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THE MEAN DAILY RAINFALL IN SZEGED DEPENDING ON WIND-DIRECTION AND CLOUDINESS (PRELIMINARY INVESTIGATION)

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Összefoglalás - A dolgozat a Szegeden 1987 és 1993 között márciustól májusig mért napi és havi napfénytartam, a felhőzet és a csapadék mennyisége, illetve az erre az időszakra vonatkozó európai szinoptikus térképek segítségével vizsgálja a csapadékviszonyokat. Körülbelül 125 állomás adatai alapján megadja a felhők u.n. csapadék-effektivitását (REC) és annak regionális eloszlását Európa (köztük négy magyarországi város Mosonmagyaróvár, Kecskemét, Nyíregyháza és Szeged), Észak-Afrika és Kis-Ázsia területére. Az elvégzett vizsgálatok eredményei alapján Szeged vonatkozásában megállapítható, hogy a Mediterraneum felől érkező felhőzet átlagos csapadék-effektivitása az 1987 - 1993 közötti hónapokban jóval nagyobb volt, mint az Atlanti-óceán felől érkezőké.

Summary - This paper examines the macro-precipitation conditions using the data of the mean daily and monthly sunshine duration, the amount of cloudiness, the rainfall in Szeged and in Europe, parts of North Africa and Turkey for the period of 1987 - 1993, from March to May. 125 stations were involved, which show the rain effectivity of clouds (REC) and its regional distribution for the above mentioned areas (including the data of four Hungarian cities: Mosonmagyaróvár, Kecskemét, Nyíregyháza and Szeged). By the results of the investigation it can be proved that the mean REC is much higher in the Mediterranean cases than in the Atlantic ones.

Key words: rainfall, sources of water vapour, condensation nuclei, convection, clouds, rain-effectivity of cloudiness

INTRODUCTION

Szeged city is located in the Southern or Southeastern part of Hungary and its distances from the nearest Seas or Ocean are as follows:

Szeged - Adriatic Sea		5-600 km
Szeged - Black Sea	cca.	700 km
Szeged - Atlantic Ocean		1500 km
(English Channel, North Sea).		

It is likely that the main water sources providing rain in South-Hungary (or even in the entire country) are those mentioned above. The purpose of this investigation is to distinguish between daily average rainfall concerning the water sources the water-vapour had been transported from. It is supposed and partly proved by means of conditional climatology that daily rainfall exhibits one maximum in days with SSW - SW - WSW wind direction and a minimum in case of NE wind direction (*Koppány*, 1982), while a modest secondary maximum occurs in days with NW - NNW winds. These results corresponds with assumption of main water sources, namely the Adriatic or the Mediterranean Sea and the Atlantic Ocean have modest secondary role in this respect.

One other term to be investigated in this paper is the so-called rain effectivity of clouds, *REC* expressed in mm/deca clouds for a definite time (day, month, year). The *REC* depends upon the intensity of convective activity, i.e. the strength of vertical air motion on one hand and the quality of condensation nuclei, on other. The maritime nuclei consist mostly of sodium-clorine hence of hygroscopic quality, while the continental nuclei are predominantely ammonium-sulfate. Thus it is expected that over or near the Seas more rain will fall from the same quantity of clouds than far from the Sea over the continents, in other words: the *REC* will decrease with growing distance from the Sea.

METHOD AND DATABASE

The daily observations of rain, sunshine duration made in Szeged and synoptic maps presenting the weather situations over Europe, the Mediterranean Sea and partly the Atlantic Ocean have been used for this research. Furthermore climatic data of monthly and annual mean precipitation and mean amount of the cloudiness were also involved into this work. The monthly precipitation and cloudiness averages were taken from Szeged for illustration annual variation of *REC* and those from additional three climatic stations in Hungary. Annual averages of the same data were taken from a sufficiently great number of European, North-African climatological stations in order to demonstrate the areal distribution of *REC*.

Selected days were chosen in which more than one mm precipitation was reported in Szeged; the time interval consists March to May 1987 - 1993. The choice of a single season (e.g. Spring) is justified by the annual variation of *REC* and so only the data of the same season are comparable with each other. Altogether 81 cases were found and out of them 77 cases could be identified and put into two groups according to the prevailing wind direction. The first group consists rainy days with WNW - NNW wind direction (45 cases), into the other group the rainy days with SE - SSW wind were put (32). The prevailing wind directions were established by means of synoptic maps presenting the large-scale pressure field. The first group is considered including cases, when water transport came from the Atlantlic Ocean, the second one including cases with rainfall provided by water transport mainly from the Mediterranean Sea. For both groups the averages and standard deviations of daily rain amounts were calculated, and t-test was made.

