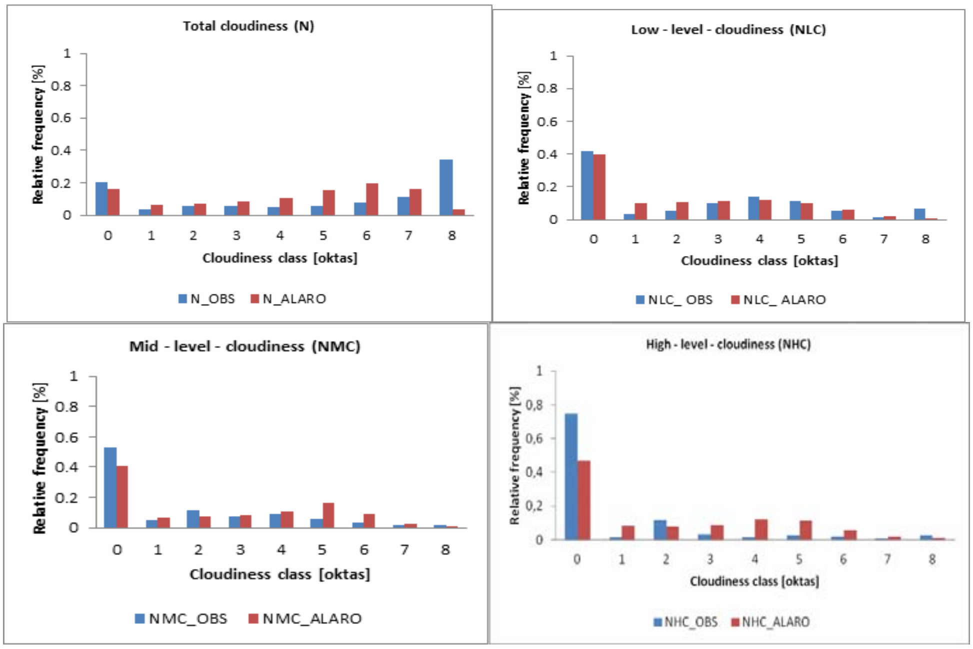


Fig. 7 – Relative frequency distribution of total (N), low-level (NLC), medium (NMC) and high-level (NHC) cloudiness (blue – observations, red – ALARO) in Moldova, March 2010–March 2011.

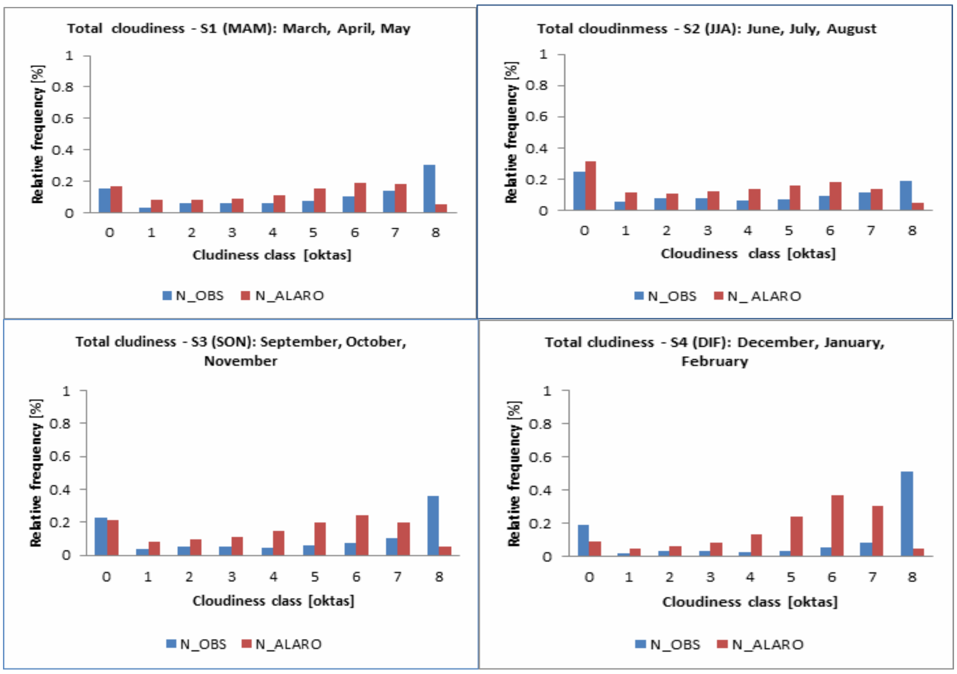
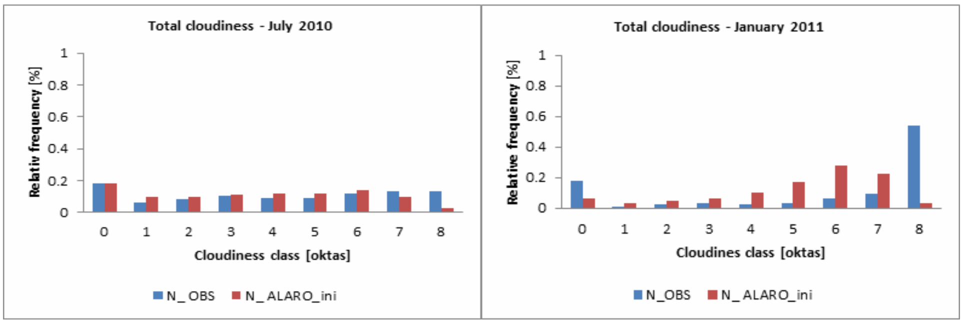


