INFLUENCE OF THE ATMOSPHERIC CIRCULATION ON THE DROUGHTS

SAVIN, E.; CAZACIOC, L. & POENARU, V.

Abstract: *In this paper a study is presented on the connection between the atmospheric circulation over the Atlantic-European region and the occurrence of drought in the Romanian territory over the 1961-1990 WMO-established reference period. The large-scale atmospheric circulation is studied according to the classification proposed by Hess and Brezowsky, and the identification of drought periods has been made using the Palfai index. The spatial and temporal characteristics of drought in Romania for the 1961-1990 agricultural years have also been analyzed. The most affected regions by drought over this period were north-eastern Wallachia, south-western Oltenia, south-eastern Moldavia, and Dobrudja. It has been noticed that the drought had a general tendency to extend towards western and northern Romania. During the analyzed period, the atmospheric circulations from the western and eastern sectors over the Atlantic-European region were frequent, the western types prevailing.*

Key words: *drought index, large scale circulation, correlation*

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1. Introduction

Drought, desertification, and land degradation have been acknowledged as a major threat to human welfare worldwide.
Drought is associated in temperate regions with scanty precipitation, temperatures higher than normal, water level lowering, and soil erosion.
The impact of such an event grows in strength together with the size of the affected region, its duration, intensity, and, also, the vulnerability of systems that is often connected to the synchronism and sequence of dry periods.
Drought is a phenomenon hard to diagnose or forecast, as it has a slow evolution, in contrast with the violent and short-range weather phenomena. Generally, its presence is ascertained only when it is too late to act against it. This phenomenon affects large areas and can have disastrous socio-economic effects. For this reason drought is defined more in terms of its impact and consequences than its origin.
Romania is one of the countries most affected by drought. The frequency of droughty years in Romania has increased almost continuously from 33% (1942-1953) to 80% (1982-1990).
For the study of drought in Romania various indexes have been used. MaresI. et al. (1996) calculated the so-called EOF drought index using the index proposed by Ped (1975). They have modified the formula, taking into consideration the EOF 1components of the two 1950-1993 fields instead of monthly temperatures and precipitation. Briffa et al. (1994) have calculated the PDSI (Palmer Drought Severity Index) values for Europe, and MaresI. et al. (1998) have used them to characterize the humidity conditions for Romania.
This paper aims at identifying the drought periods in Romania by using the Palfai index specific to the October 1-August 31 periods from two consecutive calendar years. The spatial and temporal variability of the drought phenomenon described by this index can be estimated through the Palfai index annual values for the main regions of Romania.In order to establish the large-scale meteorological context that could influence the occurrence of drought in Romania, the frequencies of Hess-Brezowsky atmospheric circulation types for the 1961-1990 years and the precipitation amounts recorded for the most frequent types have been calculated. In this paper’s final part, the distribution of precipitation amounts in the droughty years is analyzed, and it is shown that the meteorological drought is not always accompanied by the agricultural drought, and inversely.

2. Data

In this study there have been used monthly precipitation amounts, monthly mean temperatures, and 3 correction factors for temperature, precipitation, and ground water layer level, from 29 weather stations in Romania, in order to calculate the Palfai index.
The atmospheric circulation over the Atlantic-European region has been studied using the 1961-1990 daily types, according to the classification proposed by P. Hess and H. Brezowsky (1977). They have defined 30 types of pressure distribution for the

Atlantic-European region, each including the pressure field at ground level and the 500 hPa geo potential field. Romania is located on the eastern border of the analyzed area. It should be emphasized that the circulation-type name is suggestive for a spatial domain that includes the western and central Europe (table 1).

Code	Name
1	West Anticyclonic
2	West Cyclonic
3	West Southern
4	Low Zonality
5	South-West Anticyclonic
6	South-West Cyclonic
7	North-West Anticyclonic
8	North-West Cyclonic
9	Central-European Trough
10	North Anticyclonic
11	North Cyclonic
12	Maximum British Isles
13	Maximum North Sea Anticyclonic
14	Maximum North Sea Cyclonic
15	North-East Anticyclonic
16	North-East Cyclonic
17	Maximum Fenoscandia Anticyclonic
18	Maximum Fenoscandia Cyclonic
19	Maximum North Sea and Fenoscandia Anticyclonic
20	Maximum North Sea and Fenoscandia Cyclonic
21	South-East Anticyclonic
22	South-East Cyclonic
23	South Anticyclonic
24	South Cyclonic
25	Minimum British Isles
26	West-European Trough
27	Minimum Central Europe
28	Maximum Central Europe
29	Ridge Central Europe
30	Undefined