For determination of daily mean amount of cloudiness the daily sunshine duration was used, because the night observations of clouds are rather unreliable, moreever the amount of clouds changes frequently within two adjacent observations, while the records of heliograph are quite reliable. The conversion sunshine duration into daily mean cloudiness (in decas) was carried out by formula, as follows :

$$cloudiness(decas) = \left(1 - \frac{SD}{SD_{max}}\right) \cdot 10,$$

here SD standes for observed sunshine duration, SD_{max} for possible maximum SD in relevant month.

It is noteworthy that Summer is not a suitable season for this investigation due to a heavy and very changeable convective activity. One more comprehensive research is planned including much more data taken from Autumn to Spring. This paper is considered as a preliminary probe of extended research of this kind.

ANNUAL VARIATION OF *REC*

In *Table 1* are given the monthly and annual mean precipitation and cloudiness for Szeged (*Péczely*, 1979), and also the monthly and annual *REC* for Szeged, Mosonmagyaróvár, Kecskemét and Nyíregyháza representing various regions of Hungary.

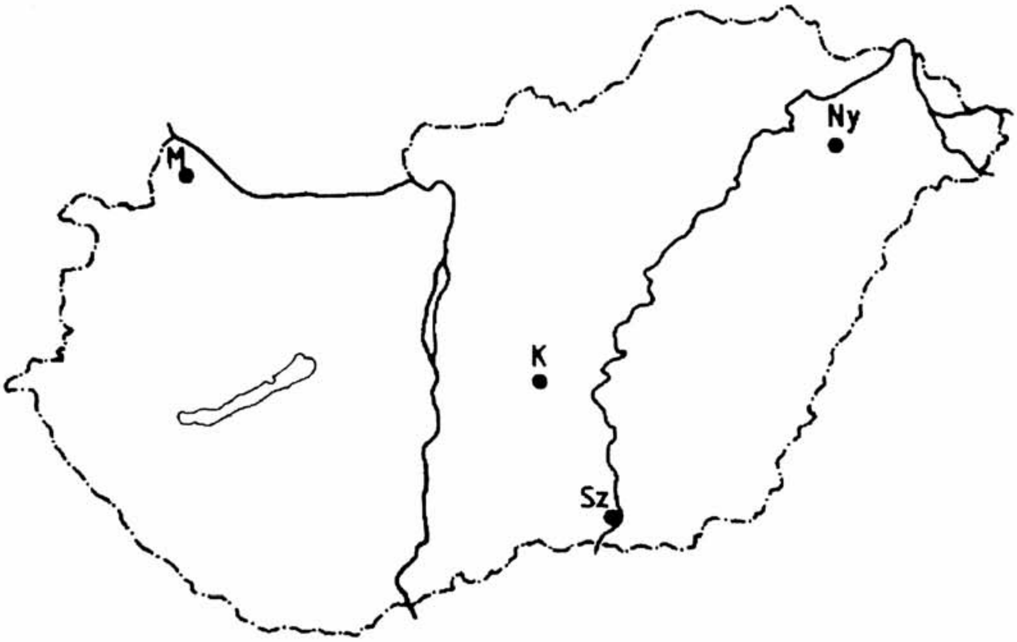

Fig. 1 Climatic stations in Hungary mentioned in *Table 1* (M = Mosonmagyaróvár, K = Kecskemét, Ny = Nyíregyháza, Sz = Szeged)

	J	F	M	A	M	J	J	A	S	O	N	D	Y
Precipitation (mm)	32	34	38	49	61	68	51	48	47	52	52	41	573
Clouds (deca)	7.1	6.5	5.9	5.9	5.3	5.1	4.2	3.9	4.2	5.4	6.9	7.5	5.7
***REC* Szeged**	4.5	5.2	6.4	8.3	11.5	13.3	12.1	12.3	11.9	9.6	7.5	5.4	100
***REC* Mosonmagyar-óvár**	6.1	6.4	7.8	8.8	14.7	12.9	15.7	14.8	12.5	10.2	8.6	7.7	122
***REC* Kecskemét**	4.8	5.9	7.3	10.4	14	14.3	14.3	14.4	13.7	11.7	9.8	6.5	120
***REC* Nyíregyháza**	5.2	5.8	7.1	10	13.8	17.5	19.5	21.8	13.4	11.8	9.1	6.2	128

Table 1 Climatic data in Szeged and *REC* for Szeged and other cities

It is evident that the monthly precipitation is much more in Summer than in Winter, while the monthly amount of the cloudiness exhibits maximum in Winter and decreases by late Summer or early Autumn, consequently, the *REC* has maximum in Summer and minimum in Winter. From the point of view of cloud physics warm season is favorable for convection, rapid formation of clouds and growth of water droplets, finally all these factors lead to falling shower of moderate or strong intensity. On the contrary, in cold season the frequent fogs and Stratus clouds consist of very small droplets whose weights are not enough in many cases to fall down and reach the ground surface. One important conclusion of this brief presentation is that the annual variation of *REC* has a reversed form compared with annual course of clouds and this can be understood with respect to the increased vertical air motions in warm season.