Fig. 8 – Relative frequency distribution of the total cloudiness (blue – observations, red – ALARO) in Moldova per season (S1– spring, S2 – summer, S3 – autumn, S4 – winter), March 2010–March 2011.

The idea of Christoph Whittmann (personal communication) to reduce the effect of the by a coefficient ε, the so called "near maximum overlap" can improve the cloudiness diagnostics. The weight ε is a tuneable parameter, depending on the geographical specific features of the integration domain. The values between 0 and 1 of the coefficient ε allows the transition between random ($\varepsilon = 0$) to maximum overlap ($\varepsilon = 1$).



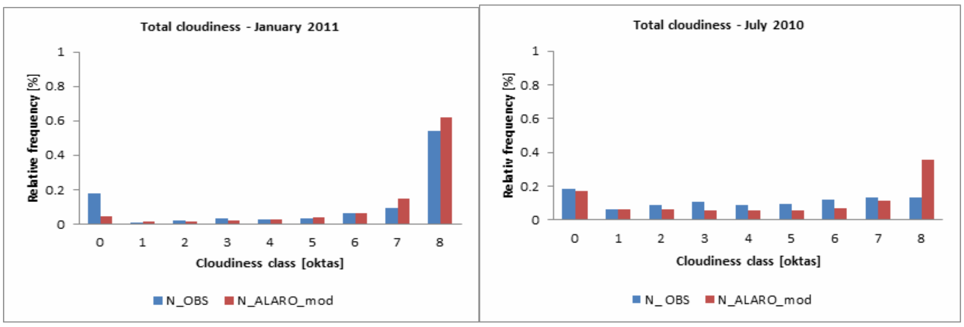


Fig. 9 – Relative frequency distribution of the total cloudiness (blue – observations, red – ALARO) for Moldavia region, in July 2010 (left) and January 2011; operational forecast (top row), ALARO with combined random and overlap assumptions (bottom row).

Two months, July 2010 and January 2011 have been chosen to test this solution. For July (Fig. 9, top row left) the relative frequency histogram per cloud cover classes show the ALARO slight overestimation of the total cloudiness in respect to observations for all classes except the class N = 8. For January (Fig. 9, top row right) the overestimation occurs for the classes 1–7 more pronounced for higher values, and an underestimation at the spectrum limits (n = 0 and N = 8). The cloudiness diagnostics carried out with the coefficient $\varepsilon = 0.8$ change the relative frequency distribution in the opposite sense for both months (Fig. 9, bottom row) for cloud cover between 1 and 8 oktas, the ratio of observed/forecast clear sky situations remaining almost the same. Even if the general pattern of the ALARO total cloudiness relative frequency is improved, further tests are necessary since the value 0.8 seems to be a little bit to low especially for completely covered sky situations.

5. CONCLUSIONS

An observational data basis for cloudiness over Moldavia region was built by using an algorithm for improving the accuracy of partial cloudiness. Consequently the specific features found for the cloudiness variability for the analyzed region are more reliable although the uncertainties in determining the medium and high level cloudiness cannot be completely eliminated.

The study underlined the main contribution of low and medium clouds to the total cloudiness with approximately the same weight for both annual and seasonal averages. The seasonal variation shows a decrease of the cloudiness for all cloudiness types during the warm season. The highest frequency of the low cloudiness in winter is a mesoscale feature for Moldavia region due to the typical circulations induced by the persistence of the East-European Anticyclone and the presence of the Carpathian mountain chain generating frequently low stratus clouds, especially in the northern and eastern part of Moldavia. Differences in the total and partial cloudiness distribution were found between eastern and western part which can be explained mainly by the Moldavia topography.

Generally the statistics of the average total cloudiness per cloud cover classes show a bimodal structure with maxima for the limits of the spectrum: clear and overcast sky.

As an application, the more accurate data for partial cloudiness were used to validate the cloudiness simulations of the limited area ALARO model. It was proved that the deficiencies found in the cloudiness distribution per classes of the total and partial cloudiness can be cured by tuning a free parameter of the algorithm used for their computation.

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