THE STATUS OF ATMOSPHERIC INSTABILITY INDICES ASSOCIATED WITH HAIL EVENTS THROUGHOUT MOLDOVA

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ABSTRACT. – The status of atmospheric instability indices associated with hail events throughout Moldova. The lower pressure of water vapor of the outer eastern and south-eastern Carpathians, as well as in Dobrogea, determines within these areas an average annual number of days of under 2 days**.** In sheltered areas from Bârlad Plateau the average multi-annual value decreases even below 0,5 days. Hail events that affect the territory of Moldova are, in most cases, caused by thunderstorms during May and June (frequency of over 60 %). We had analysed in the present paper a representative number of statistical severe convective events causing hailstorms and material damage between 1990-2013 period. Values of atmospheric instability indices have been analyzed for these episodes as CAPE (Convective available potential energy), SWEAT (severe weather threat), Li (lifted index), KI (K index), TT (total totals) to evaluate their medium range forecast under the hail production conditions. These indicators measure the degree of atmospheric instability providing information about possible occurrence of clouds with large vertical extent. The most powerful correlations have been recorded in the case of parameter LI, for which the daily mean value was used. The status of these indices is assessed for both the days with hail, but also on previous intervals with hail to assess their capacity to forecast this extreme weather phenomenon.

Keywords: hail, Moldova, instability indices, weather forecast.

1. INTRODUCTION

Moldova and Bărăgan at continental level, situated at the external side of the Carphatians, precisely replay in Europe, undoubtedly on a smaller scale, physico-geografical conditions that facilitate the extreme instability in North America: large surfaces with regions in general broad that can receive big amounts of radiation heat during summer wich can fuel large convective systems (Bărăgan, Siret and Prut Valleys and Moldavian Plain), an important source of atmospheric moisture in the Southern latitudes (the Black Sea and the Mediterranean Sea) and north-south oriented mountain chain (the Oriental Carphatians) leading to synoptic-scale atmospheric circulation pattern as air mass deviation is produced from tropical to westward, that are associated with intense thermal disequilibrium in vertical section. It is no accident that at a continental level this region has very high annual instability indices as CAPE (Siedlecki, 2008). Hail is the most common form of manifestation of extreme instability and can produce natural disasters of

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huge proportions in the short term, depending on the trajectory of Cumulonimbus cloud which generated them, bringing systematic economic losses, Bogdan, Niculescu, (1999). Being a phenomenon whose maximum frequency is in the warmer period of the year, hail affects agricultural crops, vineyards and fruit trees in sequences of different phenophases, with impact on the proper biological life cycle. Information concerning the regional features of hail from Moldova can be found in a relatively small number of sources. Characteristics of hail regime, as well as other hazardous phenomena caused by severe atmospheric instability are shown in monographic works or scientific articles, both for the national territory, Iliescu, Popa (1983), Bogdan, (1999) or at the level of Moldova Apostol, Machidon, (2009), Necula , (2012). Hail forecasting is quite a difficult step, and the numerous authors who have studied this phenomenon at international level, as well as Edwards and Thompson (1998) or Jewell and Brimelow (2009) did not pay sufficient attention when comparing it to other storm related hazards, as torrential precipitation, electric discharges or windstorms. Severe convection events can be forecasted using instability indices derived from upper air sounding. In this respect, detailed studies have been carried out by Doswell, C. A. III, and D. M. Schultz (2006) and Manzato, A. (2003, 2011) in which the usefulness of these indices is assessed in hail forecasting. The chart below (Chart no. 1) briefly provides a few instability indices used in the present study. The main objective of this study is to point out the instability conditions expressed through values of these indices during hail. By knowing the conditions of instability associated with hail, the efficient use of these indices increases within hail forecasting, which is the main purpose of this study.

2. DATA AND METHODS

Data used in this paper were taken from specialized websites but also from media sources. For 1990-2014 period, taking into consideration hail, a number of 168 cases in which this phenomenon occured were found. Most data come from weather stations of NMA network and were taken from the National Climatic Data Center (NCDC) website. Moreover, hail or extreme instability phenomena were

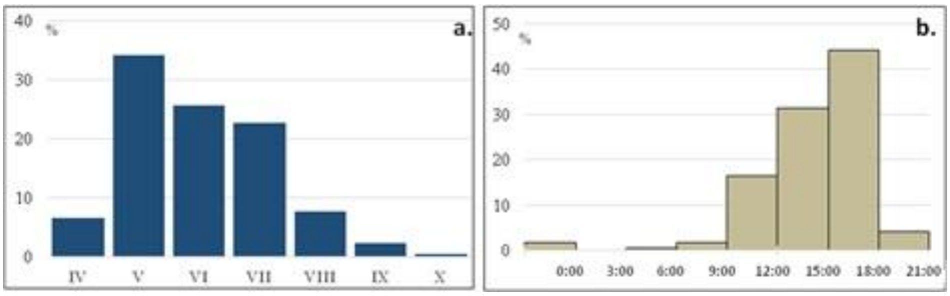

Fig. 1. ***Monthly and hourly frequency of hail cases on the territory of Moldova (1990-2014)***

added – which are automatically associated to hail, even though the latter were not reported in any official weather station. The value of atmospheric instability indices used in this study were taken directly from upper air data from București-Afumați.