Tab. 1. Hess Brezowsky atmospheric circulation types

3. Method

The Palfai Index (PAI) allows us to ascertain the occurrence and severity degree of a drought situation on the basis of some meteorological and/or hydrological parameters. The main causes of aridity expansion are the insufficient precipitation amounts and, at the same time, the relatively high temperature (Palfai, I., Petrasovits, I. and L. Vermes, 1995).

The Palfai-proposed formula (1984) for calculating the basic index-values is:

$$PAI_0 = \frac{t_{IV-VIII}}{P_{X-VIII}} \cdot 100 \qquad (1)$$

where PAIo = the basic index-value (^oC/100 mm)
$t_{IV-VIII}$ = April-August mean air temperature
P_{X-VIII} = sum of the October-August precipitation amounts (mm), monthly corrected by a weight factor depending on the plant water-requirement.

The weight-factor values for Romania's natural conditions are the following:
0.1in October
0.4 in November
0.5 in December-April period
0.8 in May
1.2 in June
1.6 in July
0.9 in August
It is evident that July is the most critical period from the point of view of plant water-requirement.
The final PAI value is obtained from the basic value (PAI0) corrected by 3 factors:

$$PAI = k_t \cdot k_p \cdot k_{gw} \cdot PAI_0 \qquad (2)$$

where k_t is the temperature correction-factor

$$k_t = \sqrt[6]{\frac{n+1}{n_m+1}} \qquad (3)$$

n – number of days from June to August with temperatures higher than 30^{o}C
nm – multiannual mean of the number of days with maximum temperatures higher than 30^o
k_p – precipitation correction-factor]

$$k_p = \sqrt[4]{\frac{\tau_{max}}{\tau_{max_m}}} \qquad (4)$$

τ_{max} – the longest period (of successive days) in which the total precipitation amount is not higher than 6 mm, from June 15 to August 15

τ_{max_m} - multiannual mean of the τmax values;
k_{gw} is the ground water level correction factor

$$k_{gw} = \sqrt{\frac{H}{H_m}} \tag{5}$$

H – November-August ground water mean-depth (m)

H_m – multiannual value of November-August ground water mean-depths (m)

The k_t, k_p, and kgw correction coefficients have been calculated for homogeneous regions from a physic-geographical point of view.

The droughty periods have been identified by the Palfai index values higher than 6. We have different drought severity-levels for various PAI values:

6-8 : moderate drought

8-10 : medium drought

10-12: intense drought

higher than 12: extreme drought

Those values lower than 6 characterize the humid and very humid years (Palfai, I., Petrasovits, I. and L. Vermes, 1995).

4. Results

4.1 Palfai index

The annual values of PAIo and PAI according to (1) and, (2) respectively, for the period 1961-1990 and the multiannual mean of PAI for the same period have been calculated using data from 29 weather stations located in the low areas of Romania. Fig. 1 shows the mean Palfai index spatial distribution interpolated with the kriging method.