REGIONAL DISTRIBUTION OF *REC* IN EUROPE AND THE MEDITERRANEAN AREA

Out of nearly 250 climatic stations presented by *Péczely* (1984) 125 stations were involved in determination of regional distribution of *REC* in Europe and partly in North Africa and Turkey. In this study the annual amounts of precipitation (largely in form of rain in most places mentioned above) and annual of clouds in decas were taken into account. So the annual *REC* is a simple ratio between annual rain (precipitation) and annual average of clouds:

$$REC = \text{annual rain} : \text{mean clouds (mm/deca)}$$

Fig. 2 presents the distribution of *REC* in Europe and surrounding area. As one consequence of the extremely great areal variation of annual rainfall, remarkably different *REC*-s occure within relatively small distance in many cases, e.g. Norwegian coast is contrasted with inner Scandinavia as well as Western part of British Islands with Eastern part or Portugal with Spain etc.

Nevertheless there is no doubt upon some regularities in areal distribution of *REC*: 1. clear decreasing trend can be found from West to East, i.e. with growing distance from the Atlantic Ocean; 2. increasing trend appears from North to South, in other words: towards lower latitudes. Concerning the first regularity, it must be taken into account that during westerlies water vapour will be undergoing condensation over the continent forming clouds and in many cases rain as well. In this phenomenon the orography plays important role, strengthening rainfall at luv and stopping it at lee sides. Thus the water content of air masses will gradually decrease in growing distance from the Atlantic. On the other side plausable decrease in mixing ratio of sodium-clorine may occur as well causing less vigorous growing of water droplets in clouds, consequently less rainfall will drop.

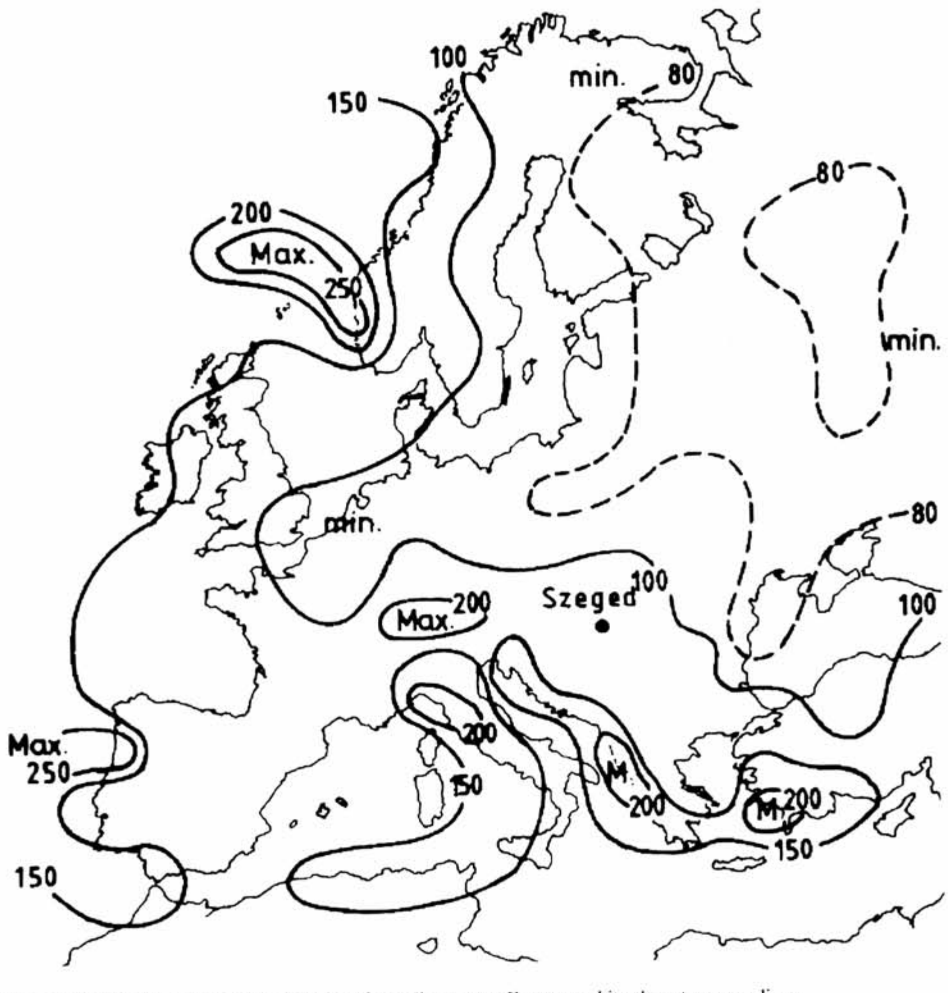

Fig. 2 Macroscale distribution of rain effectivity of cloudiness over Europe and its closest surroundings