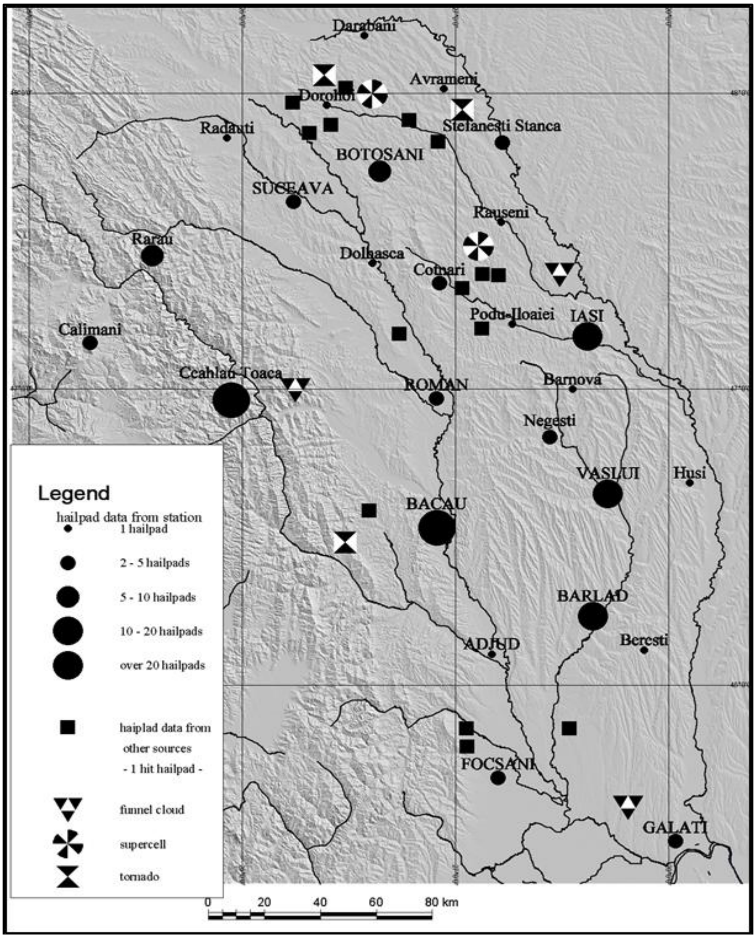

Fig. 2. ***Hailpad data(total number of cases) and other instability related phenomena on the territory of Moldova (1990-2014)***

Processing statistical data takes place after receiving them. First of all, the row of data concerning hail was analyzed in order to achieve temporal and spatial frequency of the phenomenon.Values of instability indices were statistically analyzed in order to notice any association between those values and hail. To emphasize the instability conditions related to hail, the monthly variability of indices was assessed through the quartile method in April-August period that comprises the absolute majority of hail events in the extracarpathian area. The indices were analyzed for all the number of days with hail from the weather stations in Moldova. In order to assess the forecasting capacity of hail for LI, the conditions were analyzed at a three-level temporal scale (days with hail, respectively with 1 or 3 days in advance).

3. RESULTS AND DISCUTIONS

3.1. Temporal and spatial distribution of hit hailpad

The 108 cases of hail occured over a 24-year period from 1994 to 2014, resulting an average number of 0,5-1 days with hail per year for the hill and plateau regions of Moldova. This value is very close to the 1961-1983 period of 1-2 days/year (Iliescu, Popa, 1983) this difference may be due either to the different analyzed period, or to the possible decrease in the frequency of the phenomenon in the last 3 decades. For the period 1961-2000 the average number of days with hail within the studied area increases to 2-4 days/year, Climate of Romania (2008), being clear that the last period of time contributed to decreasing the frequency. This decrease could not be argued due to the smaller number of weather stations after 1998. On yearly level 60% of hail events occur in may and june, and during the day some 50% of hail events are concentrated between 15 and 18 PM local time.