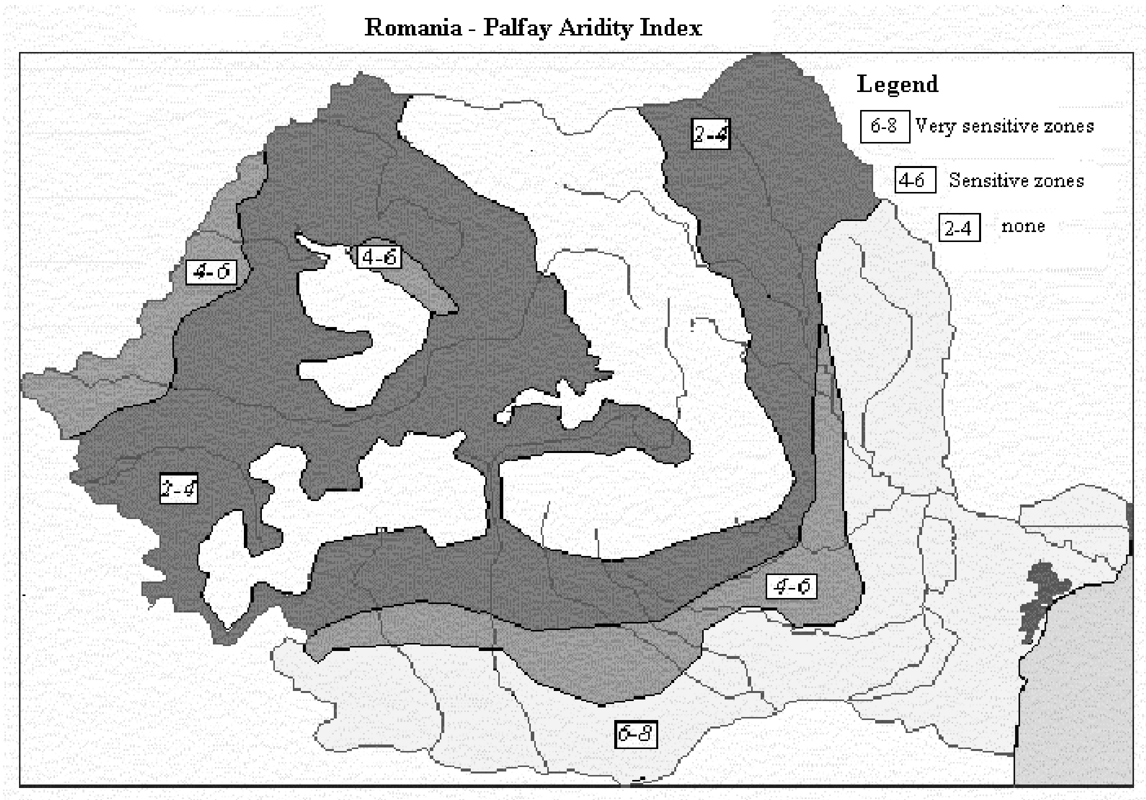


Fig. 1. Palfai Aridity Index

The results are synthetically presented in Figure 2, where the blackened spaces correspond to an aridity index that is higher than 6. The stations have been grouped on historical Romanian provinces in order to obtain a suggestive view of the drought extension (Diaz, H., F., 1983).
Some comments can be made on Figure 2. Firstly, the periods 1961-1965 and 1982-1990 were droughty for most of Romania. Secondly, the drought did not affect simultaneously and with equal intensity the ensemble of a large region. For this reason drought should not be considered from a static point of view, but as a time evolving pattern with certain characteristics and consequences. The temporal evolution of this phenomenon shows an extension towards western and central Romania, as its severity grew higher to late 80s.