The explanation of the second regularity may be found in the fact that in high latitudes Stratus clouds and fogs are formed much more frequently consisting of micro-sized droplets. Contrariwise in low latitudes, e.g. in Mediterranean region and especially on the coast of North Africa the rare cloudiness has largely Cumulus or Cumulonimbus form as consequence of intensive convections and strong vertical air motions. Hence if clouds are forming, they consist of comparatively large droplets due to their rapid coagulation, and thus the appearance of clouds is followed with rain shower in most cases or even heavy cloudburst sometimes.

For the sake of simplicity partial averages of *REC* were calculated according to geographical longitude and latitude, respectively. These averages demonstrate the regularities, mentioned above, namely decrease of *REC* towards the East, and its increase towards the South:

	0-20 W	**0-10 E**	**10-20 E**	**20-30 E**	**30-60 E**
REC	145	130	136	104	90
(number)	(22)	(25)	(33)	(33)	(12)

	60-70 N	**50-60 N**	**40-50 N**	**30-40 N**
REC	130	103	126	138
(number)	(15)	(32)	(49)	(24)

DIURNAL MEAN RAINFALL IN SPRING IN SZEGED WITH RESPECT TO WIND-DIRECTIONS AND CLOUDS

The rainy days included into this research were chosen from March, April and/or May of 1987, 1988, 1989, 1991 or 1993 depending on sufficient amount of monthly rainfall in Szeged. Such months were April and May of 1987 (54 and 127 mm monthly sum, respectively), March and May of 1988 (60 and 44 mm), April and May of 1989 (86 and 62 mm), April and May of 1991 (63 and 110 mm), April 1993 (40 mm). Altogether 81 cases were found with more than one mm diurnal precipitation and the direction of prevailing wind was identified in 77 cases out of 81 by means of daily synoptic weather maps. In four cases the prevailing wind directions were out of our interest (e. g. NE or E). Having taken into account the wind direction, two groups were selected: 1. with WNW - NNW directions which correspond water vapour transmission from the Atlantic, 45 cases were found; 2. with SE - SW directions which indicate water vapour transport from the Mediterranean Sea including the Black Sea, 32 cases were found. The number of samples included into this research is rather modest, but it has been considered sufficient for some statistical probes, e.g. t-test. By extending time series using Autumn - Winter - Spring data, which is planned for the next step, results may change more or less, however the most important feature of the basic phenomenon will be invariant according to the author's expectation. The main characterstics are presented in *Table 2.*

Wind direction	WNW-NNW	SE-SW
Transport of water vapour	Atlantic	Mediterranean
Samples n_1,n_2	45	32
Mean daily rain, mm	***4.8***	***11.0***
Standard deviation, mm	5.05	11.06
Clouds in decas	***8.44***	***7.8***
Standard deviation, decas	1.95	2.39
***REC* per day**	0.57 mm/deca	1.41 mm/deca

Table 2 Explanation see in text

An apparent difference is found in mean daily rainfall between two groups of samples, namely in cases with water vapour transport from the Mediterranean Sea the average rainfall is remarkably greater (11 mm) than in cases of water vapour transport from the Atlantic (4.8 mm). On the other hand, the mean clouds is less in the Mediterranean samples than in the Atlantic ones. The statistical *t*-test was examined and was obtained for *t*-value: $t = 3.31$ using the formula:

$$t = \frac{\bar{x}_2 - \bar{x}_1}{S\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \ ,$$

where $\bar{x}_1$ and $\bar{x}_2$ are the averages of two groups S stands for standard deviation combined for both groups, n_1 and n_2 the numbers of samples in each group. The differences in averages calculated for two populations are significant for 77 samples (both populations) at 1 % level if t is greater than 2.64, at 0,1 % level if t is greater than 3.4. Hence the difference in averages of daily rain between the Mediterranean and the Atlantic samples is signifcant at 1 % level, moreover not far from 0.1 % level.The mean *REC* is much higher in the Mediterranean cases than in the Atlantic ones. The plausible reason of this result lies in the fact that the Mediterranean Sea (including the Adriatic and the Black Sea) is nearer to Szeged.

The authors feel encouraged to continue this investigation for longer time series and support their assumption on the link between *REC* and distance from sea, since the latter is in inverse proportion to the quantity of clorine nuclei per total amount of condensation nuclei. The mixed ratio of clorine must have important role in the growth of water droplets and forming rainfall.

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