3.2. Instability indices description

The convective aviable potential energy (CAPE) is represented by the area on a skew-T enclosed by environmental temperature profile and the saturation adiabat running from the LFC (level of free convection) to the EL (equilibrium level). Generic CAPE is calculated by integrating vertically and local buoyancy af a parcel at these two levels, Glickman (2000). It is recommended that CAPE calculation should include the virtual correction - Doswell, C. A. (1994). Then result CAPEV (CAPE computed using the virtual temperature).

a. CAPE is a robust indicator of the potential for deep convection intensity and provides a measure of stability integrated over the depth of the sounding, as opposite to others stability indices, but have some limitation. The computation of CAPE is extremely sensitive to the mean mixing ratio in the lowest 500 m. For instance, a 1 g/kg increase can increase CAPE by 20%. Since the conputation of CAPE is based on parcel theory, it does not take into account processes such as mixing, wather loading, and freezing (http://www.meted.ucar.edu/). Moderately unstable conditions are indicated by values over 1000, very unstable by values over 2500 and extremely unstable by values over 3500, Glickman (2000) .

b. The Lifted index (LI) is a commonly utilized measure of stability wich mesures the difference between a lifted parcel's temperature at 500 mb and the environmental temperature at 500 mb, Galway (1956) . LI is relatively easy to determine with the aid of a skew-T diagram. It is limited because it relies on only three sounding inputs: temperature and dewpoint of the boundry layer and thte temperature at 500hPa. LI does not take into account vertical wind shear, wich is often an important element in the severe convective environment. Generally values below -9 indicate extremely unstable conditions, between -6 and -9 very unstable and -3 to -6 moderately unstable.

c. The K index (KI) is a particulary useful for identifying convective and heavy rain producing environments. It is sinply computed from temperatures at 850, 700 and 500 hPa, and dewpoint at 850 and 700 hPa, George (1960) . The KI is a useful tool for diagnosing the potential for convection. However, it can not be used to infer the severity of convection. Values exceding 40 point out the best potential for thunderstorm with heavy rain.

Tabel 1. ***Formula of diverse instability indexes***

Index Name	**Formula**	**References**
Showalter index	SI = $T_{500} - T_{lp(850\ hPa)}$	Showalter (1947)
Lifted index	LI = $T_{lp(fcst\ surface)} - T_{500}$	Galway (1956)
K-index	K= $(T_{850}-T_{500}) + D_{850} - (T_{700} - D_{700})$	George (1960)
Convective available potential energy	CAPE $\int_{LFC}^{EL}(\alpha_{lp} - \alpha)dp$	Glickman (2000)
Vertical totals	VT = $T_{850} - T_{500}$	Miller (1972)
Cross totals	CT = $D_{850} - T_{500}$	Miller (1972)
Total totals	TT = VT +CT	Miller (1972)
SWEAT index	SWEAT = 20(TT–49 ºC) + $12D_{850}$ + $2V_{850} + V_{500}$ + 125[sin($\Delta V_{500-850}$) + 0.2]	Miller (1972)

d. The Total Totals index (TT) is yet another severe weather index. It is computed using the temperature and dewpoint at 850 hPa and the temperature at 500 hPa. TT values are empiricaly related to severe weather when values are over 44, and severe thunderstorm are likely, even tornadoes, for values greater than 55, Miller (1972).

e. The Severe Weather Threat (SWEAT) index differ from many of the other severe weather indices in that it takes into account the wind profile in assessing severe weather potential. Imput include 850 hPa dewpoint, 850 hPa wind speed and direction, 500 hPa wind speed and direction. SWEAT index values have been empiricaly linked to convective events as fallows: *150 – 300 -slight severe, 300 – 400 -severe possible and 400 or greater - tornadic possible,* . Miller (1972)

The SWEAT index is advantageous for diagnosing severe convective potential since it take into account many important parameters including low-level moisture, instability, and vertical wind shear. However, a limitation is that inputs are only from 850 and 500 hPa levels obscuring any inversions, dry layers that may be present in intervening layers.

3.3. Evaluation of forecast utility

Out of the five analyzed instability indices it was noticed that the CAPE values exceed 2000 only in extremely rare cases, thus having the poor ability to forecast severe convections and much less hail formation and fall. For Lifted Index there is a tendency to decrease its value by the end of the interval. The extreme values of this index in the days with hail are between 6 and -6.

However, predominantly values are negative, describing a marginal or moderately unstable environment. SWEAT index and K index have a monthly evolution almost similar (Fig. 3), their values increasing from April to August. TTI, unlike other analyzed indices always presents values that are associated with pronounced atmospheric instability and storm development.

Although it seems to be the most powerful forecasting hail index according to recorded values, we consider that a comparison for a longer period of time is needed, between the values of the recorded days with hail and values of days when convective events occurred but without hail.