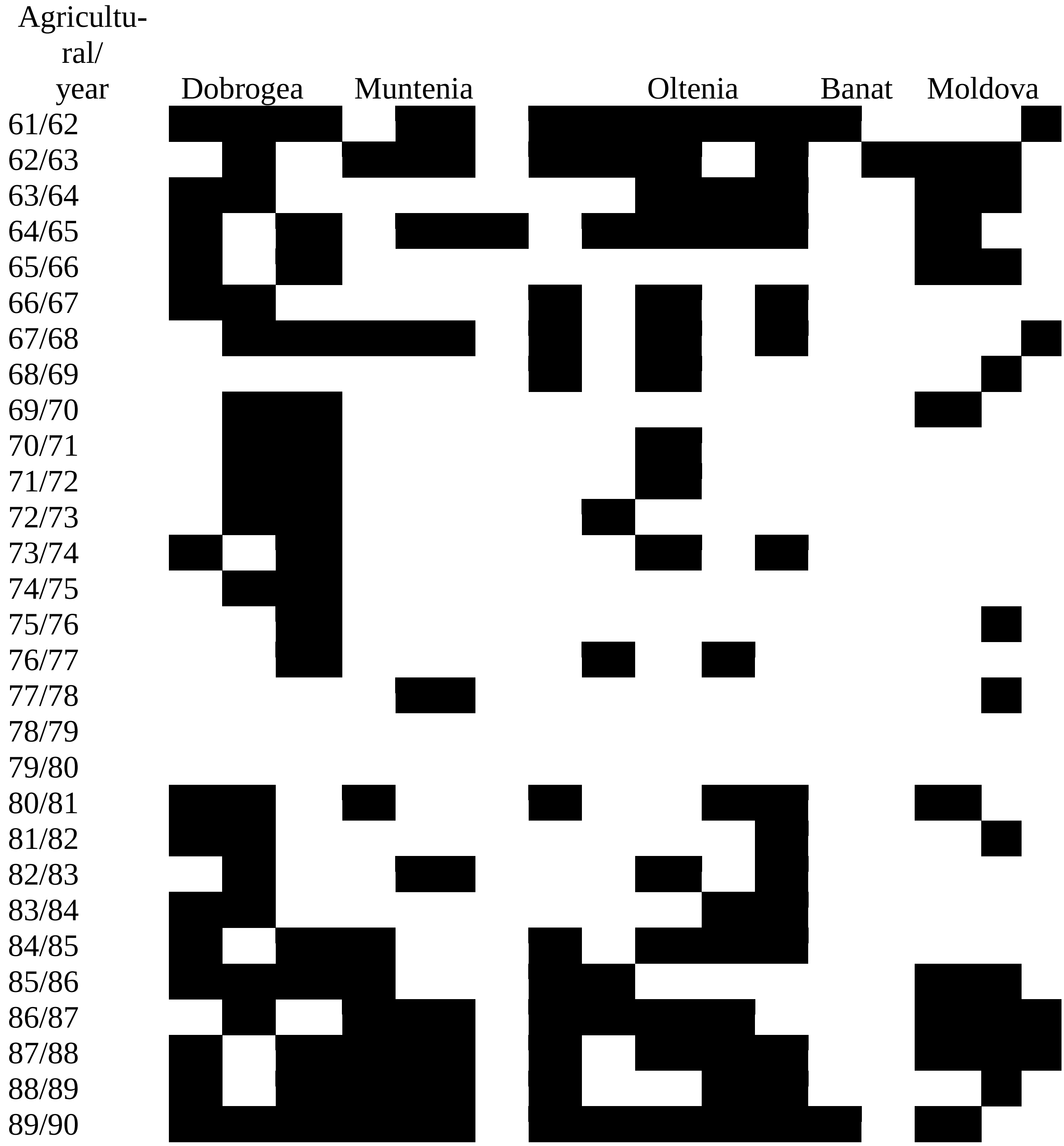


Fig. 2. Agriculturaldrought events

At the same time, the regions affected by drought as well as those less affected can be easily noticed. The latter ones are Banat, Crisana, Maramures, and Transylvania. The rest of the territory runs a higher drought risk. The Carpathian mountain chain lies between these two groups of regions. The drought severity has a significant variation in time and space, depending on the spatial-temporal irregularity of precipitation distribution and the heterogeneous hydrological response of the affected basins.
The spatial character of two drought periods is shown in Figure 3. The isolines drew on the map of Romania represent the Palfai index values in the agricultural years 1962/1963 and 1989/1990. In the first case, the northern, central, and western territories were humid, while in southern Moldavia, north-eastern Muntenia, and southern Oltenia (figure 3a) a moderate-to-medium drought was recorded.

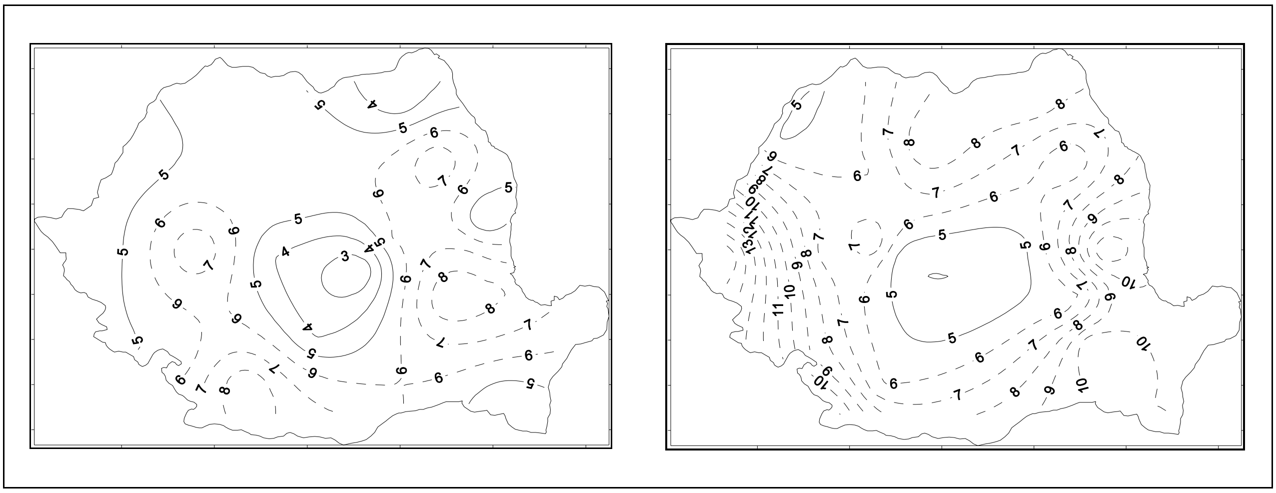


Fig. 3a. Palfai Index 1.10.1962–31.08.1990

Fig. 3b.Palfai Index 1.10.1989-31.08.1963

The other droughty episode (figure 3b) certifies for a drought intensification and spatial extension, excepting only the central and north-western territories. The drought of the 1989/1990 agricultural year can be placed among the intense ones, with extremely powerful accents in north-western Banat, south-eastern Moldavia, and south-western Oltenia.

4.2 Frequency of the Hess Brezovski types during the period 1961-1990

The connection between drought events and atmospheric circulation is extremely important both for climatologists and for forecasters. For this reason an assessment of the frequency of circulation types (in days) for each agricultural year from 1961 to 1990, based on their calendar, according to the code and naming given by P. Hess and H. Brezowsky (table 1) has been made.
The results regarding the frequency of occurrence for those 30 HB types are included in figure 4. The prevailing circulation types (hatched areas) are 2, 28, and 29, i.e. west cyclonic, maximum over Central Europe, and ridge over Central Europe.
The highest frequency corresponds to type 2, which implies the western component circulation over most of Europe, except the south-east (figures 5a and 5b).

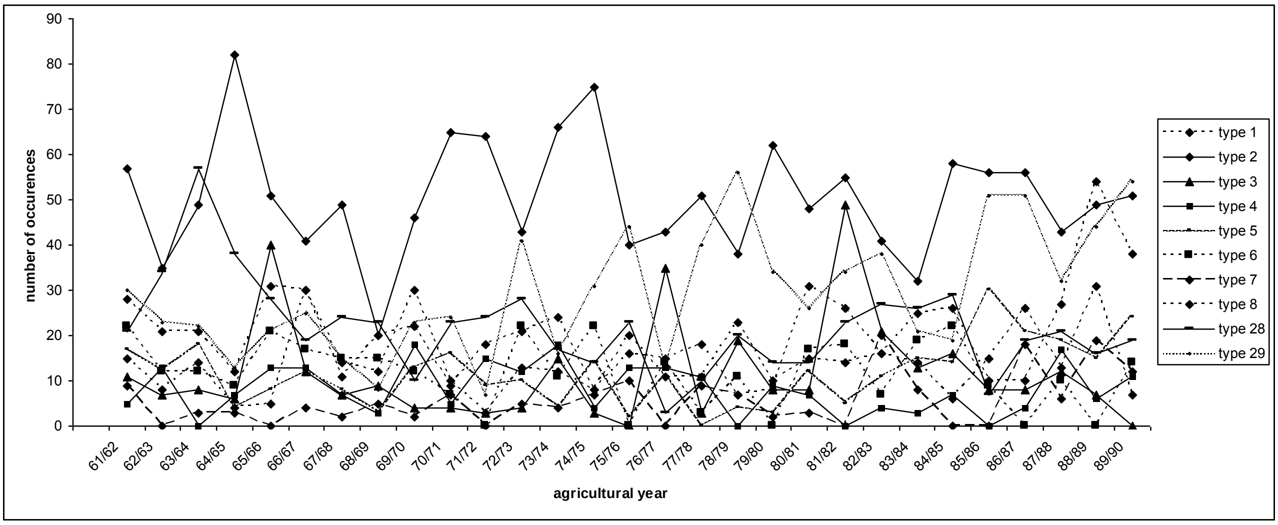
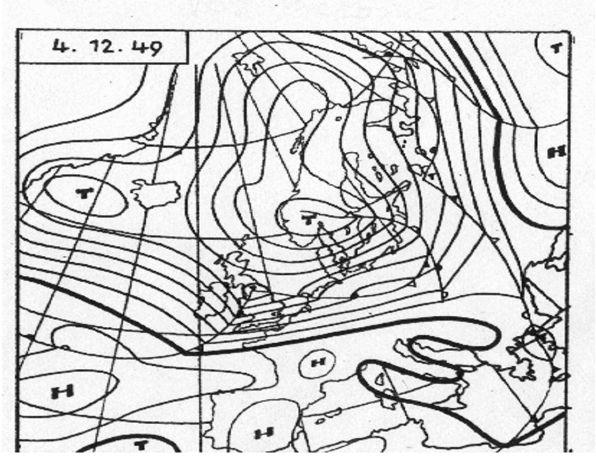