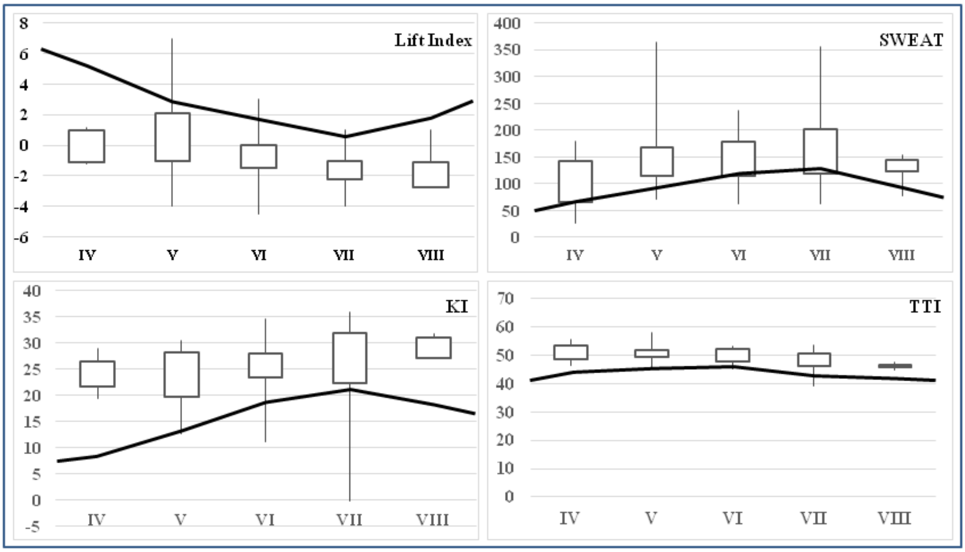

Fig. 3. ***Evolution of monthly instability indices for the days with hail reports across Moldova (box-plot showing first and third quartile) in comparision with mean conditions (black line) recorded on București-Băneasa radiosounding observations (2001-2011)***

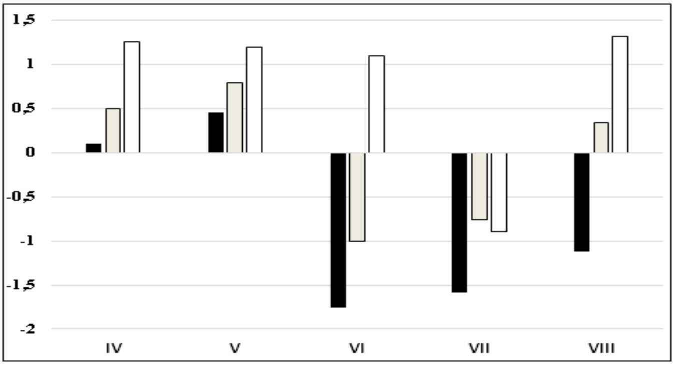

Fig. 4. ***Mean values of Lifted index in Moldova during days with hail reports (black column), 1 day before (grey column) and 3 days before (white column)***

Towards better viability measurements of these indices within hail forecast, we compared their monthly values recorded in the days with hail with their average values on the basis of gridded data of Lifted index from NCEP/NCAR data base (Fig. 3). A big difference between the two values in April, May and August is seen for the four indices, so it is useful to consult their values when the risk of solid precipitation production is analyzed during days with high degree of atmospheric instability. Moreover, for July, the hottest month of the year, the values of the occurrence day of hail are very close to the average values, possible causes being the large amount of the instability energy and the high variability of thermodynamic parameters during the day and even during convective events. With the help of Lifted Index we tried to study the state of the atmosphere three days or one day prior to hail events (Fig. 4). Only in rare cases the value of the Lifted Index recorded in the day preceding the hail event is higher. As we approach to the day of the occurrence of the phenomenon there is a distinct progressive reduction of LI values. Therefore, in most cases, hail formation and fall require atmospheric instability and abounding resources for the development of Cumulonimbus clouds.

4. CONCLUSIONS

Hail, a phenomenon with high spatial and temporal variability, causes significant damage in the outer Carpathian region of Moldova, especially in the agricultural sector. Even if the conditions for the hail formation and fall are known, hail forecast can only be short-term and highly uncertain because the values of the necessary thermodynamic parameters for this undertaking are taken from the aerological diagram, and they change rapidly throughout the day. The instability degree of the atmosphere can be accurately expressed by means of values of indices such as those used in the present paper. We believe that it is not possible to exclusively use the atmospheric instability indices for hail forecast but the utility of some of them such as LI is not negligible. In the future, completing the database by increasing the reviewed period and a thorough study of interdependencies between thermodynamic parameters might lead to satisfactory results.

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