Fig. 4. The frequency of occurrence for Hess Brezowski atmospheric circulation

The 500hPa western circulation favours a rapid motion of the atmospheric fronts that reach the Romanian geographic region with a rather diminished humidity.
The regions strongly influenced by those atmospheric fronts due to some cyclones centered in the Scandinavian Peninsula are the western, north-western, and central ones. Here precipitation is of higher frequency and quantity than anywhere else in the territory. This is due to the Carpathian mountainous chain, which, through its shape and massiveness, makes up a natural barrage hard to be passed over by most of the atmospheric fronts.



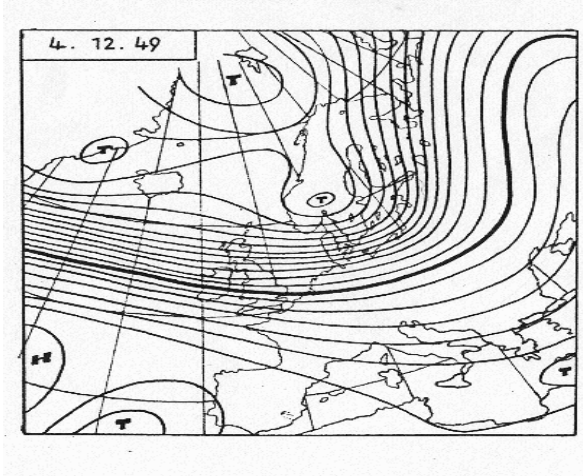
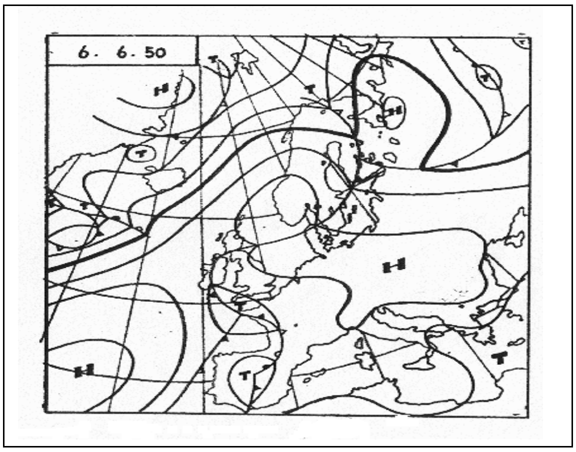


Fig. 5a Distribution of pressure field   Fig. 5b 500 hPa geopotential field by
at ground level by type 2type 2

The characteristics of precipitation in southern and eastern Romania by the type 2 are connected with the descending air-motions when the mountain has been climbed over. Northern Moldavia is an exception, as it is influenced by the frontolysis of many disturbances favouring rather long rainy periods but of a low quantity in general (Cazacioc Liana and Cipu Corina, 1996b).Types 28 (figure 6a) and 29 (figure 7a) describe the northern circulation at ground level, with the north-western and, respectively, north-eastern variants in south-east of Europe. These circulation motions allow those atmospheric fronts carried along the highs' front part to act more strikingly in eastern and southern Romania than in its other parts. However, the associated precipitation is not frequent, but lasts more than that which is due to the western circulation motions. The configuration of the 500 hPa geo potential field on type 28 (figure 6b) is similar to the ground one, the direction of air circulation being the same, so that in the western regions of Romania the precipitation frequency is lower than in the rest (Cazacioc Liana and Cipu Corina, 1996b).



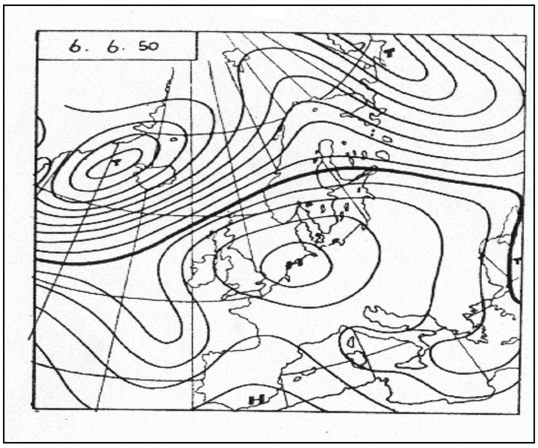
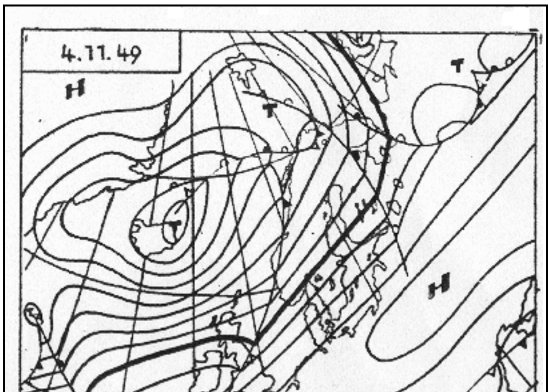


Fig. 6.a Distribution of pressure field at ground level by type 28

Fig. 6.b 500 hPa geo potential field by type 28

Type 29 (figure 7b) shows a different situation, the south-western circulation from high altitude favoring an ascending motion of the warm air of Mediterranean origin over south-eastern Europe, including Romania, and, finally, bringing about of precipitation. Due to the convergence of air circulation at the two pressure levels (ground and 500 hPa), precipitation in south-western Romania has also a rather high frequency. It is to be noticed (figure 4) the higher weight of type 29 in the 1985-1990periods as against 1961-1965, while type 28 had an inverse variation.



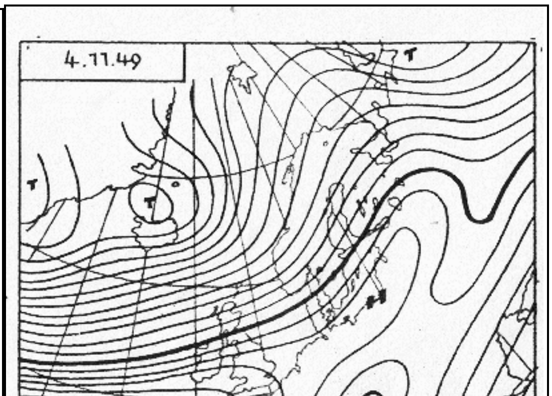


Fig 7a Distribution of pressure field at ground level by type 29

Fig.7b 500 hPa geopotential field by type 29

4.3 Precipitation amounts in the droughty years

The analysis of distribution over the Romanian territory of the total precipitation amount for the agricultural years 1962/1963 and 1989/1990, depending on the most frequent circulation types, namely 2 and 29, shows that the agricultural drought is not necessarily accompanied by the meteorological drought.

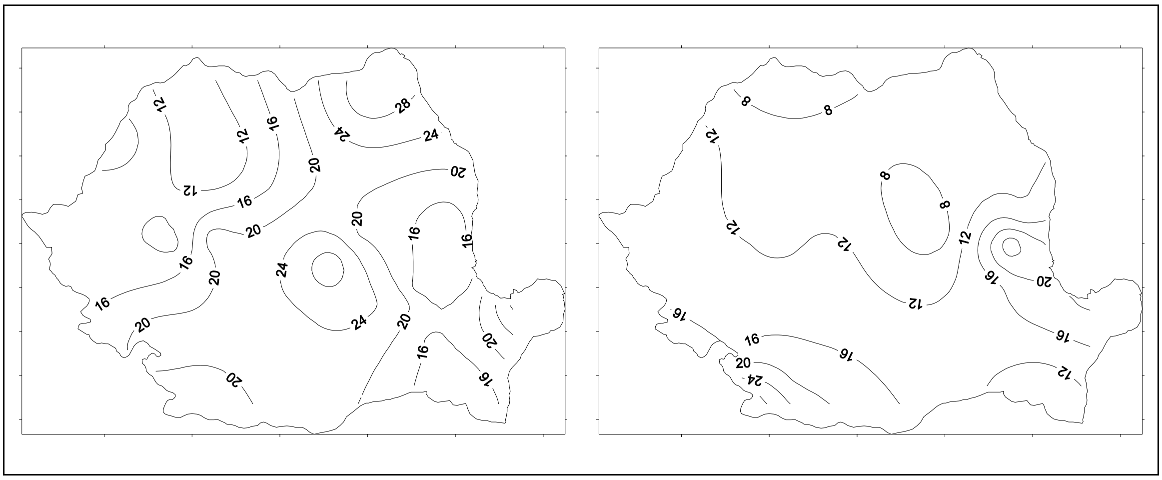


Fig. 8a.Precipitation amounts by type 2 for 1.10.1962 – 31.08.1963   Fig. 8b. Precipitation amounts by type 2 for1.10.1962–31.08.1963

As has been shown in paragraph 3, in the year 1989/1990, an intense drought was recorded in most of Romania. Nevertheless, the precipitation amounts fallen (figures 9a and 9b) were greater than in 1962/1963 (figures 8a and 8b), when the drought was moderate, comparing the precipitation distributions only by types 2 and 29.

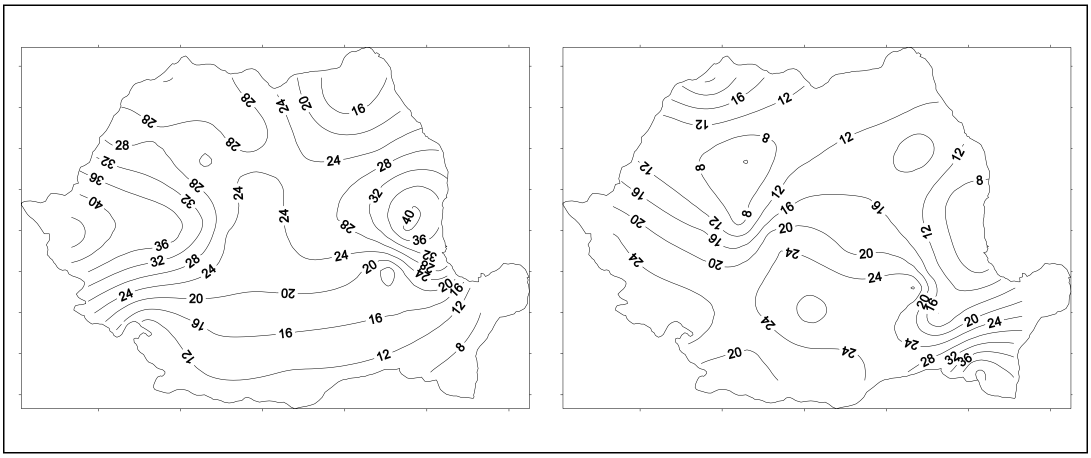


Fig. 9a. Precipitation amounts by type 2 1.10.1989 –31.08.1990   Fig. 9b Precipitation amounts by type 29 31, 1990 1.10.1989 – 31.08.1990

Significant precipitation nuclei can be noticed (figures 9a and 9b) in areas qualified as droughty with the Palfai index (figure 3b). An explanation of this contradiction is given by formula (2), through the precipitation correction-factors that take into account the plants' water requirements and not the water quality as such. On the other

hand, the total precipitation amount in 1989/1990, although greater than in 1962/1963, is still rather low compared to the plant requirements.
The relative growth of precipitation amounts in 1989/1990 as against those in 1962/1963 cannot be explained only on the basis of the prevailing atmospheric circulation type, since there are many other geophysical factors, which contribute to the regional climate change.

5. Conclusions

Using the Palfai Index (PAI) calculated at 29 weather stations in Romania, the droughty agricultural years from the 1961-1990 period have been identified. The spatial and temporal distribution of drought has been analyzed. The regions with a high risk of drought are south-eastern Moldavia, south-western Oltenia, north-eastern Wallachia, and Dobrudja. The phenomenon had a tendency to extend towards the western and central territories of Romania as its severity grew higher to the late 80s.

The 1961-1990 prevailing atmospheric circulation types over the Atlantic-European region were the western and northern ones, which explains the higher precipitation frequency and consistency in western, central, and north-western Romania than in the other territories.
The precipitation amounts for the most frequent circulation types do not explain entirely the agricultural drought recorded, so that the agricultural drought and the meteorological one do not occur at the same time.

6. Acknowledgement

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